Sunday, 17:30-19:00

■ SA-01

Sunday, 17:30-19:00 - UPV Nexus

Opening Session

Stream: Opening and Closing
Chair: *Ramon Alvarez-Valdes*
Chair: *Ruben Ruiz*

1 - **Opening session**
Ramon Alvarez-Valdes, Ruben Ruiz

Opening session

Monday, 8:30-10:00

■ MA-01

Monday, 8:30-10:00 - UPV Nexus

Six Decades of Interior Point Methods: From Periphery to Glory

Stream: Keynotes
Chair: *Attila Gilanyi*

1 - Six Decades of Interior Point Methods: From Periphery to Glory
Tamás Terlaky

The basic concepts of Interior Point Methods (IPMs) were introduced by Frish in 1950's, and further developed in the 1960's, among others by Fiacco-McCormick (SUMT) and Dikin (Affince scaling). By the early 70's it was concluded that, mostly due to numerical instability, IPMs most probably will not be viable algorithms for solving large scale optimization problems.

Karmarkar's 1984 paper and the subsequent "Interior Point Revolution" fundamentally changed the landscape of optimization. IPMs become the method of choice to solve large-scale linear optimization problems, new classes of conic and convex optimization problems become efficiently solvable. The new powerful algorithmic and software tools opened new areas of applications. In this talk we walk through the history of IPMs, highlight the scientific and computer technology advances that make the Interior Point revolution possible.

■ MA-02

Monday, 8:30-10:00 - SOUTH BUILDING UV S101

Scheduling Practice

Stream: Scheduling Practice
Chair: *Daniel Guimarans*

1 - Project scheduling in real-world test laboratories
Florian Mischek, Nysret Musliu

In industrial test laboratories, a large number of tests has to be performed by qualified personnel using specialised equipment, while respecting deadlines and a number of other constraints. Under those circumstances, creating high-quality schedules manually is both time-intensive and error-prone, indicating a need for automated solutions. This problem is related to the well-known Resource-Constrained Project Scheduling (RCPSP) problem, but contains several unique features requiring special considerations by solvers. Most notable among these is the dynamic grouping of smaller, similar tasks into larger activities, which allow for shorter overall processing times. Solvers must both find such a grouping and create a suitable schedule for the resulting activities, which respects all constraints. We provide a formal definition of this problem, as well as benchmark instances, both real-world and randomly generated, together with a heuristic solution approach.

2 - Heuristic approaches for scheduling jobs and vehicles in a cyclic flexible manufacturing system
Martin Gutjahr, Sophie Parragh, Hans Kellerer

This paper considers the Scheduling of Automated Guided Vehicles (AGVs) in a flexible flow shop environment. The AGVs travel along a single loop. All machines are set alongside the track in the correct order, with multiple machines per stage. All AGVs are to be scheduled for a specific starting time and will then circle the track without stop. Pickup and delivery times are included in the travel time of a vehicle between two machines. Jobs may start as soon as they have arrived and their predecessor has been started for processing. Therefore, job completion times are dynamic. The considered objectives are the minimization of the number of AGVs and the minimization of the makespan. For the resulting problem, different metaheuristic search procedures are proposed and compared among each other as well as a basic local search algorithm relying on small changes to the AGV starting times. Optimal results are produced by means of a brute force enumeration algorithm. Finally, fixed permutation schedules are compared to processing jobs according to the first-come-first-serve rule.

3 - A mixed integer programming model for airline fleet maintenance scheduling.
David Torres Sanchez

Fierce competition between airlines has led to the need of minimising airlines' direct operating costs, where possible, while also ensuring quality of service. Given the large proportion of direct operating costs dedicated to aircraft maintenance, cooperation between airlines and their respective maintenance provider is paramount. However, there are, clearly, conflicting objectives which have to be resolved through negotiations. In this research, our aim is to develop a fast maintenance scheduling tool which could aid maintenance scheduling negotiations between the airlines and maintenance providers. Using preprocessing and two different interval MIP formulations we generate maintenance schedules (in airframe and engine checks) that maximise aircraft utilisation (flying hours, flight types and number of cycles) with limited workshop resources. Moreover, when a flight schedule doesn't provide enough maintenance opportunities (long turnaround times), we allow perturbations to the flight schedule or an aircraft rotation to create a feasible maintenance schedule. By updating the "maintenance requirement" according to precise flying hours between maintenance opportunities we ensure that the aircraft are airworthy at all times. Computational tests were run on real flight data over a planning horizon of a month. Results show that even with multiple airlines (34745 flights, 1412 aircraft, 16 workshops) our solution procedure can obtain optimal maintenance schedules within minutes.

4 - A decision support system to assist airport operators solving terminal disruptions ASAP
Daniel Guimarans, Arjen Peters, Younes Boulaksil

The Airport Stand/Gate Assignment Problem (ASAP) is an important problem most airport operators need to solve on a regular basis. It consists of assigning every flight a suitable stand and gate, aiming at maximising passenger convenience and the airport's operational efficiency. Airport planners may benefit from applying a set of business rules to solve the problem, but strict operational, safety, and security constraints (e.g. dependent stand usage) in connection with capacity limitations may hinder solutions' quality. We propose a Constraint Programming (CP) formulation that naturally deals with such constraints, finding suitable solutions for the ASAP either during regular or disrupted operations. We define multiple objectives to accommodate the needs of different stakeholders and business interests, extending the problem beyond traditional approaches minimising passenger walking distances and assignment costs. We embed our CP model as a repair operator in a Large Neighbourhood Search (LNS) metaheuristic framework, aiming at improving the efficiency of the solving process. A simulation model of the terminal is used to evaluate additional aspects of our solutions, such as Level of Service or the number of missed connections. These aspects can be integrated within the LNS framework to guide the search towards more desirable solutions. To verify the effectiveness of our approach, we assess our methodology on scenarios derived from real operations at Barcelona airport.

■ MA-03

Monday, 8:30-10:00 - SOUTH BUILDING UV S103

Facility Location I

Stream: Location Analysis and Optimization
Chair: *Robert Aboolian*

1 - A Lagrangian relaxation method for solving the p-median radius formulation
Minerva Martin del Campo, Sergio García Quiles

The p-median problem is one of the most important problems in discrete location. It was originally defined by Hakimi in 1964 as a network problem and later formulated as an integer linear programming problem by ReVelle in 1970. The most recent exact method to solve the p-median problem is a radius formulation where the problem is formulated as a set covering problem. The algorithm proposed there starts with a partial formulation and develops a row generation technique to add more inequalities as needed. This strategy is embedded in a branch-and-bound algorithm and it is able to solve very large instances with several thousands of nodes. However, it does not work so well for problems with small values of p. In this work we have developed a heuristic method based on Lagrangian relaxation and branch-and-bound to obtain good solutions. The radius constraint is relaxed to form the Lagrangian dual problem and subgradient optimization was used to solve it. If the full set of radius constraints is relaxed, the dual problem can be solved quickly, however the bounds generated are weak. In order to obtain stronger bounds, we explore relaxing only a subset of the radius constraints. We look into how this affects the solution time and bounds for large instances with all types of values for p.

2 - Heuristic framework to reduce aggregation errors in location models
Carolina Castañeda P., Daniel Serra

Solving large discrete location problems may be time consuming or intractable due to the presence of a large number of demand points, that usually are aggregated. This aggregation introduces error on the solution of location models and consequently produce inaccurate values of the objective function. We propose a heuristic framework to reduce errors caused by aggregated demand points on classical location models on networks, such p-median, p-center and covering problems. The proposed framework contains four stages. In the first stage we obtain an initial aggregation making groups of the original demand points through a heuristic algorithm based on k-means algorithm, then in the second stage we calculate the centroid of each group, using the concept of a centroid in a minimum expansion tree, these centroids will be the candidate locations to be selected by a location model in the third stage. In fourth stage we evaluate the quality of the solution calculating the improvement in the objective function with the current aggregation, and the dispersion of demand points respect to the centroid of their group in order to make a perturbation of the current aggregation. Iteratively, we go back to the first stage where we aggregate demand points according to the perturbation obtained at the end of the fourth stage in the previous iteration, we follow the order of the stages until the quality of the solution does not improve.

3 - Location problems with continuous demand on a polygon with holes: characterising structural properties of geodesic Voronoi diagrams
Thomas Byrne, Jörg Kalcsics

The problem of finding optimal locations for a set of service facilities is of strategic importance and has generated a large body of research literature. In most models customer demand is assumed to be discrete and aggregated to a relatively small number of points. However, in many urban applications the number of customers can be in the millions and representing every residence as a separate demand point is infeasible. Therefore it may be more accurate to represent demand as continuously distributed. Moreover, the demand region and the region in which a facility can be located are often assumed to be convex polygons. However this is not realistic for real world applications. While a non-convex demand region can be modelled as its convex hull with zero demand where appropriate, a non-convex feasibility region requires more work. Yet more problems occur when we introduce areas that cannot be traversed since we now must use geodesic distances.

We consider the market share problem where the locations of p facilities are fixed, and we seek the optimal location for an additional facility with the objective of maximising the total demand attracted by that facility; the function of which depends on the partition of the demand space into 'Voronoi cells'. In this talk we extend the structural properties of classic Voronoi diagrams to their geodesic counterparts and discuss how to determine the parametric representation of the objective function in order to solve the problem.

4 - Mathematical characterization of interregional freight flows by road
Javier Rubio-Herrero, Jesús Muñuzuri

Multimodal transportation is defined as the movement of freight or people via two or more means of transportation. It is understood as a concept that allows the enhancement of the competitiveness and efficiency of the global transportation network, as its study offers the opportunity to improve the methods by which such means are interconnected. In order to take advantage of the benefits of multimodal transportation, it is necessary to delve deeper into the factors that influence the performance of each of these modes. In particular, the present work aims at exploring how the supply and demand of different products determine the commodity flows among regions via the road network. A frequent hindrance is that those flows are often not available and therefore they need to be estimated. Based on the information provided by the Spanish National Statistics Institute (INE), we propose an optimization model that improves our ability to predict, at the macro level, the interregional freight flows and we apply it to the Spanish case. Moreover, we discuss the algorithms used to solve our models and present the results obtained, as well as propose future lines of research.

■ MA-04

Monday, 8:30-10:00 - SOUTH BUILDING UV S104

Dynamic and Stochastic Scheduling

Stream: Dynamic and Stochastic Scheduling
Chair: *Wim Vancroonenburg*

1 - A reinforcement learning based algorithm to schedule multi-category patients at a multi-facility hospital
Usha Mohan, Varun Jain

Preventive health check-up packages are prevalent in emerging economies where a collection of medical tests are bundled together at a competitive price for the patient. The health check-up adds to a new category of patients in addition to the existing broad categories of in-patients, out-patients, and emergency patients. Most of the hospitals are resource constrained with the different categories competing for the same resource at a respective test facility. One of the key operational decisions faced by such hospitals is the choice of the category to serve at a test facility. The health check-up patients adds to the complexity since they have to be served in a series of test facilities as against the other categories of patients who usually are served at one test facility. Hence, the challenge is two-fold: i) to capture the inherent dynamics of the system and ii) implement the decisions in real time. We formulate a Markov Decision Process (MDP) to capture the system dynamics with the objective of maximizing net revenue. We factor the MDP formulation to a decentralized MDP (DMDP), and we propose a reinforcement learning based heuristic to solve it. We show the efficiency of the developed heuristic through extensive numerical experiments.

2 - A tactical planning model for allocating resources to a project under uncertainty
Tetsuo Iida, Ken-ichi Suzuki

We consider the tactical decision problem of allocating resources to a project at the phase of project planning in which activity durations, costs, and resource usage are uncertain. It is not uncommon that for a new product development project or a large information system development project, the project manager faces uncertainty at the planning phase because of the lack of information about the detail of the project. We develop a framework for making a tactical project plan under uncertainty, considering the aspects of time, cost and resource usage. The aspects of time, cost, and resource usage are interrelated with each other, which makes the problem complicated. The framework uses directly manageable indicators such as due-date, budget, and allocated amounts of resources to a project so that it makes the problem tractable. With the framework, the tactical planning problem of allocating resources to a project is formulated as a stochastic program which incorporates the interrelatedness between time, cost and resource usage with execution modes of activities. Also, the formulation is consistent with operational project scheduling because it is partly based on the conventional PERT network model. The formulation is further elaborated so that it could deal with distinctive features of resource usage such as aggregation and substitutability of resources. We see, with an illustrative example, that the formulation is useful for quantitatively analyzing the problem.

3 - An event-driven project planning model with a Bayesian network based approach

Ken-ichi Suzuki, Tetsuo Iida, Akinori Yokota

As a project inherently has uncertainty in its elements, it is inevitable to evaluate the effects caused by uncertainty with an appropriate measure. A standard method is to introduce random variables that represent the task duration, resource consumption, and so forth. As a consequence, the resource should be allocated to subcomponents by monitoring such random variables. On the other hand, in the actual operation, the project manager is expected to take an action reacting to various types of events, such as a change of the product specification, replacement of people, and a contract renegotiation. Therefore, considering project planning, we require a framework that incorporates an event-driven decision making: a decision is made whenever an event is observed to occur. To facilitate an event-driven decision making, we construct a model that includes an influential diagram induced from a Bayesian network as a Bayesian network can describe the influential relationship between factors (events) in an intuitive manner. There exist a few techniques to solve the Bayesian network model with decisions; however, they become ineffective when the dimension of decision variables increases. We propose to employ a stochastic programming approach to numerically find an optimal solution for the problem with a moderate size. In the presentation, we will demonstrate the computational experiment for a hypothetical example.

4 - Chance-constrained admission scheduling for elective surgical patients

Wim Vancroonenburg

Rising healthcare expenditure over past decades has led governments worldwide to re-evaluate their spending, thereby pressuring hospitals into rationalizing their resource usage with a view to reducing costs. Scheduling the admission of elective patients is a crucial process in this regard, enabling hospital management to control the inflow of patients in order to best match the demand for various hospital services (such as surgery and imaging) and resources (beds and personnel) with available capacity. The uncertain and dynamic nature of the care process does, however, complicate decision-making. Careful planning, oversight of all resources, as well as forecasts and estimates of uncertain parameters are therefore all required. In the present study, an admission scheduling model for elective surgical patient admissions is presented which supports this decision-making process. A chance-constrained optimization model is proposed, for which the primary objective is minimizing operating theater costs and patient waiting times while simultaneously avoiding bed shortages at a fixed risk level. Due to the problem's computational complexity, this model is solved by using sample average approximation and a Late Acceptance meta-heuristic algorithm. The applicability of the model in a dynamic setting is demonstrated by implementing four admission scheduling policies which are evaluated using different criteria in a computational study using simulation.

■ MA-05

Monday, 8:30-10:00 - SOUTH BUILDING UV S105

Results on Benders' Decomposition

Stream: Mixed-Integer Linear and Nonlinear Programming

Chair: *Alfredo Moreno*

1 - Simultaneously exploiting two formulations: an exact Benders decomposition approach

Richard Lusby, Stefan Ropke, Mette Gamst, Simon Spoorendonk

When modelling a given problem using linear programming techniques several possibilities often exist, each resulting in a different mathematical formulation of the problem. Usually, advantages and disadvantages can be identified in any single formulation. In this paper we consider mixed integer linear programs and propose an approach based on Benders decomposition to exploit the advantages of two different formulations when solving a problem. We propose applying Benders decomposition to a combined formulation, comprised of two separate formulations, augmented with linking constraints to ensure consistency between the decision variables of the respective formulations. We demonstrate the applicability of the proposed methodology to situations in which one of the formulations models a relaxation of the problem and to cases where one formulation is the Dantzig-Wolfe reformulation of the other. The proposed methodology guarantees a lower bound that is as good as the tighter of the two formulations, and we show how branching can be performed on the decision variables of either formulation. Computational results are reported for the Bin Packing Problem and the Split Delivery Vehicle Routing Problem.

2 - A joint inventory-location problem under periodic review with generalized Benders decomposition

Francisco Tapia-Ubeda, Pablo A. Miranda, Guillermo Cabrera-Guerrero

This paper focuses on a capacitated Joint Inventory Location Problem model that integrates a periodic review Inventory Control Policy. This model is of a Mixed Nonlinear Nonconvex Integer Programming nature and integrates strategic Supply Chain Network design and tactical inventory control decisions. The model integrates the well-known periodic review inventory model with an (R, s, S) policy, where the inventory is inspected every R units of time considering a re-order point of s units and a target inventory level of S units. A solution approach based on Generalized Benders Decomposition is proposed and developed to solve the model. The proposed decomposition relies on a Master Problem that embraces the strategic Supply Chain Network decisions (i.e., warehouse location and assignment of customers), and a Subproblem that comprehends the tactical inventory control decisions for each warehouse. The Master Problem is of a Mixed Integer Linear Programming nature and is solved using a commercial solver while the Subproblems are solved analytically. Optimality cuts to be integrated into the Master Problem are obtained based on Karush-Kuhn-Tucker optimality conditions and Lagrangian duality. Instead of using standard feasibility cuts of Benders Decomposition, some valid inequalities are added iteratively into the Master Problem similar to a cutting plane approach. Optimal solutions where obtained in competitive times.

3 - A Benders decomposition algorithm for quadratic network design problem

Emine Gundogdu, Sinan Gürel

We consider a quadratic capacitated concentrator location problem in which the capacities of hubs are also used for backbone traffic. The objective is to minimize total transportation cost between spokes and hubs, installation cost of hubs.As the mathematical model includes nonconvex nonlinear capacity constraints and the linear capacitated model is NP-hard, the problem under consideration is also NP-hard. We handle this nonlinearity by using an exact branch and check algorithm that is integration of Benders decomposition and branch and bound algorithm. We compare our decomposition algorithm with a special algorithm in IBM CPLEX for mixed integer quadratically constrained programs (MIQCP). In the computational study, we show that the settings where our proposed algorithm gives better results than the special algorithm in CPLEX in terms of number of instances solved to optimum and the optimality gap when the instances are not solved to optimal.

4 - The road restoration crew scheduling and routing problem: accelerated Benders decomposition using meta-heuristics
Alfredo Moreno, Pedro Munari, Douglas Alem

The Road Restoration Crew Scheduling and Routing Problem (RRC-SRP) consists of determining the best route and schedule for a single crew to repair damaged nodes in a network affected by extreme events. The objective is to minimize the sum of time that each demand node remains inaccessible. The scheduling and routing decisions make the problem too complicated to be effectively solved using Mixed Integer Programming (MIP) formulations. Exact approaches based on dynamic programming and Benders decomposition (BD) have been proposed in the literature to solve the problem. The dynamic programming approach failed at solving even some small instances of the problem, while the BD was able to obtain feasible solutions for all the instances, but with high gaps between the upper and lower bounds for most of them. In this talk, we propose techniques to speed up a BD-based approach for the RRCSRP using meta-heuristics. Computational experiments using instances from the literature indicates that hybridizing BD methods with meta-heuristics can simultaneously improve both the lower and upper bounds. The upper bound can be improved when new best solutions are found at evaluating the neighborhood of the current master problem solution, while the lower bound can be improved at generating feasibility or optimality cuts from the solutions found with the meta-heuristics. The lower and upper bounds were improved on average by 35% and 75%, respectively, in relation to the results in the literature.

■ MA-06

Monday, 8:30-10:00 - SOUTH BUILDING UV S106

Stochastic Models and Queueing

Stream: Stochastic Models and Queueing
Chair: *Sarah Dendievel*

1 - QMCD approach for perishability models: the (S,s) control policy with lead time
Yonit Barron, Opher Baron

We consider cost minimization for an (S,s) continuous-review perishable inventory system with random lead times and times to perishability, and a state-dependent Poisson demand. We derive the stationary distributions for the inventory level using the Queueing and Markov Chain Decomposition (QMCD) methodology. Applying QMCD, we develop an intuitive approach to characterizing the distribution of the residual time for the next event in different states of the system. We provide comprehensive analysis of two main models. The first model assumes a general random lifetime and an exponential distributed lead time. The second model assumes an exponential distributed lifetime and a general lead time. Each model is analyzed under both backordering and lost sales assumptions. We consider a fixed cost for each order, a purchase cost, a holding cost, a cost for perished items, and a penalty cost in the case of shortage. We also derive the models' characteristics by using an analytic approach based on the supplementary variables method. Numerical examples are provided and show that variability of lead time is more costly than that of perishability time. Therefore, after reducing lead time and increasing perishability time, managers should focus on reducing variability of lead time.

2 - Three-moment approximation for the mean queue time of a GI/G/1 queue
Kan Wu

The approximation of a GI/G/1 queue plays a key role in the performance evaluation of queueing systems. To improve the conventional two-moment approximations, we propose a three-moment approximation for the mean queue time of a GI/G/1 queue based on the exact results of the H2/M/1 queue. The model is validated over a wide range of numerical experiments. Based on the paired t-tests, our three-moment approximation outperforms the two-moment ones when the inter-arrival time variability is greater than one.

3 - A discrete-time two-server queue where one server is only intermittently available
Freek Verdonck, Herwig Bruneel, Sabine Wittevrongel

In this work we analyse a discrete-time queueing system with an infinite storage capacity and 2 servers. Specific to this analysis is that one of the servers is subject to random interruptions, independent of the queue content. Customers enter the system according to a general independent arrival process and their service time is deterministically equal to 1 time slot. The system under study can be described as a two-state system; in the first state 2 servers are available and in the second state only 1 server is available. State changes can only occur at slot boundaries and mark the beginning and end of so-called up-periods (2 available servers) and down-periods (1 available server). As opposed to earlier work where the up-periods were assumed to have geometrically distributed lengths, our analysis allows for general distributions of the lengths of the up-periods and down-periods, with the only restriction that these have rational probability generating functions (pgfs). We obtain analytical expressions for the pgfs of the system content just after the last slot of an up-period or down-period and just after an arbitrary slot. The resulting pgfs are expressed in terms of the finite number of roots within the complex unit disk of a non-polynomial function. Different from previous work, the variance of the lengths of the up-periods can be taken into account in our analysis. Several numerical examples illustrate the impact of this variance on the average system content.

4 - The power series alorithm for a queueing system with batch arrivals
Sarah Dendievel, Dieter Fiems

We consider a queueing system with batch arrivals and finite capacity. The infinitesimal generator has a block-structure and is organized in levels representing the total number of jobs in the system. We develop a power series algorithm for the computation of the stationary distribution vector of the queue. This method uses power series expansions as function of an artificial parameter.

We perturb the infinitesimal generator by a parameter: when the parameter is equal to one, we get the original system, when the parameter takes values between zero and one, transitions to lower levels are not changed while transitions to higher levels are multiplied by a power of the parameter. When the parameter is equal to zero, transitions to higher levels are not possible: level zero is recurrent and all the other levels are transient. We derive a power series expansion of the stationary distribution around zero in terms of the associate deviation matrix of the system. We use the coefficients of the series expansion to solve the original queue and we provide numerical examples to illustrate the method.

■ MA-07

Monday, 8:30-10:00 - SOUTH BUILDING UV S107

Analytic Hierarchy Process I

Stream: Analytic Hierarchy Process / Analytic Network Process
Chair: *Alessio Ishizaka*

1 - Solar energy plant project selection with hesitant fuzzy linguistic term sets based AHP decision making method
Veysel Çoban, Sezi Cevik

Fossil-based energy sources used as primary sources to meet rising energy demand causes environmental, economic and social problems. Solar energy is the most important alternative energy source in order to remove the fossil-based hazards. The solar rays are converted into electrical energy with photovoltaic (PV) and concentrated solar power (CSP) solar energy systems. Although solar energy systems have the advantages of environmental sensitivity and low operating costs, the high initial cost is the most important problem in solar energy technologies. Therefore, solar power systems must be installed in the right place and on the right conditions. Hence, investors need to decide on the most optimum project by evaluating alternative solar energy projects under environmental, social and economic criteria. In this study, it is aimed to determine the most suitable project among the alternative projects proposed for the installation of PV solar energy plant. affected by economic, political, technical and social factors. AHP MCDM model is used to evaluate the criteria affecting the project and evaluation of the alternative. The linguistically expressed pairwise evaluations based on the knowledge and experience of experts are converted into numerical values using hesitant fuzzy linguistic term sets (HFLTS) and applied in the AHP method. The best PV project with the highest overall priority value is preferred according to the decision makers who make consistent evaluations.

2 - Identifying the influencers on twitter: the case of the world championships in track cycling

Amparo Baviera-Puig, Jose Maria Lamiran Palomares, Tomas Baviera

Identifying the most influential users of a social network is a key question nowadays. Without a doubt, the sports industry has been affected by the consolidation of social media like few others, and has changed in several ways. Using AHP, the objective of our research is to identify the influencers on Twitter during the World Championships in Track Cycling two years ago. For our research, we downloaded all tweets with the hashtag #TWC2016 sent from February 15 to March 14. In total, 55,572 tweets were analysed. These tweets were launched by 20,175 users. According to the literature review, we define the following criteria for user influence on Twitter: activity, authority and popularity. We chose two sub-criteria to measure each of the criteria of influence. Of each pair, one is offered by Twitter, whereas the other is a network centrality measure derived from social network theory. Activity is measured by number of tweets and outdegree. Authority is measured by number of retweets and pagerank. At last, popularity is measured by number of followers and indegree. The AHP methodology shows that the most influential factors for a Twitter user in a sport event are related to authority and popularity. To identify the most influential users, we only considered the 25 most important users for every sub-criterion. In this event, the most influential ones are related institutions (federations, cycling teams and/or organizations), media (TV) and athletes participating in the event.

3 - Distribution center location - allocation problem for a stationery manufacturer

Ozay Ozaydin, Ozge Tas, Begum Oktay

Increasing competition and demands of customers push the companies to provide their products to customers faster while maintaining and even reducing the logistics costs. Distribution centers play an important role in optimizing a logistics system. In this study, a distribution center location selection and allocation problem are investigated for a stationery manufacturer, which initially had one warehouse located within the manufacturing plant. A two-level MCDM approach is adopted, the first level being the analysis of the region to determine alternatives, the second level being the actual selection and allocation. For analyzing the regions, infrastructure, socio-economic structure, transportation, service level, target market, environment, technology, sales volume, and political and social factors are used as main criteria. For geographic data population and analysis, a geographic information system tool is used, and for the selection phase, analytic hierarchy process is used by means of a decision meeting in order to take into account the preferences of decision makers.

4 - ANPSort for sorting alternative with interdependent criteria

Alessio Ishizaka

Six problem formulations exist in multi-criteria decision analysis (MCDA): choice, sorting, ranking, description, elimination and design problems. MCDA methods are generally developed for choice or ranking problems. Recently, several methods have been adapted for sorting problems. However, they all assume that the criteria are independent, which is often not the case in real life. Therefore, this paper proposes the new sorting technique ANPSort, which can handle problems with interdependent criteria. Moreover, another practical limitation of ANP is that a high number of alternatives implies a large number of comparisons. ANPSort requires far less comparisons than ANP, which facilitates decision making within large scale problems. It allows a structured, transparent and consistent evaluation integrating qualitative and quantitative criteria. In this paper, a real case study for researcher classification is used to illustrate our approach.

■ MA-08

Monday, 8:30-10:00 - SOUTH BUILDING UV S108

Multi-Objective Combinatorial Optimization

Stream: Combinatorial Optimization I
Chair: *Matthias Ehrgott*

1 - The multiobjective Dijkstra's algorithm

Antonio Sedeño-Noda, Marcos Colebrook

We address the problem of determining all efficient solutions of the Biobjective Shortest Path (BSP) problem. We generalize Dijkstra's algorithm to the Multiobjective Shortest Path (MSP) problem since the proposed methods keep only one candidate label per node in a priority queue of size n. The algorithm runs in O(Nlogn +mNmax2) time and uses O(N + m) space to solve the one-to-all BSP problem determining all non-dominated points in the outcome space and one efficient path associated with each one of them. Here n is the number of nodes, m is the number of arcs, N is the number of non-dominated points in outcome space for the one-to-all BSP problem and Nmax is the greatest number of non-dominated points in the outcome space for the one-to-one s-i BSP problem for all node i =1,. . . ,n. For the case of the one-to-one s-t BSP problem, we incorporate the classical Bidirectional Search scheme in the proposed algorithms to reduce the number of iterations in practice. Also, the proposed algorithms include pruning strategies to avoid the computation of unnecessary dominated labels. The result is a fast algorithm to solve the BSP problem in large networks. A computational experiment comparing the performance of the proposed methods and state-of-the-art methods is included.

2 - Leveraging single-objective heuristics to solve multi-objective problems: applications in vehicle routing

Piotr Matl, Richard Hartl, Thibaut Vidal

After decades of intensive research on the vehicle routing problem (VRP), many highly efficient single-objective heuristics exist for a multitude of VRP variants. But when new side-objectives emerge - such as service quality, workload balance, pollution reduction, consistency - the prevailing approach has been to develop new, problem-specific, and increasingly complex multi-objective methods. Yet in principle, multi-objective problems can be efficiently solved with existing single-objective solvers - this is the fundamental idea behind the well-known epsilon-constraint method (ECM). Despite its generality and conceptual simplicity, the ECM has been largely ignored in the domain of heuristics and remains associated mostly with exact algorithms. In this talk, we dispel these preconceptions and demonstrate that frameworks based on the ECM can be a highly effective way to directly leverage the decades of research on single-objective VRP heuristics in emerging multi-objective settings. We propose an improved version of the classical ECM - Heuristic Box Splitting - that rapidly generates representative sets of heuristic compromise solutions. Based on an extensive computational study on the VRP with Route Balancing, we show the added value of Heuristic Box Splitting compared to the classical ECM, and demonstrate that both epsilon-constraint-based algorithms significantly outperform the current state-of-the-art multi-objective metaheuristics with respect to multiple quality metrics.

3 - Solving a bi-objective stochastic facility location problem by branch-and-cut
Sophie Parragh, Walter Gutjahr, Fabien Tricoire

Many decision problems involve multiple objectives as well as uncertainty in the considered data. In this paper, we focus on facility location decisions which play an important role, e.g., in public service infrastructure planning or relief goods distribution. In many of these contexts, accurate demand figures are not available. The assumed demand values rely on estimates and their actual realizations depend, e.g., on the severity of the drought or the demographic population development in an urban district. Since facility location decisions usually involve longer-term investments, the uncertainty involved in the demand figures should be taken into account already at the planning stage. Furthermore, quite often both client-oriented and cost-oriented objectives are of concern to decision makers. We model a bi-objective stochastic facility location problem that considers cost and coverage as two competing and concurrently optimized objectives. Furthermore, we incorporate stochastic information on possible realizations of the considered demand figures in the form of scenarios sampled from probability distributions. The two-stage problem is solved by combining a recently developed bi-objective branch-and-bound algorithm with the L-shaped method and different strategies with respect to the incorporation of optimality cuts are evaluated. The resulting branch-and-cut algorithm is tested on instances derived from real world data in a disaster relief context.

4 - Bi-objective branch-and-cut algorithms based on LP relaxation and bound sets
Matthias Ehrgott, Sune Lauth Gadegaard, Lars Relund Nielsen

Most real-world optimization problems are multi-objective by nature, with conflicting and incomparable objectives. Solving a multi-objective optimization problem requires a method, which can generate all rational compromises between the objectives. This paper proposes two distinct bound set based branch-and-cut algorithms for general bi-objective combinatorial optimization problems, based on implicit and explicit lower bound sets, respectively. The algorithm based on explicit lower bound sets computes, for each branching node, a lower bound set and compares it to an upper bound set. The other, on the other hand, fathoms branching nodes by generating a single point on the lower bound set for each local nadir point. We outline several approaches for fathoming branching nodes and we propose an updating scheme for the lower bound sets that prevents us from solving the bi-objective LP-relaxation of each branching node. To strengthen the lower bound sets, we propose a bi-objective cutting plane algorithm that adjusts the weights of the objective functions such that different parts of the feasible set are strengthened by cutting planes. In addition, we suggest an extension of the branching strategy "Pareto branching". We prove the effectiveness of the algorithms through extensive computational results.

■ MA-09

Monday, 8:30-10:00 - SOUTH BUILDING UV S109

The Role of Mathematical Optimization in Data Science I

Stream: European Working Group: Data Science Meets Optimization
Chair: *Vanesa Guerrero*

1 - Tree-structured data clustering
Derya Dinler, Mustafa Kemal Tural, Nur Evin Ozdemirel

Traditional clustering techniques deal with point data. However, improving measurement capabilities and the need for deeper analyses result in collecting more complex datasets. In this study, we consider a clustering problem in which the data objects are rooted trees with unweighted or weighted edges. Such tree clustering problems arise in many areas such as biology, neuroscience and computer or social networks. For the solution of the problem, we propose a k-means based algorithm which starts with initial centroid trees and repeats assignment and centroid update steps until convergence. In the assignment step, each data object is assigned to the most similar centroid determined by the Vertex Edge Overlap (VEO). VEO is based on the idea that if two trees share many vertices and edges, then they are similar. In the update step, each centroid is updated by considering the data objects assigned to it. For the unweighted edges case, we propose a Nonlinear Integer Programming formulation to find the centroid of a given cluster which is the tree maximizing the sum of VEOs between trees in the cluster and the centroid itself. We solve the formulation to optimality with a heuristic. For the weighted edges case, we provide a Nonlinear Programming formulation for which we have a heuristic not guaranteeing optimality. We experiment with randomly generated datasets and compare the results with those of the traditional k-modes and k-means algorithms. Preliminary results are promising.

2 - Dealing with heterogeneous data via constrained lasso
M. Remedios Sillero-Denamiel, Rafael Blanquero, Emilio Carrizosa, Pepa Ramírez-Cobo

The Lasso has become a benchmark data analysis procedure, and it has been studied in depth and extended by many authors. In particular, we can find in the recent literature some Lasso variants which deal with data collected from distinct strata, as it is standard in many biomedical contexts. In this work we propose a novel variant of the Lasso in which the degrees of reliability of the different data sources are taken into account. However, this is not enough to guarantee the good performance across all the considered sources. Therefore, we shall additionally demand that overall performance measures, as well as performance measures for the data from each source, attain certain threshold values. As a result, a generalized regression model is obtained, addressed by solving a nonlinear optimization problem.

3 - DCA for robust principal component analysis
Hoai Minh Le, Vo Xuan Thanh

In many real-world applications such as image processing, genomic analysis, etc we encounter very high-dimensional data. Analysis of such data is challenging due to the curse of dimensionality. Principal Component Analysis (PCA) is one of the most popular dimensionality reduction methods to handle high dimensional data. In this work, we deal with Robust PCA (RPCA), a modification of PCA which works well with corrupted observations. RPCA has been succesfully applied to many real life important applications such as Video Surveillance, Face Recognition, etc. RPCA consists in decomposing a given data matrix A as a sum of a low rank matrix and Y and is a sparse noise matrix Y. Thus, RPCA can be formulated as a minimization of the trade-off between the zero-norm of Y and the rank of X. It is well-known that the minimization of a zero-norm is NP-hard problem. We approximate the zero-norm by a DC (Difference of Convex function) function. The resulting problem is then a DC program. We investaged a DCA based method to solve the latter. Numerical experiments on several synthetic and real datasets show the efficiency of our DCA-based algorithm.

4 - On mathematical optimization to interpret factor analysis
Vanesa Guerrero, Emilio Carrizosa, Dolores Romero Morales, Albert Satorra

A natural approach to interpret the latent variables arising in Factor Analysis consists of measuring explanatory variables over the same samples and assign (groups of) them to the factors. Therefore, each factor is explained by means of their assigned explanatory variables yielding a straightforward way to give meaning to the factors. Whereas such assignment is usually done by the user based on his/her expertise, we propose an optimization-based procedure which seeks the best transformation of the factors that yields the best assignment between them and given (groups of) explanatory variables.

■ MA-10

Monday, 8:30-10:00 - SOUTH BUILDING UV S110

Decision Aiding Methods I

Stream: Multiple Criteria Decision Aiding
Chair: *Salvatore Corrente*
Chair: *Milosz Kadzinski*

1 - Redefining the concordance index in ELECTRE by means of OWA aggregation operators

Aida Valls, Jonathan Orama

Aggregation operators are used to merge the information provided by different criteria about a set alternatives. The overall score could then be used to construct a rank order or ordered classification of alternatives. Many different aggregation operators can be found in the literature, with different mathematical properties. In this work we propose to integrate aggregation operators into the ELECTRE multi-criteria decision aiding method. ELECTRE technique employs the weighted average operator (WA) to compute the overall concordance index when constructing the outranking relation. The WA operator can be observed to have a sometimes an undesired compensative effect, so we propose substituting WA for three operators from the Ordered Weighted Average (OWA) family of operators to give more flexibility to the definition of concordance as "a sufficient majority in favor of the outranking relation". In particular, we study these 3 operators: OWAWA (Ordered Weighted Average Weighted Average), WOWA (Weighted Ordered Weighted Average), IOWA (Induced Ordered Weighted Average). They are appropriate because they are designed to combine the advantages of the WA operator and OWA operator. That is, they retain the importance given to each criterion while adding also a conjunctive/disjunctive character to the definition of majority. Within project 2017PFR-URV-B2-60, the results of two case studies will be presented to see the difference with the conventional method used in ELECTRE.

2 - On the use of semantic criteria in ELECTRE in a touristic recommender system

Antonio Moreno, Miriam Martinez-Garcia, Aida Valls, Joan Borràs

The representation of the user preferences is a key component in decision support systems, in particular in recommender systems, because the solution must take into account the decision maker's preferences. The alternatives are usually defined on a set of diverse criteria; thus, multiple criteria decision aiding (MCDA) methods are suitable to be applied in recommender systems. SigTur/E-Destination is a recommender system of touristic activities in the region of Tarragona (Spain) that infers numerical interest scores about different types of activities by capturing and analysing the actions of the user. We included more than 300 types of activities in an ontology that is exploited to evaluate the alternatives. The current system uses an Ordered Weighted Average (OWA) aggregation operator to rank and filter the alternatives. In this work we propose a new way of handling semantic criteria to avoid the aggregation of the numerical scores before the ranking procedure. This method, called ELECTRE-SEM, follows the same principles than the classic ELECTRE-III, but the concordance and discordance indices are defined in terms of the pairwise comparison of the interest scores. With the support of URV Research Funds (2017PFR-URV-B2-61) we have compared 4 tourist profiles and we have observed that the aggregation of interest scores into a single overall score may produce a loss of information. Our method, instead, makes recommendations that fit better the preferences of each user.

3 - Negative interactions between criteria are not necessary in MCDA

Brice Mayag, Denis Bouyssou

In a Multiple Criteria Decision Analysis (MCDA) context, there are some problems where the Decision Maker (DM) needs to interpret some interaction phenomena among criteria. As the interaction between two criteria seems easily to compute, we choose to model by a 2-additive Choquet integral model the preference information of the DM on the set of alternatives. The 2-additive Choquet integral is a useful aggregation function extending the well-known arithmetic mean. In such model, three types of interactions are detected, w.r.t. the sign of the interaction index, and computed from the preference information, on the set of alternatives, given by the DM: positive (complementary), negative (substitutability) or null (independence). In general, the sign of these interaction indices strongly depend on the choice of the parameters representing the DM's preference.

To overcome this problem, we introduce the notion of necessary interaction, like an interaction which do not depend on the set of parameters compatible to our model. When the DM expresses an ordinal information (preferences containing only a strict preference and an indifference relations) on a binary set of alternatives, we give necessary and sufficient conditions to get a negative interaction between two criteria. This characterization is based on the strong condition called 2-MOPI, but easy to interpret.

4 - Selection of a sustainable third-party reverse logistics provider based on the robustness analysis of an outranking graph kernel conducted with ELECTRE I and SMAA

Milosz Kadzinski, Kannan Govindan, Grzegorz Miebs

Pressure from legislation and customers has motivated companies to consider reverse logistics (RL) in their operations. Since it is a complex procedure that requires an adequate system, the recent trend consists in outsourcing RL to third-party reverse logistics providers (3PRLPs) We provide the background of sustainable triple bottom line theory with focus on economic, environmental, and social aspects under 3PRL concerns. The relevant sustainability criteria are used in a case study conducted in cooperation with an Indian automotive remanufacturing company. To select the most preferred service provider, we use a hybrid method combining a variant of ELECTRE I accounting for the effect of reinforced preference, the revised Simos procedure, and Stochastic Multi-criteria Acceptability Analysis. The incorporated approach exploits a set of all parameters of an outranking model compatible with the incomplete preference information of the Decision Maker. In particular, it derives the newly defined kernel acceptability and membership indices that can be interpreted as a support given to the selection of either a particular subset of alternatives or a single option. The proposed ELECTRE-based method enriches the spectrum of multiple criteria decision analysis approaches that can be used to effectively approach the problem of the 3PRLP selection.

■ MA-11

Monday, 8:30-10:00 - SOUTH BUILDING UV S111

Data Envelopment Analysis (DEA) and Performance Measurement

Stream: DEA: Theory
Chair: *Jesus T. Pastor*

1 - A survey on measuring and decomposing overall efficiency in data envelopment analysis

Juan Aparicio, Jesús T. Pastor, José L. Zofío

Farrell (1957) was the first author in introducing an econometric way of measuring and decomposing cost efficiency into technical and allocative components through frontier methods. Farrell's paper inspired other authors to continue this line of research estimating overall efficiency. Nowadays, it is possible to find a lot of approaches devoted to this topic but resorting to many different measures of technical efficiency for decomposing certain measure of economic performance. In this paper, we revise the main characteristics of most important approaches to determine overall efficiency in the context of Data Envelopment Analysis (DEA).

2 - A data envelopment analysis toolbox for MATLAB
Javier Barbero Jiménez, José L. Zofío, Inmaculada C. Álvarez

Data Envelopment Analysis Toolbox is a new package for MATLAB that includes functions to calculate the main DEA models. The package includes code for the standard additive and radial input and output measures, allowing for constant and variable returns to scale, as well as recent developments related to the directional distance function, and including both desirable and undesirable outputs when measuring efficiency and productivity; i.e., Malmquist and Malmquist-Luenberger indices. Bootstrapping to perform a statistical analysis is also included. This paper describes our methodology and implementation of the functions, and it reports numerical results with well-known examples to illustrate their use.

3 - Technical efficiency in the Spanish virgin olive oil protected designations of origin: what is their real performance?
Fernando Vidal Giménez, Jesús T. Pastor, Juan Aparicio, Lidia Ortiz

Spain is the world's leading producer of olive oil, contributing 44% to global production and exports that exceeded to a value of 3,100 million euros in 2016. The commitment to quality production in the sector has resulted in the production of virgin olive oil, generally under the Protected Designation of Origin PDO status, a recognized legal framework that guarantees the quality of agri-food products at European level. In Spain, there are currently 29 PDOs (a great jump in number, compared to only 11 in 2000), which encompass a surface area of almost 700 thousand hectares and involve more than 125,000 farmers. The production of virgin and extra virgin olive oil in accordance with the corresponding PDO specification (regardless of whether they achieve certification or not) is over 289 thousand tons. However, only just over 90 thousand tons are certified and marketed as protected oil. This research analyzes the technical efficiency of these protection figures, taking into account both the total growing area already registered under the Regulatory Body for the PDO and the number of farmers. This is done through Data Envelopment Analysis (DEA), in particular CCR models with an output orientation, in an attempt to determine what their real performance is and if this is related to the prevailing corporate type within the PDO.

4 - Does the CCD Malmquist index measures total factor productivity?
Jesus T. Pastor, Juan Aparicio

We show that the Malmquist Index is a total factor productivity index provided a specific directional distance function is used. Being more specific we study the proportional Directional Distance Function (pDDF) and reformulate it, being able to show that, under constant returns to scale, the associated Caves, Christensen and Diewert (CCD) Malmquist technology index is a total factor productivity index. In fact we are able to measure separately the contribution of inputs and outputs.

■ MA-12
Monday, 8:30-10:00 - SOUTH BUILDING UV S112

Multiobjective Fuzzy Optimization

Stream: Fuzzy Optimization
Chair: *Mariano Jimenez-Lopez*

1 - A better approach for solving a fuzzy multiobjective programming problem
Beatriz Hernández-Jiménez, Rafaela Osuna-Gómez, Gabriel Ruiz-Garzón, Antonio Rufián-Lizana

In this paper we use the Nearest Interval Approximation Operator for solving a fuzzy multiobjective programming problem. We establish necessary Pareto optimality conditions for the resulting interval multiobjective program. We propose an algorithm to indetify and characterize Pareto optimal solutions.

2 - On the use of preference-based evolutionary multiobjective optimization for solving a credibilistic portfolio selection model
Ana Belen Ruiz, Rubén Saborido, José D. Bermúdez, Mariano Luque, Enriqueta Vercher

The portfolio selection problem tries to identify the assets to allocate the capital, and the proportion to be devoted to each asset, for maximizing the returns at the minimum risk. By nature, this is a multiobjective optimization problem. In this work, we propose a three-objective model for portfolio selection, in which the uncertainty of the portfolio returns is modelled by means of LR-power fuzzy variables. We consider as criteria the credibilistic expected return (to be maximized), the below-mean absolute semi-deviation as a risk measure (to be minimized), and a loss function which evaluates the credibility of achieving a non-positive return (to be minimized). The uncorrelation among the risk and loss measures concludes that they provide different information. Budget, cardinality, and diversification constraints are considered. To generate non-dominated portfolios fitting the investor' expectations, preference-based evolutionary algorithms are applied. The preferences are given by aspiration values to be attained by the objectives and profiles representing aggressive, cautious, and conservative investors are analysed. The results for data of the IBEX35 show that portfolios improving the preferences are found in the cautious and aggressive cases, while portfolios with objective values as close as possible to the expectations are obtained in the conservative case. In the generation process, the credibilistic loss has played an important role to find diversified portfolios.

3 - A goal programming model for solving preferences expressed by importance weights: an application to allocate assets upon corporate sustainability criteria
Mariano Jimenez-Lopez, Amelia Bilbao-Terol, Mar Arenas-Parra

The aim of this work is to propose a new methodology for solving a multiobjective problem in which the DM preferences are expressed by importance weights of the criteria and no aspiration level has been set. Since the reference points for the criteria have not given for the DM we propose to work with ideal and anti-ideal points. So, the objective functions are substituted by membership functions that measure the degree fulfillment to the fuzzy set "to be close to the ideal values". In this way, a GP model is formulated where the aspiration level associated to each membership function is the weight of the corresponding objective. The maximizing target function is a convex linear combination of the weighted sum of the degrees of membership and the sum of the unwanted deviations. The presented methodology is applied to a portfolio selection problem being the firms assessed both financial and corporate sustainability (CS) criteria. We have CS valuations of the firms from corporate sustainability rating agencies and the financial measures are gathered from the financial rating agencies. We assume that the investor reveals her preferences assigning importance weights for the criteria. This could be a more easy way to express preferences than to set aspiration levels. The model is solved and sensitivity analysis is carried out.

4 - A fuzzy goal programming approach tightening aspiration levels to weighted preferences
Manuel Díaz-Madroñero, Mariano Jimenez-Lopez, Josefa Mula

In this paper, we propose a new fuzzy goal programming model for decision making in a multiobjective uncertain context. Here, we consider problems where the uncertainty is inherent to right hand side parameters and technological coefficients of fuzzy constraints. In order to deal with these fuzzy constraints, a fuzzy ranking method based on feasibility degrees is used. We assume known the weights of the relative importance of each objective function but not their corresponding aspiration levels. These aspiration levels are adjusted to the decision maker preferences as possible by optimizing the convex combination of the weighted sum of the degrees of membership and the sum of the unwanted deviations of the degrees regarding the weights. The validation of the proposal is carried out through a material requirement planning (MRP) problem. Some guidelines are proposed for selecting solutions according to the tradeoff between feasibility degrees and objective function results.

■ MA-13

Monday, 8:30-10:00 - SOUTH BUILDING UV S201

Supply Chain Management I

Stream: Supply Chain Management II
Chair: *Zelong Yi*

1 - Supply chain profit distribution under uncertainty
Songsong Liu

Traditional to the maximisation of the total profit of a supply chain may lead to an uneven profit distribution and a high degree of dissatisfaction of members. Thus, how to distribute the profit of the whole supply chain fairly to ensure adequate rewards for each member is still a key issue, especially under uncertain environment. Transfer prices could affect each member's costs and revenues then influence its planning strategies and are therefore considered as a mechanism for profit distribution. This work aims to develop an optimisation-based decision-making framework supply chain planning under demand uncertainty of three-echelon supply chains, including primary and secondary manufacturing, and markets, to obtain a fair distribution of the total profit. A stochastic mixed integer linear programming (MILP) model is proposed for the optimal production, distribution and capacity planning of a supply chain network. The classic proportional fairness criterion is adopted to define fair profit distributions, and a game theoretic solution approach is developed for fair transfer pricing using Nash bargaining principles. An illustrative example of a supply chain network in the process industry is investigated, and the obtained results demonstrate the applicability of the proposed model and approach.

2 - Effects of trust on price contract design in a supply chain
Hangfei Guo, Mahmut Parlar, Min Zhang

This paper explores how trust impacts the buyer's price contract design in a supply chain. Depending on the risk attitude toward each other, the buyer and the supplier build either goodwill trust or capability trust through their long-term relationship. By modelling the capability trust through a power function and the goodwill trust through an exponential function, the authors obtain the optimal price contract as a solution to a nonlinear ordinary differential equation and provide the explicit solution for the resulting four combinations. If the capability trust is built between the buyer and the supplier, then the optimal price contract will be concave, convex or linear w.r.t the supplier's output, depending on both parities' degrees of risk aversion. If goodwill trust exists between the buyer and the supplier, then the optimal price contract is always linear w.r.t the supplier's output. If the buyer has capability trust toward the supplier but the supplier has goodwill trust toward the buyer, then the optimal price contract is always concave in the supplier's output. In reverse order, then the optimal price contract is always convex in the supplier's output. These interesting findings extend existing knowledge on the contingent conditions under which the buyer is more willing to provide a concave or convex contract to its supplier. The results also clarify the mechanism through which trust and risk aversion impact the price contract design in a supply chain.

3 - Metrics and methods for improving resilience in agribusiness supply chains
Golnar Behzadi, Michael O'Sullivan, Tava Olsen

By definition, increasing supply chain resilience improves the supply chain's ability to return to normal, or to an even more desirable situation, quickly and efficiently after being hit by a disruption. This is especially critical in agribusiness supply chains (ASCs) where products are perishable and have a short life-cycle. In this paper, we propose a number of resilience metrics to capture the recovery process in an ASC following a transportation disruption. The resilience measures include 1) time to recovery, 2) the recovery level, 3) the loss of profit during the recovery time window, and 4) the net present value of the loss of profit over all time-periods. Then, we provide an analytic model that determines supply chain planning and risk management (RM) strategy decisions that optimize each of the resilience measures as well as profit in an ASC problem under transportation disruption. The RM strategy is either risk acceptance (RA) strategy or a resilient backup transportation strategy with varying levels of utilization during disruption periods. Results from the proposed mathematical model with closed-form solutions show that given particular conditions, first the resilience measures are improved by utilizing the proposed resilient strategy. Then, the optimal RM and supply chain decisions are particularly dependent on type of resilience measure that aimed to improve, strategy cost, the perishability fraction of products, and the initial design of the ASC.

4 - Sustainability building of an agricultural supply chain with a capital-constrained farmer in developing economies
Zelong Yi

In this study, we consider a decentralized agricultural supply chain consisting of a capital-constrained smallholder farmer and an intermediary platform. The smallholder farmer sells the agricultural products through the intermediary platform but lacks the financial resources for production. In addition to the traditional solution of bank financing (provided by a bank) as a source of finance for the capital-constrained farmer to ensure the sustainable production of the agricultural goods, the intermediary platform can also provide loans directly to the smallholder farmer (known as direct financing) or serve as a guarantor if the capital-constrained farmer has insufficient creditworthiness to obtain bank loans (known as guarantor financing). The farmer can thus obtain a loan through three methods: bank financing, guarantor financing, and direct financing. We find that the smallholder farmer produces the most under direct financing and the least under bank financing, and that the intermediary platform prefers direct financing over guarantor financing in a weak sense. Specifically, when the farmer's production cost is low, the intermediary platform prefers financing the farmer directly; when the cost is in an intermediate range, the platform prefers either direct or guarantor financing; and

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■ MA-14

Monday, 8:30-10:00 - SOUTH BUILDING UV S202

On Proximal Algorithms for Structured Optimization Problems

Stream: Nonlinear Programming: Methods
Chair: *Ting Kei Pong*

1 - A successive difference-of-convex approximation method for a class of nonconvex nonsmooth optimization problems
Tianxiang Liu, Ting Kei Pong, Akiko Takeda

In this talk, we consider a class of nonconvex nonsmooth optimization problems whose objective is the sum of a nonnegative smooth function and a brunch of nonnegative possibly nonsmooth functions, some of which are composed with linear maps. This kind of problems arises in various applications and is challenging due to the coupled nonsmooth functions. To solve it, we propose a successive difference-of-convex approximation method, in which we approximate the nonsmooth functions by their Moreau envelopes and make use of the DC structure of the Moreau envelope. We prove the convergence of the method to a stationary point of the objective under suitable assumptions and discuss how the method can be applied to concrete applications. Finally, numerical simulations are shown to illustrate the performance of the method.

2 - a family of inexact sqa methods for non-smooth convex minimization with provable convergence guarantees based on the luo-tseng error bound property

Man-Chung Yue

We propose a new family of inexact sequential quadratic approximation (SQA) methods, which we call the inexact regularized proximal Newton (IRPN) method, for minimizing the sum of two closed proper convex functions, one of which is smooth and the other is possibly nonsmooth. Our proposed method features strong convergence guarantees even when applied to problems with degenerate solutions while allowing the inner minimization to be solved inexactly. Specifically, we prove that when the problem possesses the so-called Luo-Tseng error bound (EB) property, IRPN converges globally to an optimal solution, and the local convergence rate of the sequence of iterates generated by IRPN is linear, superlinear, or even quadratic, depending on the choice of parameters of the algorithm. As a consequence of our result, IRPN is capable of solving regularized regression or classification problems under the high-dimensional setting with provable convergence guarantees. We compare our proposed IRPN with several empirically efficient algorithms by applying them to the regularized logistic regression problem. Experiment results show the competitiveness of our proposed method.

3 - Fast method for non-smooth non-convex minimization

Peng Zheng

We proposed a new class of algorithms for structured non-smooth nonconvex problems that are expressible as compositions of non-smooth non-convex functions with linear maps. In many cases, these algorithms only require (1) least squares solvers and (2) proximal operators. An immediate consequence is that direct factorization technique, e.g. SVDs, as well as efficient iterative methods such as preconditioned CG, fast-gradient methods and (L)BFGS can be leveraged to solve non-smooth non-convex problems.

We provided a convergence analysis and empirical results for a selected set of representative applications, including phase retrieval, stochastic shortest path, semi-supervised support vector machine, and exact robust PCA. In all of these applications, we see linear and superlinear rates of convergence. In particular, we need fewer than 20 iterations to solve large-scale robust phase retrieval problem.

4 - Iteratively reweighted l1 algorithms with extrapolation

Ting Kei Pong

Iteratively reweighted l1 (IRL1) algorithm is a popular algorithm for solving a large class of optimization problems whose objective is the sum of a Lipschitz differentiable loss function and a possibly nonconvex sparsity inducing regularizer. Motivated by the success of extrapolation techniques in accelerating first-order methods, in this talk, we explore how widely used extrapolation techniques such as those in FISTA can be incorporated to possibly accelerate the IRL1 algorithm. We will present three versions of such algorithms, discuss their convergence and compare their numerical performance against some other popular first-order methods. This is joint work with Peiran Yu.

■ MA-15

Monday, 8:30-10:00 - SOUTH BUILDING UV S203

Selective Vehicle Routing and Extended Network Design Problems

Stream: Vehicle Routing and Logistics Optimization II
Chair: *Jana Ries*
Chair: *Pablo A. Miranda*

1 - Hazard and time of exposure as objectives in HM transportation

Andrés Bronfman, *German Paredes-Belmar*, *Vladimir Marianov*, *Diego Beneventti*

A model for hazardous materials (HM) route design between multiple origin-destination pairs is proposed in which public concerns are taken into account. Population is assumed to be distributed in discrete points in a plane, denoted population centers, each of which is surrounded by a circular hazard area. The hazard area is defined by the public perception about, or the actual reach of an accident involving HMs. The use of a route segment that falls within a hazard area for HM transportation exposes the corresponding population center to the associated hazard. The proposed methodology incorporates a population center's exposure in terms of time and level of hazard as new objectives. The level of hazard to which a center is exposed, is a function of the distance between the center and each point on the link within its hazard circle. A mathematical programming problem integrating these new objectives is formulated and solved. Finally, the methodology is applied in a real case to define an optimal HM transport route for the city of Santiago, Chile.

2 - Dynamic pricing for multi-period home delivery

Alejandro Lamas

We consider a firm that delivers goods (or provides services) to a set customers located in an urban area. Customer requests arrives stochastically in a rolling booking interval. Once a request arrived, the firm sets a price based on the geographical location, the available capacity and the lead-time of such request. The customer accept/reject the proposal of the firm with a certain probability that depends on the price. Thus, the firm uses prices as mean for selecting customers that will require a visit. For a day of delivery, the firm determines the routing of a vehicle one day in advance; this routing consists of visiting the customers whose request is due to such day of delivery. The goal of the firm is to select the combination of price and lead time that maximizes its revenues. We model the problem by a Dynamic Programming formulation, whose Bellman equation requires solving a Traveling Salesman Problem (TSP). Although the formulation leads to optimal pricing for small instances of the problem, its efficiency is hurt due to both the complexity of the TSP and the "curse of dimensionality". Thus, we propose heuristic approaches based on TSP approximations and state aggregations.

3 - Advanced goal programming formulations for an insular traveling salesman problem with fairness concerns

Pablo A. Miranda, *Jana Ries*, *Dylan Jones*

Insular Vehicle Routing Problems (InVRP) and particularly the Insular Traveling Salesman Problem (InTSP) search for the optimal design of a transport system to serve a set of islands or isolated regions for freight collection or distribution purposes. A simultaneous optimization of visit sequencing and port selection at the islands must be addressed, while ensuring that at least one port is selected for each island.

Bi-Objective optimization approaches are an appropriate methodology to address these problems in which Maritime Transportation Costs (MTC) associated to a barge and Ground Transportation Costs (GTC) inside the islands are optimized as two conflicting objectives. However, in many applications, these approaches fail to address fairness aspects related to deviations from an ideal solution for each individual island (i.e. visiting all the ports at each island), and across them.

This research explores and analyses different Goal Programming formulations to incorporate fairness concerns within a previously studied InTSP, where a network of stakeholders is employed to characterize the underlying decision making process. Results for real world applications and fictitious instances are presented, discussing advantages and shortcomings of each of the proposed formulations.

4 - An instance-based algorithmic performance study for the INTSP using a co-evolutionary based solution approach
Jana Ries, Pablo A. Miranda

The Insular Travelling Salesman Problem (InTSP) seeks to find simultaneously the best selection of nodes within a set of isolated regions and the cost-optimal routing sequence amongst it. A further element that characterises the InTSP is the consideration of the underlying infrastructure within each isolated region.

Motivated by the different levels of complexity within the problem structure and the subsequent impact on a suitable solving approach, the research presents a discussion of key characteristics of an InTSP and the corresponding impact on algorithmic performance using a co-evolutionary based strategy. Hereby, particular focus will be drawn towards spatial features within and between the set of isolated areas.The analysis is presented using a real-world household waste collection problem that originated in the South of Chile, in addition to a set of fictitious instances.

■ MA-16

Monday, 8:30-10:00 - SOUTH BUILDING UV S115

Social Networks: Community Detection and Information Propagation I

Stream: Network Optimization and Social Networks
Chair: *Mario Ruthmair*

1 - Robust StQP and community detection in social networks
Michael Kahr, Immanuel Bomze, Markus Leitner

We consider the robust variant of the Standard Quadratic Problem (RStQP), in which a (possibly indefinite) quadratic form is extremized over the standard simplex (which is considered certain), and the quadratic form is uncertain. The uncertain data realizations are assumed to lie in known uncertainty sets, which we model particularly by ellipsoids, polyhedra, and spectrahedra, more precisely, intersections of sub-cones of the copositive matrix cone. We show that the copositive relaxation gap of the RStQP equals the minimax gap under some mild assumptions for arbitrary uncertainty sets, and present conditions under which the RStQP reduces to a deterministic instance of a StQP. These conditions also ensure that the copositive RStQP relaxation is exact. A specific application is community detection in social networks based on profile similarity, for which a computational study is presented.

2 - Parsimonious formulations for low-diameter clusters
Austin Buchanan, Hosseinali Salemi

In the analysis of networks, one often searches for tightly knit clusters. One property of a "good" cluster is a small diameter (say, bounded by k), which leads to the concept of a k-club. In this talk, we propose new path-like and cut-like integer programming formulations for detecting these low-diameter subgraphs. They simplify, generalize, and/or dominate several previously existing formulations. Our best-performing formulation uses only n variables (quite unlike previous formulations) and imposes the diameter-at-most-k constraints via an exponentially large class of cut-like inequalities. A relatively simple implementation of the cut-like formulation easily outperforms previous approaches, solving dozens of instances of the maximum k-club problem in a second or two that would take hours by other formulations. Moreover, the cut-like formulation is more general in the sense that it applies even when distances are not measured in terms of hops. While we consider only the k-club problem in this paper, the proposed techniques may also be useful in other applications where compact solutions are key (e.g., political districting and wildlife reserve design).

3 - Lagrangean relaxation based heuristics to solve influence maximization in social networks
Evren Guney

The Influence Maximization Problem (IMP), which seeks for a small subset of influentials out of a large stochastic social network that can activate maximum number of individuals, has been a popular topic among researchers and practitioners recently. Assuming that the spread of influence is following certain popular diffusion models, such as independent cascade or linear threshold, the expected influence which is the objective of the optimization problem possesses submodularity property. Benefiting from this property, most of the researchers apply greedy based heuristics that guarantee a (1-1/e) worst case bound. Since the network is stochastic exact solution methods are intractable for even small networks, therefore sampling based strategies are used for approximate solutions. In this study, we focus on the optimal solution of IMP, which is usually neglected by most of the researchers. The LP relaxation of IMP is strong with small optimality gaps under certain formulations. Based upond this observation, we analyse various Lagrangean Relaxation formulations of IMP and develop heuristics for solving IMP efficiently. We compare the performance of our algorithms both in terms of solution quality and computation time with the state-of-the-art algoritms.

4 - Least cost influence propagation in (social) networks
Mario Ruthmair, Matteo Fischetti, Michael Kahr, Markus Leitner, Michele Monaci

Influence maximization problems aim to identify key players in (social) networks and are typically motivated from viral marketing. In this work, we introduce and study the Generalized Least Cost Influence Problem (GLCIP) that generalizes many previously considered problem variants and allows to overcome some of their limitations. A formulation that is based on the concept of activation functions is proposed together with strengthening inequalities. Exact and heuristic solution methods are developed and compared for the new problem. Our computational results also show that our approaches outperform the state-of-the-art on relevant, special cases of the GLCIP.

■ MA-17

Monday, 8:30-10:00 - SOUTH BUILDING UV S205

Accounting, Auditing and Taxation

Stream: Operational Research in Financial and Management Accounting
Chair: *Matthias Amen*

1 - Opportunities for earnings management offered by IAS 36
Matthias Amen

According to IAS 36 an entity has to recognise an impairment if the recoverable amount of a cash generating unit is lower than its carrying amount. The recoverable amount as value in use is the sum of the discounted net cash inflows of a detailed planning period and a terminal value. Thus, the recoverable amount and of course the impairment of the asset are the results of forecasts be based on best estimates. On one hand, IAS 36 gives some guidelines in forecasting the cash flows and in choosing the discount rate.

On the other hand, IAS 36 offers a large range of opportunities at different stages during the impairment calculations. We concentrate on selected spots and analyse how to cope with the requirements with respect to a well-to-define long-term reporting objective by means of OR techniques.

2 - The cooperative bargaining game of audits - regulatory provisions for truthful reporting and independent audits
Tobias Filusch, Sascha H. Moells

Truthful financial reporting is closely related to the independence of the auditor. Once effective auditing routines have been established, incentives for setting up fraudulent statements by the management can be assumed low due to a high risk of detection. In the opposite case, however, a cooperative behavior between the auditor and the auditee is likely to occur. To capture this potential threat for the independence of audits we use the cooperative Nash bargaining game to model the auditor-client management negotiation (ACMN) that concludes an audit period and assume that the subject of negotiation is the division of a surplus created by the management through "managed" financial statements. From a regulatory perspective, it is interesting to know if regulatory provisions discussed in academia and/or practice either target the setup of the game or its Nash solution. Our results indicate that most provisions, such as a mandatory auditor rotation after a certain tenure, usually only affect the setup. However, our research shows that including the Nash solution can have an even more positive impact. In addition, we propose a minimum audit contract term (MACT) complementing the auditor rotation that increases the auditor's bargaining power while simultaneously eliminating the management's surplus-earnings from the bargaining. By anticipating this unattractive outcome, the management is incentivized to abandon any fraudulent strategy at earlier stages.

3 - The constant-growth valuation model and firm-specific inflation - theory & empirical evidence
Stefan Laun, Sascha H. Moells

A well-founded forecast of the cash flows is one of the main problems of any firm valuation and for quite a while has been controversially discussed on a theoretical level concerning the consideration of growth when estimating the terminal value. Given the high relevance of the terminal value with a contribution often exceeding 50% of the total firm value, this component is typically estimated by using the "Constant Growth Valuation" model relying on sustainable (infinite) cash flows and a constant growth rate. The precise derivation of the growth rate, however, is complex as it involves different causes of growth (e.g. the reinvestment rate or the inflation rate). Regarding the incorporation of inflation existing approaches focus on the question whether or not macroeconomic inflation should be taken into account. In addition, only few empirical studies on the growth of firm cash flows have yet been presented whose results cannot provide convincing guidance for practical problem solving due to conceptional and/or data-related restrictions. Against this background, first we derive the "General Growth Model" that distinguishes between macroeconomic and firm-specific inflation. In a second step, we provide - based on our model - detailed evidence for the estimation of growth discounts utilizing a sample covering 12 countries and applying a conceptually improved methodology. Our results show the necessity of differentiations for an appropriate design of valuation calculi.

4 - The impact of tax legislation on inventory and supplier selection models
Hua Jin, Patrick Beullens

Operational Research (OR) provides the methods and techniques by which firms can maximise their profits by taking smart decisions. The OR literature in the area of logistics, however, pays scant attention to cash flows that arise in order for the firm to fulfil its legal obligations. This paper develops a methodology for constructing models that explicitly account for the impact of tax legislation on a series of classic inventory management problems. It does this by expressing the future profits of the firm after tax as the Net Present Value or Annuity Stream Value of the cash flow function associated with the activity for the firm, including these cash flows exchanged with relevant third parties and the government that are needed in the context of ensuring compliance with tax legislation. Using the legislation in the United Kingdom (before Brexit), the research established how the explicit consideration of Value Added Tax (VAT) scheme, Corporate Tax (CT) and import duties and tariffs rules affect optimal decisions for a firm with respect to the optimal associated product ordering policies. We examine the implications from European Union legislation on acquisitions as well as international based import on inventory management. We find that tax rates as well as tax schemes that apply to the firm are important in particular for products with lower profit margins. Taxes not only affect the optimal inventory policy, but may also influence the sourcing and supplier selection strat

■ MA-18

Monday, 8:30-10:00 - SOUTH BUILDING UV S206

Algorithms in Convex Optimization

Stream: Convex Optimization
Chair: *Alfredo Iusem*

1 - Non-linear conjugate gradient method for vector optimization
Luis Roman Lucambio Perez, Leandro Prudente

We propose non-linear conjugate gradient methods for finding critical points of vector-valued functions with respect to the partial order induced by a closed, convex, and pointed cone with non-empty interior. No convexity assumption is made on the objetives. The concepts of Wolfe and Zoutendjik conditions are extended for the vector-valued optimisation. In particular, we show that there exist intervals of stepsizes satisfying the Wolfe-type conditions. The convergence analysis covers the vector extensions of the Fletcher-Reeves, Conjugate Descent, Dai-Yuan, Polak-Ribière-Polyak, and Hestenes-Stiefel parameters that retrieve the classical ones in the scalar minimisation case. Under inexact line searches and without regular restarts, we prove that the sequences generated by the proposed methods find points that satisfy the first-order necessary condition for Pareto-optimality. Numerical experiments illustrating the practical behaviour of the methods are presented.

2 - Gradient projection methods for the n-coupling problem
Sangho Kum

We are concerned with optimization methods for the L2-Wasserstein least squares problem of Gaussian measures (alternatively the n-coupling problem). Based on its equivalent form on the convex cone of positive definite matrices of fixed size and the strict convexity of the variance function, we are able to present a successful optimization algorithm for the unique minimizer. Its global convergence rate analysis is provided according to the derived upper bound of Lipschitz constants of the gradient function.

3 - The mathematical structure of the mathematical programming
Javier Diaz, Luis Moreno

Linear Programming (LP) tries to optimize a linear function subject to linear constraints. Its solution, if it exists, gives the value of variables, objective function, shadow prices, and reduced costs. The sensitivity analysis gives the b and C variation ranges allowed for the solution to remain feasible or optimal. Particular LP problems are the knapsack (one constraint), the resource allocation (type constraints), and the diet (type constraints). The Transport Problem (TP) is a LP where all the technological coeficients are 0 o 1. The Assignment Problem (AP) is a TP where all bi are 1. These last two cases can be generalized as the Transshipment Problem and the Generalized Assignment Problem. Mixed Integer Linear Programming (MILP) allows continuous, integer and binary variables in the same model. Branch and bound methods allow MILP to be solved using PL approximations. Benders presents partition procedures for solving mixed-variables programming problems including non-linear components in the objective function. Large-scale techniques such as Generation of Columns, Dantzig-Wolfe, Dynamic Programming, Stochastic Dynamic Dual Programming, Lagrangian Relaxation, and Convex Programming are analyzed.

4 - Splittting methods for complementary eigenvalue problems
Alfredo Iusem

We consider the Complementary Eigenvalue Problem CEiP(A,B), which, given square n-matrices A, B, consists of finding a nonnegative n-vector x and a scalar a such that Ax + aBx is nonnegative and x(Ax + aBx) vanishes.

We propose two splitting methods for this problem. Assuming that B is positive definite, we partition A as A=C+D. In each iteration we solve a Linear Complementarity Problem with a positive definite matrix for updating the x vector variable and then update the a scalar variable thorough a closed formula.

We will discuss the convergence properties of several variants, some of which include an additional line search for updating the x variable. We also present computational experiments for validating and comparing the proposed methods.

■ MA-19

Monday, 8:30-10:00 - SOUTH BUILDING UV S207

Vector and Set-Valued Optimization I

Stream: Vector- and Set-Valued Optimization
Chair: *Lidia Huerga*
Chair: *Vicente Novo*

1 - Global stability results for interval optimization problems
Ruben Lopez

We study the global stability of optimization problems with interval-valued objective functions. We focus on set-type solutions that are defined by means of the Kulisch-Miranker order between intervals. We employ a variational convergence notion for vector functions from the literature. We provide geometric and metric characterizations of this convergence notion. We describe the global behavior of level, colevel and solution sets under perturbations of the data. We show that the coercivity and coercive existence conditions for these problems are preserved locally within certain classes of functions. We compare the variational convergence with other convergence notions. Finally, we study the behavior of operations with interval functions under perturbations.

This work has been supported by Conicyt-Chile under project FONDECYT 1181368 and by Ministerio de Economía y Competitividad-Spain under project MTM2015-68103-P

2 - A multiobjective trust region algorithm
Jana Thomann, Gabriele Eichfelder

In many applications of multiobjective optimization the objective functions are heterogeneous and differ in some properties. An important aspect of heterogeneity is the evaluation time of the functions. Some objectives are not given analytically, but are an expensive black-box function, for instance given by a time-consuming simulation. Thus, obtaining function values involves high computational effort and derivatives are not available with reasonable effort. This talk presents a solution method for such heterogeneous multiobjective problems where one objective is an expensive function for which only function values are available. The other objective functions are given analytically and the function values and derivatives are easily available. The presented solution method is based on the scalar trust region approach and generalizes it to multiobjective problems. Following the trust region concept the computations are restricted to a local area in every iteration and the functions are replaced by local models. The search direction is generated in the image space and local ideal points of the model functions are used. Convergence to Pareto critical points can be proved.

3 - A global solution method for nonconvex multiobjective optimization
Julia Niebling, Gabriele Eichfelder

Even in multiobjective optimization we have to distinguish between locally and globally optimal solutions. In general algorithms for solving multiobjective optimization problems are highly investigated. Most of these algorithms are based on scalarization approaches, where a new scalar valued problem depending on some parameters is formulated and solved by mostly local methods for scalar-valued optimization problems. But if we are interested in globally optimal solutions and use a global solver for each choice of parameters for the scalarized problem then this is a very time consuming and inefficient approach. In this talk a new branch-and-bound based algorithm for smooth nonconvex multiobjective optimization problems will be introduced, which is able to calculate an approximation of the whole globally optimal solution set. The new algorithm uses selection rules, discarding and termination tests. The discarding tests are the most important aspect, as they examine in different ways whether a box can contain optimal solutions and determines by that the speed and effectiveness of the algorithm. We present a new discarding test which combines techniques from the alphaBB method from global scalar-valued optimization with outer approximation techniques from convex multiobjective optimization and the concept of local upper bounds from combinatorial multiobjective optimization.

4 - Limit behaviour of Henig approximate proper solutions in vector optimization
Lidia Huerga, César Gutiérrez, Vicente Novo, Miguel Sama

We introduce a concept of approximate proper efficiency in the sense of Henig for vector optimization problems. We study the properties of this type of approximate proper solutions and we provide sufficient conditions for these solutions to tend to exact weak/efficient/proper solutions when the error tends to zero. An illustrative example is shown.

■ MA-20

Monday, 8:30-10:00 - SOUTH BUILDING UV S301

Advances in Decision and Sensitivity Analysis

Stream: Decision Analysis and Decision Support Systems
Chair: *Emanuele Borgonovo*

1 - An interactive Bayesian method for multicriteria sorting problems
Canan Ulu

Decision makers (consumers, firms or policy makers) are sometimes interested in assigning alternatives to preference classes instead of choosing the best alternative or ranking all the alternatives. This problem is referred to as the multicriteria sorting problem. We encounter such problems in diverse application areas: credit agencies need to classify customers according to their risks; graduate programs need to decide which prospective students to accept, put on the waiting list or decline. In this paper, we develop an interactive Bayesian method that aids a decision maker (DM) with a multicriteria sorting problem by learning about her preferences and using that knowledge to sort alternatives. We assume the DM has a linear value function with an additive error and value thresholds for preference classes. Our method starts with a prior on these uncertainties and asks the DM to sort alternatives from time to time. We seek to minimize expected total cost from misclassification and cost of consulting the DM. In each stage, we compare the expected cost of stopping and placing all the remaining alternatives in preference classes and the expected cost of continuing to consult the DM. If it is optimal to continue, we pick an alternative to present to the DM and given the DM's response, we update the prior distribution using Bayes' rule via a Markov Chain Monte Carlo algorithm. We study the performance of various heuristic policies for our algorithm.

2 - Multidimensional attitudes in intertemporal choice
Veronica Roberta Cappelli
Many everyday decisions can be framed as choices between streams of multidimensional alternatives. At the same time, there is by now substantial evidence that decision makers may have domain specific attitudes toward outcomes. In particular, different categories of outcomes, or different attributes, may be discounted differently and associated with different levels of risk aversion. This work aims at providing an axiomatic model of choice between streams of multidimensional alternatives. Our objective is to allow for an evaluation functional that takes into account the fact that not only utility, but also discounting, may be attribute, or domain, dependent and discuss its possible applications.

3 - A comparison of variance-based and moment-independent sensitivity analysis approaches
Samuele Lo Piano, Emanuele Borgonovo, Andrea Saltelli
A suggestion has been made to better structure sensitivity analysis as a discipline (Saltelli et al. 2018), by offering for different settings and applications a set of recommended good practices. Various versions of the so-called variance-based measures (Saltelli et al. 2008), and the newer class of moment independent methods (Borgonovo, Castaings, and Tarantola 2012; Wei, Lu, and Song 2015) offer promising material to structure a new taxonomy of general use. In a nutshell variance-based measures look at the variance of the output when one input factor is kept constant, and they are the extension to mathematical models of the analysis of variance (ANOVA) taught in statistics. Moment-independent methods look instead at how the entire distribution of the output is modified when one input is fixed. Among the desirable properties possessed by these two classes of methods are the ability to provide for a multidimensional averaging of the output, e.g. by evaluating the effect of a factor while all others are also varying, and of being model independent - they function regardless of the additivity or linearity of the model. Additionally these methods are able to treat grouped factors as if they were single factors. This property of synthesis is essential for the agility of the interpretation of the results. One would not want to be confronted with an SA made of large tables of sensitivity measures. We discuss these features on some relevant test cases.

4 - Information density in sensitivity analysis and optimization
Emanuele Borgonovo
We discuss the notion of information density and its applications to sensitivity analysis and optimization. In particular, we consider its application to linear programs with uncertain coefficients.

5 - Copula theory and probabilistic sensitivity measures
Elmar Plischke, Emanuele Borgonovo
Copula theory deals with defining and studying dependence measures among random variables. Probabilistic sensitivity analysis aims at quantifying the strength of the dependence among the output of a computer code and the uncertain simulator inputs. In this talk, we investigate to which extent these two families of methods match. To do so, we propose four classes of dependence measures based on the distance between an appropriate copula and the product copula. We discuss the new classes in the light of Rényi's postulate D (the nullity-implies-independence property) of dependence measures. The match is constructive: the new classes extend the current definition of sensitivity measures and one obtains a method for understanding which sensitivity measures in use are, in fact, copula-based. A strong link to transformation invariant measures is established. We investigate copula-based estimators, direct and through Bernstein copulas, and propose new visualization tools. Application to the benchmark simulator for computer experiments concludes the work.

■ MA-21
Monday, 8:30-10:00 - SOUTH BUILDING UV S303

Robust Project Management Approaches

Stream: Project Management and Scheduling
Chair: *Izack Cohen*

1 - Lessons learnt from solvable cases of determining optimal policies for the RCPSP with stochastic activity durations
Erik Demeulemeester

When considering the resource-constrained project scheduling problem (RCPSP) with stochastic activity durations, the recent literature mainly considers two different approaches. On the one hand, researchers have focused on proactive and reactive project scheduling, where proactive planning attempts to build a stable project plan that takes the possible disruptions as much as possible into account, while the reactive planning procedures are called every time the disruption changes the baseline schedule such that it cannot be executed anymore as planned. On the other hand, a lot of research has been done on the stochastic RCPSP that introduces scheduling policies that decide at each of the stages of a multi-stage decision process which activities selected from the set of precedence and resource feasible activities have to be started. Recently, Davari and Demeulemeester have introduced an integrated proactive and reactive project scheduling problem for the RCPSP with uncertain durations and developed different Markov Decision Process models to solve this NP-hard problem. This means that not only a good baseline schedule is determined, but also several good continuations in case certain combinations of the activity durations occur that prohibit the baseline schedule or an already adapted schedule from being executed as planned. In this presentation, I will indicate in which cases of the problem truly optimal policies can be constructed and what can be learnt from these policies.

2 - A distributionally robust approach to project planning
Ernst Roos, Dick den Hertog

Traditionally, stochastic project planning problems are modeled using the Program Evaluation and Review Technique (PERT). PERT is an attractive technique that is used a lot in practice as it requires specification of few characteristics of the activities' duration. Moreover, its computational burden is practically nonexistent. Over the years, four main disadvantages of PERT have been voiced. In this paper, we propose an alternative technique for modeling the distribution of activity lengths that addresses three of these disadvantages: use of the beta distribution, restricting the analysis to three different scenarios for the whole project and PERT's optimistic expected project length. In particular, we alleviate the assumption on distribution and only assume the distribution of the activity duration to be partially specified as is common in Distributionally Robust Optimization. By only requiring specific characteristics of the activities' duration we retain one of PERT's major advantages. The worst and best possible distributions that satisfy these characteristics can be specified exactly. We additionally develop an algorithm such that the expected project duration for these distributions can be calculated for realistic instances up to 100 activities. Knowing the best- and worst-case project duration allows us to comment on the 'value of information', that is we know what the potential value of knowing the true distribution is.

3 - Stochastic dual dynamic integer programming for financial portfolio and network revenue management
Andy Sun

Multistage stochastic integer programming (MSIP) combines the difficulty of uncertainty, dynamics, and non-convexity, and constitutes a class of extremely challenging problems. A common formulation for these problems is a dynamic programming formulation involving nested cost-to-go functions. In the linear setting, the cost-to-go functions are convex polyhedral, and decomposition algorithms, such as nested Benders' decomposition and its stochastic variant, stochastic dual dynamic programming (SDDP), which proceed by iteratively approximating these functions by cuts or linear inequalities, have been established as effective approaches. However, it is difficult to directly adapt these algorithms to MSIP due to the nonconvexity of integer programming value functions. In this talk, we present a significant extension to SDDP - called stochastic dual dynamic integer programming (SDDiP) - for solving MSIP problems with binary state variables, which is shown to have finite convergence with probability one. We apply SDDiP to a financial portfolio management problem and a network revenue management problem and demonstrate its effectiveness in solving these large-scale multistage stochastic integer programs.

4 - The robust multi-mode resource constrained project scheduling problem
Izack Cohen, Noemie Sellam Balouka

This research deals with the multi-mode resource constrained project scheduling problem (MRCPSP) in which the objective is to minimize a project duration while activities are performed in one of several possible modes (a mode determines an activity's duration and resource requirements). We consider uncertain activities; that is, their duration is stochastic and can vary within a so-called uncertainty set. We formulate the problem such that the level of conservatism can be adjusted; for example, one can omit (or keep) unreasonable scenarios such as one in which all activities are realized in their longest possible duration. Using Benders approach, we find an optimal robust solution that minimizes the project's duration while satisfying precedence, resource and some additional constraints. The solution determines optimal mode selections and resource flows to enable setting a project schedule. The solution approach is validated using the PSBLIB. Then, a series of experiments is performed to demonstrate the approach's performance in comparison to other options.

■ MA-22

Monday, 8:30-10:00 - SOUTH BUILDING UV S304

Data Mining in Business Analytics

Stream: Analytics, Data Science and Data Mining
Chair: *Koen W. De Bock*

1 - The effects of word-of-mouth and promotion on online marketplaces
I-Chi Lin, Mei-Ting Tsai, Quang Thy Lam

Nowadays, more and more consumers prefer to purchase a wide variety of goods (food, electronics, clothing etc) on the internet in order to save time and money. Thus the e-commerce industry of the online marketplaces has bloomed over the recent years. Previous research objects mainly aimed at English online marketplaces, and investigate only one single factor that affects online marketplaces, for instance electronic word-of-mouth (eWOM), promotion, shipping, brand etc. Therefore, the main purpose of this research is to identify whether the eWOM (review) and promotion of a product will simultaneously affect their online sales itself and other online marketplaces' sales. Particularly, we deal with the eWOM in Chinese characters instead of English texts. We first do text mining to process the online Chinese reviews into values. Then, we classify them into three categories (Positive, Negative and Neutral) using Naive Bayes classification. Finally, the effects of the two factors on sales are analyzed by log regression analysis. of the product on online marketplaces by using the method mentioned above. To illustrate the algorithm, we collect data continued for eight months period from two well-known and most used e-commerce platforms. The experimental results provide useful insights to enhance the online marketplace management.

2 - Problematic issues of the sustainable development of real estate market and its assessment opportunities
Linda Kauskale, Ineta Geipele

Influencing factors of sustainable development of real estate market should be analysed at multiple levels, at least at enterprise, industry and national levels. The aim of the research is to identify the problematic issues of the sustainable development of real estate market and to define its assessment opportunities. Literature analysis, expert method, focus group, logical access and statistical data analysis methods have been used in the research. Indicators of real estate market development assessment were developed as well. The developed assessment opportunities of sustainable development of real estate market makes it possible to identify the problematic issues in the sustainable development of real estate market in the country and to develop recommendations to improve the situation at various levels. The financial considerations are one of the most important factors influencing sustainable development of real estate market at enterprice level, other levels were analysed in the research as well, by defining motivating and contractionary factors of sustainable development of real estate market. Analysis of real estate market development can help real estate investors in decision-making as well.

3 - Data mining based customer response prediction for a specific campaign in Penti
Fadime Üney-Yüksektepe, Neslişah Aral, Merve Mutlu, Sevra Çiçekli

PENTİ was established in 1950 in Turkey. It is growing in production and retail activities, expanding its offering of mainly women's and girls' socks, home wear and beachwear. Different campaigns are organized to increase sales and customers are informed about the campaigns mostly by SMS regardless of their previous purchasing behavior. However, there is not an analytical tool to determine which customers those SMS should be sent to in order to get a high number of responses.

In this study, an analytical tool which will predict the possible responses of customers to a specific campaign will be developed by using WEKA software. While developing this tool, attributes such as age, having child, marital status and city information of customers will be preprocessed to analyze which ones are distinguishing when determining the final attribute which is the response of customers. Following that, several data classification algorithms will be applied and the one which has the best accuracy rate will be proposed to the company. By the help of this tool, SMSs can be sent to the customers considering those attributes and the company can reach right group of people who will do shopping at stores after those informative SMSs.

4 - Properties of business cycles of post-communist countries in the European Union
Karol Szomolányi, Martin Lukáčik, Adriana Lukáčiková

Even if we consider European post-communist countries to be emerging, their business cycle characteristics differ slightly from those of emerging countries around the world. Post-communist countries' expansions and recessions are longer, recessions are more pronounced, output is relatively low in volatility, household consumption is relatively highly volatile, the government share of GDP is countercyclical and trade balances (current accounts) are relatively strongly countercyclical in post-communist countries. It follows from our study of the cyclical properties of selected European post-communist countries. We consider the post-communist countries to be emerging according their purchasing power parity converted into GDP per capita. We identify business cycles based on turning points in the aggregate time series and we discern the cyclical properties of the chosen aggregate time series by computing the moments of cyclical components. The volatility of the data series is measured using the standard deviation of its cyclical component. The persistency of the data series is measured by the serial correlation coefficient of its cyclical component. The results obtained are compared with the results of analyses of business cycles around the world. Confronting the results with the real business cycle theory, we consider an hypothesis that more persistent real shocks are a source of post-communist business cycles.

■ MA-23

Monday, 8:30-10:00 - SOUTH BUILDING UV S305

Nurse Rostering

Stream: Timetabling
Chair: *Pieter Smet*

1 - Preference scheduling for nurses under Danish legislation
Elin Bjørk Bodvarsdottir, Niels-Christian Bagger

In Denmark, applications of operations research in healthcare planning are scarce. Nurse rostering is no exception and in most hospitals it is conducted manually with no assistance from automated approaches. This project is ongoing research into the possibilities of developing and implementing a nurse rostering system in Danish hospitals where the allocation of resources is optimized using methods from operations research. The system should not only be able to generate rosters which are feasible w.r.t. Danish legal agreements, but also include various preferences in the optimization. Due to the Danish legislation, the problem formulation differs from previous research on nurse rostering. The project is in its early phases, where the scope and the formulation of the problem are being adjusted in collaboration with a few planners and with focus on their priorities. The problem is a mixture of self-scheduling and preference scheduling, where the nurses request shifts and days off based on three different priority categories. The problem is formulated as a multi-objective MIP model which is used to find a schedule minimizing the violation of preferences, both general preferences from the planners as well as individual requests from nurses. The goal is to make the system flexible to be applied to different wards, and the long-term vision is that the system will be implemented throughout multiple hospitals in Denmark.

2 - Rescheduling strategies for nurse scheduling
Lena Wolbeck, Natalia Kliewer

Much research has been done on finding solutions for nurse scheduling problems. However, academic approaches are mostly deterministic and generate schedules which are optimal under given constraints. But during the scheduling period, requirements may change due to unforeseen events, e.g. absence of a nurse due to illness, and the original schedule can become suboptimal or even infeasible. If staff shortage occurs, a substitution for all affected shifts has to be scheduled. To prevent unpleasant short-term changes, rescheduling aims at generating a new feasible schedule with minimum changes compared to the original schedule. Due to the large number of constraints and additional limitations based on previous shift assignments, this is a challenging task. Our main objective is the development of rescheduling strategies in order to evaluate their functionality and practicability within a simulation study before implementing them in a real-world setting. The strategies aim at fairness among the regular nurses concerning individual satisfaction scores and extra hours balance. In addition, costs arising from the use of temporary staff are minimised. Furthermore, we look at constraint relaxation of hard constraints of the underlying optimisation model which in practice may be occasionally relaxed during rescheduling in order to avoid additional costs. We show that the strategies have different effects on regular nurses and costs and have to be selected according to the situation.

3 - A mathematical modeling approach for robust nurse rostering
Toni Wickert, Pieter Smet, Greet Vanden Berghe

Unexpected work absences occur for a variety of reasons such as illness, excessive workloads and accidents. These shortages may cause an initially valid roster to become infeasible. A reactive procedure which assigns unscheduled employees to cover the shortages may be adopted in order to repair the infeasibility. Although this method is frequently employed, it is often inefficient due to employee unavailability, disruptions regarding employees' personal lives and also high costs. This work investigates robust nurse rostering and addresses the following research question: is it possible to organize a robust nurse roster which is not only less susceptible to disruptions but also has a lower cost to repair the roster to feasibility when disruptions do occur? The proposed methodology is validated by way of an integer programming model and a three-step simulation method. First, an initial solution is generated considering different proactive strategies. Second, disruptions are randomly generated over the solutions. Finally, the infeasible solutions are repaired and the final costs are evaluated. Several strategies are investigated employing proactive, reactive and a combination of these two strategies. Computational results demonstrate that a trade-off between proactive and reactive strategies performs best, reducing overall final cost by the most significant margin. Further insights regarding the integer programming model and robust rostering strategies will also be presented.

4 - A new compact integer programming formulation for the nurse rostering problem
Pieter Smet

The large body of research concerning optimization methods for the nurse rostering problem shows that it is a difficult problem to solve to optimality. These computational results are supported by theoretical studies in the academic literature which have proven that a specific class of nurse rostering constraints, namely those regarding the number of consecutive assignments, have a significant impact on the computational complexity of nurse rostering problems. We build upon these insights to develop a new compact integer programming formulation for nurse rostering in which these challenging constraints are reformulated as subproblems which are known to have an efficient structure. With the resulting model, previously unsolved problem instances are now solved to optimality using a standard integer programming solver. To gain a better understanding of this new model, we analyze a series of computational experiments to characterize problem instances for which the proposed reformulation significantly improves the performance of integer programming solvers.

■ MA-24

Monday, 8:30-10:00 - SOUTH BUILDING UV S306

Financial Mathematics and OR I

Stream: Financial Mathematics and OR
Chair: *Norio Hibiki*

1 - Optimal pension fund management under low interest rate environment using simulation-based multi-period optimization
Rei Yamamoto

In recent years, many developed countries implement low/negative interest rate policy. This policy is expected to grow the economy through increasing lending to companies/individuals, on the other hand it has negative effect on pension funds because of decreasing yield of national bond. In this research, we focus a simulation-based multi-period optimization model proposed by Hibiki (2006) to decide optimal asset allocation. This model uses the simulation path of the rate of return of assets based on future economic scenarios, then it is the best method for long-term investment. First, we analyze the relationship between the rate of return of national bond and the interest rate, then we represent bond return by using interest rate. Next, we solve the multi-period optimization model to decide the optimal asset allocation under various future interest scenarios.

2 - Stress testing model for macro stress testing and specific events
Muneki Kawaguchi

Stress testing has become an important risk management tool for financial entities. The risk quantity is estimated based on the scenario that low frequency and large loss events occur on stress testing. The correlation among the variables is important, particularly the tail correlation is crucial on stress testing. There are various approaches with different assumptions for stress testing. We propose a new stress testing model for credit portfolio that can be used for both macro stress testing and stress testing based on specific events. As far as I know, although both types of stress testing approach are important to analyze the risk which credit portfolio contains, these approaches have been excised by different models. To do that, we use vine copula and supply chain relationship information. Vine copula makes it possible to capture tail correlation between macro variables and corporate creditablities. By utilizing supply chain relationship information, our model can formulate the propagation of bad effect caused by specific events between borrowers in detail.

3 - The performance of multilevel Monte Carlo using Apache Spark
Hitoshi Inui
The calculation of option price using multilevel Monte Carlo (MLMC) method has two steps. First, we estimate the number of paths at each level. The estimated numbers are important inputs of the MLMC estimator. Second, we calculate option price using the estimated numbers on the MLMC framework. We consider carrying out calculations of MLMC method for options pricing by using Apache Spark. Apache Spark, which was developed at the University of California, Berkeley, is a open-source cluster-computing framework. We use Apache Spark as a parallel distributed computing framework and propose operation environments of MLMC method. We investigate the performance of MLMC method on the environments.

4 - Estimating forward looking return distribution with the generalized recovery theorem
Takuya Kiriu, Masatake Ito, Norio Hibiki
Option prices imply the forward looking information about future returns of the underlying asset. Recovery Theorem (RT) derived by Ross[2015] enables us to estimate the pricing kernel and the forward looking real world distribution of the underlying assets from option prices. Recently, Jensen et al.[2016] developed Generalized Recovery Theorem (GRT) which relaxes the assumption of the RT. However, we need to solve the ill-conditioned problem for the GRT. Therefore, we propose two-step approach to derive the solution appropriately and stably. In the first step, we estimate a rough solution under the parametric assumption about investor's risk preferences. In the second step, we estimate a solution by providing the first step solution as prior information. We show that the estimation accuracy of the proposed method is higher than that of the original method by numerical analysis using hypothetical data. We estimate the real world distribution of S&P 500 index and Nikkei 225 index from option prices and evaluate a forecasting power by statistical tests. We find the following two results. (1) The standard deviation of risk neutral distribution is positively correlated with the expected excess return of real world distribution. (2) The p-value of real world distribution for the hypothesis that the distribution has a forecasting power on the realized value is larger than that of the risk neutral distribution.

■ MA-25

Monday, 8:30-10:00 - SOUTH BUILDING UV S307

CYBECO Session on Cybersecurity and Cyber-Insurance

Stream: Fintech: Economic and Financial Challenges in Cryptocurrencies
Chair: *Jose Vila*

1 - Assessing supply chain cyber risks
Alberto Redondo Hernández, Alberto Torres Barrán
Risk supervision is a major challenge for supply chain managers potentially affecting factors such as costs, supplier competition or customer expectations. The increasing interconnection between organizations has put into focus methods for supply chain cyber risk management. Current solutions available in the market lack appropriate foundations. We introduce a framework for supply chain cyber risk management which takes into account various ways of attacking an organisation and its suppliers, as well as the impacts of such attacks. Since data is lacking in many respects, we use structured expert judgement methods to support its implementation. We couple a family of risk forecasting models to our framework to enrich monitoring. The framework may be used to set up alarms, negotiate SLAs, rank suppliers and define insurance needs.

2 - Can protection motivation theory provide a framework to help us understand cyberinsurance uptake?
Dawn Branley-Bell, Pamela Briggs
Last year, 80% of European companies experienced at least one cyber breach or attack. If widely adopted and well-functioning, cyberinsurance has the potential to encourage market-based risk management for information security, with a mechanism for spreading risk amongst multiple stakeholders. However uptake of cyberinsurance has not reached expectations. Here we explore protection motivation theory as a framework to help us understand cyberinsurance uptake.

Protection Motivation theory proposes that people protect themselves based upon four factors: the perceived severity of a threatening event, the perceived probability of the event occurring (including perceived vulnerability), the efficacy of the recommended protective behaviour and their perceived self-efficacy. Therefore, an organisation considering whether to invest in cyberinsurance may weigh up the perceived probability and severity of suffering a cyberattack attack (and the associated consequences) against the perceived benefit of not investing in cyberinsurance, i.e., costs saved due to not paying for the insurance policy. When considering whether to purchase cyberinsurance, organisations will calculate the benefit-risk trade-off. This involves weighing up the perceived rather than actual benefits (e.g., protection against attacks) and costs (e.g., high price) against the pros and cons of not insuring (e.g., saves policy cost, but less protection). We will explore influences on these perceptions.

3 - Cyber risk measurement with ordinal data
Paolo Giudici
We propose a methodology to estimate cyber risks, using ordinal data on severity of cyber attack, to prioritise appropriate interventions. The method relies on the construction of a Criticality index, whose properties are derived and compared with alternative measures employed in operational risk measurement. The proposed construction is illustrated in the context of of an international database containing cyber attacks classified by type of attack and attacker,a case-study that provides a rather general benchmark. The proposed measure is found to be quite effective to rank cyber risk types and, therefore, allow selective preventive actions.

4 - Nudging optimal cyber-insurance strategies
Jose Vila, Pamela Briggs, Yolanda Gomez, Dawn Branley-Bell
This paper analyses the decision-making process to select a cybersecurity strategy from a behavioural-experimental approach. Specifically, the paper compares the 'rational optimal' behaviour forecasted by the CYBECO model with the 'human actual behaviour' when purchasing cyber-protection and cyber-insurance. The experiment setting does also analyse the difference in the selection of the cybersecurity strategy for a random or an intentional potential attack. Finally, the paper identifies effective behavioural levers in the design and communication of cyber-insurance products in order to nudge towards optimal cybersecurity behaviour. The experiment has been run with a sample of 4,000 participants, representative of the population of internet users in four different European countries. Participants are invited to make decisions related to the purchase of cyber-insurance and protection products (firewall) in an online controlled economic experiment. The experiment included two independent phases, each of them presenting the opportunity to buy cyber-insurance and protection measures and to navigate online to perform some additional tasks. Participants obtained a variable payoff depending on all their decisions during the experiment and the fact of suffering or not the cyberattack.

■ MA-26

Monday, 8:30-10:00 - SOUTH BUILDING UV S308

Line Planning and Network Design in Public Transport

Stream: Public Transportation I
Chair: *Pieter Vansteenwegen*

1 - Optimization methods for the trip runtime determination problem
Marjan van den Akker, Marcel van Kooten Niekerk, Han Hoogeveen

We consider the problem of finding the optimal timetable for trips along a given bus route. In many transport organizations (PTOs) , the arrival and departure times of every trip at every stop are measured. These measurements are used for the determination of the appropriate planned departure times that are published at the stop and in timetables. Currently, in practice, rules of thumb are used, such as a given percentile of the measured driving or departure times. The problem to determine the set of optimal planned departure times is called the Trip Runtime Determination Problem. Our goal is to determine several new methods to solve this problem. In all methods we propose to take into account that not all stops are holding points, contrary to what is done in the known methods from literature and in the methods that are widely used in practice. We will discuss several different optimization objectives; besides the widely used objectives like punctuality and average delay we will also use passenger related objectives, like average waiting time. We will consider these objectives separately and also combine them in a weighted sum. To compare our new methods to a few well-known methods from literature, we will present computational experiments with real trip runtime measurements from the area of Groningen (The Netherlands).

2 - Determining and evaluating alternative line plans in (near) out-of-control situations
Paul Bouman, Rolf Van Lieshout, Dennis Huisman

Every once in a while, railway systems suffer from very large disruptions as the result of power outages, extreme weather conditions or other severe incidents. In railway systems that are characterized by intensive use of the railway infrastructure and strong interdependencies between rolling stock and crew schedules, such disruptions can propagate and accumulate. If no counter measures are taken, there is a risk that this leads to an out-of-control situation, where hardly any trains are running in the affected region, even though the required resources (infrastructure, rolling stock and crew) might be available. In this talk we propose a strategy to cope with these (near) out-of-control situations. The core idea of this strategy is to completely decouple the operations in the disrupted region from the rest of the railway network, with the aim to isolate the disruption. We propose to use a simplified line plan which allows for smooth operations without centralized scheduling. We introduce a novel line planning algorithm, which is designed to generate line plans that can be operated in (near) out-of-control situation by partially integrating constraints inspired by timetabling and rolling stock scheduling. We then consider several dispatching strategies that can be applied in (near) out-of-control situations. Finally, we use simulation to analyze the performance of the emerging self-organized railway system.

3 - Local evaluation techniques in bus line planning
Evert Vermeir, Pieter Vansteenwegen

Designing a public bus network generally happens in several planning stages, one of these steps is line planning. In line planning, a public transport company decides where its vehicles will drive and which stops will be served in what order. One of the challenges of the line planning problem is finding a good solution for (very) large networks. The evaluation of a line plan, and thus of a solution, is computationally quite costly. In an evaluation, the total travel time of all passengers typically needs to be calculated. This requires the route of each passenger to be known. It is this calculation that requires so much computation time. Because of transfers, even seemingly small changes can have a large impact on the passengers' routes. In this research, local evaluation techniques are developed to decrease this computational burden. One of the core principles is that routes that are close to a change in the bus network are more likely to be impacted by a change. Closeness is defined as being reachable in a certain amount of transfers or in pure distance. Secondly, possible transfer points are very important. Passenger routes will only change when they transfer. The developed method tries to reduce the bus network considered during evaluation. It is important to note that all demand that previously travelled through this reduced network is still considered, even if its origin or destination lies elsewhere. This framework is tested in an iterated local search algorithm.

4 - Flexible bus lines for congested areas
Pieter Vansteenwegen, Elina Avila-Ordóñez

Bus lines are typically designed considering several parameters that describe the situation of the area in which the buses will offer their service. The design process attempts to optimize the line plan so as to benefit the user, the operator or, in some cases, even both. The set of lines defines the routes and stops for each line and will ensure an efficient operation as long as the situation described by the input parameters remains without major alteration. Nevertheless, unusual situations frequently happen, for instance related to extra congestion or events. These alter the operation of buses causing unwanted costs and reduction in service. In this study we propose the use of flexible lines: bus lines that are allowed to modify their planned route during unusual situations. We will show that these flexible lines allow to improve the overall service performance, during these unusual situations, with little or no impact on the regular performance. This paper presents high quality results obtained with a systematic approach to design flexible lines for the bus service of the city of Cuenca in Ecuador.

■ MA-27

Monday, 8:30-10:00 - SOUTH BUILDING UV S309

Remanufacturing Operations

Stream: Production, Service and Supply Chain Management
Chair: *Mahdi Abolghasemi*

1 - Dynamic programming models for joint incentive and dispatching decisions for collection centers in remanufacturing
Mehmet Alegoz, Onur Kaya

Collection centers play an important role for sustainable development in closed-loop supply chains by managing the collection activities of end-of-life (EOL) products and presenting them back to the economy. In this study, we focus on collection, disassembly, warehousing and dispatching processes of a collection center that acquires EOL products that are composed of multiple components, disassembles them, checks the quality of their components and sends the reusable parts to a remanufacturer at a certain price. The collection center needs to decide when to dispatch the collected products to the remanufacturer as well as the optimal incentive value in order to collect the right amount of EOL products from the end users and maximize its profit. We develop dynamic programming models to maximize the long-run average profit of the collection center per unit time and analyze the optimal dispatching and acquisition fee decisions. We analyze both static and dynamic incentive determination. We also compare the performances of quantity-based and time-based dispatching heuristics, which are widely used in practice, with the optimal dispatching decisions. We finally present a sensitivity analysis in order to analyze the effects of the parameters in our model.

2 - Remanufacturing as a competitive strategy
Xiang Zhu

We study the competition between a high-end firm and a low-end firm. The high-end firm only produces new product while the low-end firm produces both remanufactured products and new products. The aim of this paper is to find out how the optimal competition strategy is affected by the cost structure and customers' valuation. We analyze a model with utility-based demand function, where customer are heterogeneous in their valuation at a new high-end product, and low-end as well as remanufacturing high-end products are valued as certain functions of the new product valuation. We show that the production cost of low-end and remanufacturing high-end products, relative to the production cost of new high-end products, drive the strategy choice. Based on this two dimensions, we graphically display optimal strategy selection. First, giving a fixed price of new high-end products, we graphically depict under what cost condition the low-end firm chooses to produce only low-end products, only remanufacturing high-end products, both or none at all. Then we do the same under the optimal response of the high-end firm, and show when that the firm increases its price under the increased (potential) competition from remanufacturing product.

3 - Hierarchical forecasting in supply chain
Mahdi Abolghasemi

Demand forecasting is a vital task in supply chain management on which many decisions are based. Hierarchical forecasting is needed because we often require forecasts for various levels of the supply chain to make effective decisions. In addition to this, hierarchical forecasting can improve overall forecasting accuracy and enhance customer satisfaction. In practice, many manufacturing companies use manual judgments to forecast demand at different levels which may cause bias in forecasting. Other factors such as promotion can also affect the accuracy of hierarchical forecasting models. However, hierarchical forecasting, and particularly top-bottom approach is unable to capture these special events. In this research, we analyze the impact of promotion on different levels of hierarchical forecasting accuracy and propose the best approach to model hierarchical methods. We also compare the results of conventional hierarchical forecasting methods with machine learning algorithms.

■ MA-28

Monday, 8:30-10:00 - SOUTH BUILDING UV S310

Optimization Models in Multiple Classifier Systems

Stream: Multiple Classifier Systems and Applications
Chair: *Sureyya Ozogur-Akyuz*

1 - Statistical tests for forecasting model selection in meta learning: a new approach
Sasan Barak, Sven F. Crone

Selecting an appropriate prediction model is a crucial step in business analytics. This can be efficiently achieved using meta-learning by feature-based time series representation without the need to implement forecasting models in the whole data set. In practice, meta-learning tries to gain knowledge from the data set and implement the gained knowledge in order to return the best forecasting model; however, its performance relies greatly on the efficiency of the implemented features. Despite the existence of a plethora of meta-features in the literature, an area which is largely neglected is the use of statistical tests as meta-features, which are filter procedures for the evaluation of time series and their efficiency. Therefore, this study proposes to use statistical tests as meta-features in forecasting model selection for the first time, and reports on their efficiency aginst existing meta-features. A brief review of the model selection approaches in time series forecasting, and the literature pertinent to feature-based time series representation is initially presented, and then the statistical test as a new meta feature is described. The relationship between the meta-features and the meta-learner algorithms are further demonstrated. To validate the proposed approach, NN3 competition time series are exploited, and the results from the comparison with common model selection techniques such as penalized likelihood function are reported.

2 - Improved MIP-formulations and suited solution procedures for the parking lot layout planning (PLLP) problem
Konrad Stephan, Nils Boysen, Felix Weidinger

This talk elaborates on optimal arrangements of parking spaces on a parking lot. Special focus is set on MIP-formulations meeting an adequate minimum width for the driving lanes that allows for an easy access to all parking spaces. Taking and improving the ideas of Stephan et al. (2017) and considering three different resolutions, e.g., with one unit of length corresponding to 5 meters (resolution R1), 2.5 meters (resolution R2) and 1.67 meters (resolution R3) in the real world, lead us to three very efficient new MIP-formulations. Furthermore, the paper proposes two heuristics and tests them against the off-the-shelf solver Gurobi and the Branch & Bound algorithm of Stephan et al. (2017). The first heuristic solves the parking lot layout planning (PLLP) problem for R1 exactly and transforms the solution to R2, whereas the second one bases on an ant colony algorithm and is especially suited for resolutions R1 and R2.

3 - Integrating individual and aggregate diversity in top-N recommendation
Ethem Canakoglu, Ibrahim Muter, Tevfik Aytekin

Recommender systems have become one of the main components of web technologies that help people to cope with the information overload. Two of the most important metrics used to analyse the performance of these systems are accuracy and diversity of the recommendation lists. While all the efforts exerted in the prediction of the user interests aim at maximizing the former, the latter emerges in various forms, such as diversity in the lists across all user recommendation lists, referred to as aggregate diversity, and diversity in the lists of individuals, known as individual diversity. In this paper, we tackle the combination of these three objectives, and justify this approach by showing through experiments that handling these objectives in pairs does not yield satisfactory results in the third one. To that end, we develop a mathematical model that is formulated using multi-objective optimization approaches. To cope with the intractability of this nonlinear integer programming model, its special structure is exploited by a decomposition technique. For the solution of the resulting formulation, we propose an iterative framework that is composed of a clique generating genetic algorithm and constructive/improvement heuristics. We conduct experiments on three data sets and show that the proposed modeling approach successfully handles all objectives according to the needs of the system, and the proposed methodology is capable of yielding good upper bounds.

4 - Ensemble learning by disciplined convex and concave programming
Pinar Karadayi Atas, Sureyya Ozogur-Akyuz

In Ensemble Learning theory, both generation and selection of ensemble members play an important role in final prediction for machine learning researches. In this study, we focus on ensemble selection approaches and develop novel selection model by using optimization theory. One of the crucial steps in this selection is accuracy and diversity of the members in the ensemble. The trade off between these two metrics makes the problem challenging when constructing the best ensemble learning algorithm. There are different approaches in the literature that consider simultaneously both of these measures such as ordering based and optimization based methods. We considered Disciplined Convex Concave Programming (DCCP) to solve the model proposed in this study. The experimental results show that the proposed approach gives better prediction results than existing methods.

■ MA-29

Monday, 8:30-10:00 - SOUTH BUILDING UV S311

Game Theory, Solutions and Structures I

Stream: Game Theory, Solutions and Structures
Chair: *Encarnación Algaba*

1 - Associated consistency, value and graphs
Florian Navarro, Gerard Hamiache

This article presents a full axiomatic characterization of a new value for cooperative games with incomplete communication. The result is obtained by slight modifications of associated games proposed by Hamiache (1999, 2001). This new associated game can be expressed as a matrix formula. We generate a series of successive associated games and show that its limit is an inessential game. Three axioms (associated consistency, inessential game, continuity) characterize a unique sharing rule. Combinatorial arguments and matrix tools provide a procedure to compute the solution. The new sharing rule coincides with the Shapley value when the communication is complete.

2 - Supermodular functions on finite distributive lattices
Michel Grabisch, Tomas Kroupa

Supermodular functions (and in particular TU-games) form a polyhedral cone whose properties have been studied in the past: facets by Kuipers et al., extremal rays by Rosenmueller and Weidner, as well and Studeny and Kroupa. We generalize the previous results by considering supermodular functions defined on any distributive lattice instead of the Boolean lattice of subsets and provide much simpler proofs. TU-Games on distributive lattices form a particularly interesting class of games with restricted cooperation.

3 - Superweak differential marginality and the weighted Shapley values
André Casajus

Casajus and Yokote (2017) suggest qualitative/weak versions of differential marginality (Casajus, 2011) and of the balanced contributions property (Myerson, 1980)). Weak differential marginality requires that whenever two players' marginal contributions to coalitions not containing either of them change by the amount, the their payoffs changes in the same direction. The weak balanced contributions property requires that when one player leaves the game, then second player's payoff changes in the same direction as the former player's payoff changes when the latter player leaves the game. In contrast, original properties require equal amounts of both changes. For variable player sets, the Shapley value is characterized by efficiency, the weak balanced contributions property, and weak differential marginality (Casajus, 2017). While the weighted Shapley values, except of the Shapley value, fail weak differential marginality, they obey a weaker property called superweak differential marginality. It requires that whenever two players' marginal contributions to coalitions not containing either of them do not change, then their payoffs should change in the same direction, i.e., the signs of the changes have to coincide. We discuss the open :(conjecture that, for variable player sets, the class of weighted Shapley values is characterized by efficiency, the weak balanced contributions property, and superweak differential marginality.

4 - Solutions for games with a hierarchical structure
Encarnación Algaba, Rene van den Brink

This paper deals with restricted cooperation coming from the players belonging to some hierarchical structure. In particular, we focus on games with a permission structure and games under precedence constraints. In both cases, the hierarchy can be represented by a directed graph which restricts the possibilities of coalition formation. These two approaches led to two different type of solutions in the literature. We will show that also the (conjunctive) permission value can be axiomatized with an axiom that applies a network power measure to the permission structure. Moreover, similar as for the precedence power solutions, we can apply any (positive) power measure and obtain a class of permission power solutions. Therefore, we have two classes of solutions for games with a hierarchy, one based on permission structures and another based on precedence constraints which can be compared through a characterization with similar axioms. Additionally, these solutions are connected with network power measures.

■ MA-30

Monday, 8:30-10:00 - SOUTH BUILDING UV S312

Evolutionary metaheuristics

Stream: Metaheuristics

Chair: *Robert Manger*

1 - Genetic programming approach for concurrent real-time optimization of detecting unexpected tasks in embedded systems design process
Adam Górski, Maciej Ogorzałek

Detection and assignment of unexpected tasks is a very practical optimization aspect of embedded system design process. When system meets unexpected situation the designer must prepare the list of problems and decide which of them must be solved. Most of problems have more than one solution however not every solution gives the correct result. The optimization can be made in two concurrent phases. Each of the phases impacts another in real time. The first phase gives problems to solve meanwhile the second gives the solution of selected problem. We propose a novel genetic programming based approach to solve described situation. The approach generates some number of random individuals. The individuals consist of chosen unexpected subtasks (given in the first phase) and theirs assignment to PEs (obtained in the second phase). According to GP rules the tasks assignment is made using chromos (selected with appropriate probability). The next generations of individuals are built using basic genetic operators: mutation, selection and crossover. All of the individuals have at least one common optimizing parameter (in our methodology it is a cost of designing system). After each generation the solutions are ranked by the common parameter. The algorithm stops if in ϵ next generations better solution will not be found.

2 - Determination of GNSS / levelling geoid by reducing model points with PSO
Mehmet Akif Sahman, Kemal Tutuncu, Ekrem Tusat

Cartesian (x,y,z) or geographical (, , h) coordinates can be found accurately by GPS technology. The ellipsoid height is the height component of the 3D geographical location information for GNSS measurements. Orthometric heights are used in engineering applications due to physical and geometric reasons. The difference between ellipsoidal (h) and orthometric height (H) is equal to geoid height (N). Therefore, geoid determination studies are so important for finding H from the GNSS measurements. The orthometric heights are usually determined by the levelling measurements. The process of levelling measurements is laborious, time-consuming and costly. Henceforth, determining the optimum GNSS/Levelling geoid by reducing the field study is practical in terms of achieving the result as well as important in terms of reducing the project costs. In this study, an approach that reduces the GNSS/Levelling geoid model points to acceptable accuracy ratio by binary particle swarm optimization (PSO) has been proposed. In the proposed approach, PSO and artificial neural network (ANN) are used as the soft computing system. A numerical application has been implemented with proposed approach and model points have been reduced by %33.

3 - An estimation of distribution algorithm based on p-median model for cell formation problem
Saber Ibrahim, Bassem Jarboui

Cell formation (CF) problem is the most important application of Group Technology (GT). It deals with grouping machines into cells and parts into part families minimizing the inter-cellular and the intra-cellular traffic issued from the different moves of both parts and machines. The p-median algorithm is shown very useful for clustering applications. It has been developed to solve medium and large sizes of cell formation problems. In this paper, we propose a modified p-median model for CF minimizing the sum of dissimilarities of machines and we develop an Estimation of Distribution Algorithm (EDA) to solve medium to large sized problems. In order to test the goodness of our results, we used two well-known evaluation criteria namely the Grouping Efficacy (GE) and the Group Capability Index (GCI) measures. The proposed algorithm is tested on 30 benchmarks taken from the literature and our experiments showed that the p-median based model using the EDA provides very promising results as compared with the CF using the classical p-median model in a speed computational time and outperforms the recent approaches especially for large sized CF problems (less than one second).

4 - An evolutionary algorithm for the robust maximum weighted independent set problem
Ana Klobučar, Robert Manger

This work deals with the robust maximum weighted independent set problem, i.e. finding the subset of vertices whose weights sum to the maximum possible value without any two vertices being adjacent to one another. Uncertainty is manifested in vertex weights and expressed by a discrete set of scenarios. Three criteria of robustness are considered: absolute robustness (max-min), robust deviation (min-max regret), and relative robustness (relative min-max regret). Since the conventional maximum weighted independent set problem is already NP-Hard, it is expected that finding the exact solution of a robust version would have even worse time complexity. In this work we propose an approximate algorithm for solving the considered problem, which is based on evolutionary computing an on various crossover operators and mutations. The algorithm is experimentally evaluated on appropriate problem instances. It is shown that satisfactory solutions can be obtained for any of the three robustness criteria in reasonable time.

■ MA-31

Monday, 8:30-10:00 - SOUTH BUILDING UV S313

Behaviour in Models I

Stream: Behavioural OR
Chair: *Rudolf Vetschera*

1 - Data-driven behavioral models of water reservoir operators
Matteo Giuliani, Andrea Castelletti, Jonathan Herman

Models of natural systems have significantly improved in their ability to accurately reproduce physical processes in space and time. However, human behaviors and their interactions with natural processes remain overly simplified in many models used to make long-term projections and support policy decisions. We distinguish two behavioral modeling approaches: descriptive models, which derive behavioral rules specifying human actions in response to external stimuli, and normative models, which assume fully rational behaviors and provide optimal decisions maximizing a given utility function. In this talk we advance data-driven behavioral modeling in water resources systems by contributing new machine learning methods to address two major challenges of state-of-the-art models. First, we develop a normative model identifying water reservoir operators' preferences in terms of tradeoff among multiple competing objectives, and the dynamic evolution of this tradeoff driven by extreme climatic events. The tradeoff selection is based on a new negotiation protocol, where multiple virtual agents represent different objectives and periodically negotiate a compromise solution. Second, we contribute a new approach based on eigenbehavior analysis to mine typical behavioral profiles from observational data across a large set of water reservoir operators in California. The extracted profiles are discussed with respect to specific features of the reservoirs (location, elevation, and capacity).

2 - Influence modeling: mathematical programming representations of persuasion under either risk or uncertainty
William Caballero, Brian Lunday

Persuasion is a fundamental element of human interaction applied to both individuals and populations. Although the study of persuasion has historically been dominated by qualitative models, this research takes a first step towards its quantitative characterization and use. This work complements the qualitative psychological literature with respect to the processing of persuasive messages by developing an influence campaign design framework. We adapt the classic Decision Analysis problem to a bilevel mathematical program wherein a persuader has the opportunity to affect the environment prior to the decisionmaker's choice. Thereby, we define a new class of problems for modeling persuasion. Utilizing Cumulative Prospect Theory as a descriptive framework of choice, we transform the persuasion problem to a single level mathematical programming formulation, adaptable to conditions of either risk or uncertainty. These generalized models allow for the malleability of all prospects and Cumulative Prospect Theory parameters through persuasion update functions. We detail the literature that supports the quantification of such effects which, in turn, establishes that they can be realized. Finally, the efficacy of the model is illustrated through three cases under varying conditions of risk or uncertainty: (1) the establishment of insurance policies, (2) the construction of a legal defense, and (3) the development of a public pension program.

3 - Managing complex adaptive systems: a resource/agent modelling perspective
Ross Kazakov, Susan Howick, Alec Morton

Complex adaptive systems are systems where those managing the system, the agents, interact with other competing agents and key resources available to the system. The behaviour of the agents and the resources are constantly changing over time thus resulting in complex systems of evolving problem configurations.

Managing such a system can be very challenging, particularly when attempting to manage rather than simplify complexity. One particular problem is the need to take a comprehensive perspective of the complex system in order to manage it effectively. Resource structure and agent behaviour are interdependent and both interconnected components need to be considered in order to support optimal decision making.

Due to the lack of an appropriate technique in the literature to achieve a comprehensive qualitative appreciation of resource/agent complex adaptive system behaviour, we have developed a novel qualitative modelling tool, A Resource/Agent Map, that aims to map and analyse both resources and agents interactive behaviour.

We show how this modelling tool can help achieve a holistic appreciation of the resource/agent perspectives and generate scenario alternatives to inform policy decision making in respect to system management and regulation. A pharmaceutical example is used to demonstrate the modelling tool.

4 - Using the Zeuthen-Hicks bargaining model to identify a fixed pie bias in negotiations
Rudolf Vetschera

In many cases, negotiators fail to realize the integrative (win-win) potential of a negotiation, since they incorrectly assume that their preferences are diametrically opposed. This phenomenon is known in literature as the fixed pie bias of negotiators. It is usually tested in empirical research by directly asking negotiators about their perceptions of the opponent's preferences. In the present paper, we propose and empirically test a different approach to identify a fixed pie bias. We utilize a dynamic bargaining model (the Zeuthen-Hicks bargaining model), that presumes that negotiators determine the amount of concessions to make taking into account their own and the opponent's preferences. We fit this model to empirical negotiation data under two alternative assumptions: that negotiators know their opponent's actual preferences, and that negotiators assume that their opponent's preferences are exactly the opposite of their own. We then compare under which assumption the model fits better to empirically observed concession data. By applying this approach to a data set of 275 electronic negotiations carried out with the negotiation support system Inspire, we find significant evidence for the existence of a fixed pie bias.

■ MA-32

Monday, 8:30-10:00 - SOUTH BUILDING UV S314

Game Theory Models for Transportation

Stream: Routing, Logistics, Location and Transportation
Chair: *Namchul Shin*

1 - Attacker-defender model against QR-adversaries for cyber security in logistics management
Kam-Fung Cheung, Michael Bell, Behnam Fahimnia, Federico Bettini

Demon game models including attacker-defender models, defender-attacker models and defender-attacker-defender models are widely used in defending infrastructures such as transportation networks and electricity power grids. There is little literature applying these models to both cyber security and logistics management. These models generally assume that an attacker is perfectly rational and would always chooses a pure strategy to maximize his expected utility or maximize the defender's loss. Attackers have biases and incomplete information which affect their decision-making processes. Increasingly, the logistics industry is implementing the Internet-of-Things (IoT), e.g., sensors and actuators, to collect data, process orders and deliver materials and/or products. This automation reduces human errors in processing orders and enhances the efficiency in order deliveries. However, this can be interrupted by malicious attacks from the Internet such as tampering with data in the database or flooding a server to make it unavailable (e.g., DDoS attacks). To highlight vulnerabilities in supply chain logistics, this study proposes a novel attacker-defender model for tiered logistics networks using the quantal response (QR) concept which allows for biases and incomplete information when defining attack probabilities. The solution to our model is a mixed strategy for defending critical components in tiered logistics networks.

2 - Collaborative allocation of transportation via combinatorial auctions: central vs. individual mechanisms
Daniel Nicola

In this work, combinatorial auction-based mechanisms are applied for interchanging requests between carriers that belong to a collaborative network. These mechanisms are composed by four processes: Request Selection, Bundle Generation, Bid Generation and Winner Determination. Bidders first select which requests will be sent to the auctioneer. The auctioneer then groups these requests into attractive bundles that are offered to the bidders. Bidders determine their own cost and bid on these bundles, and finally, the auctioneer solves a winner determination problem by assigning bundles to the bidders minimizing the total cost to be paid. All carriers operate in a two-region scenario, where short-haul vehicles cover intra-region routes and larger capacity long-haul vehicles are used for the inter-region routes. This study compares a central-auctions mechanism and an individual-auctions mechanism. In the central-auctions mechanism, a central, neutral institution is the auctioneer and carriers are the bidders, while in the individual-auctions mechanism, each carrier is the auctioneer of its own selected requests. From this comparison, besides operational and managerial implications, maximum costs to be paid to an external auctioneer in central-auction mechanisms can be obtained.

3 - Game theoretical analysis of channel power structures for two-manufacturers-two-retailers
Tatsushi Nishi

This paper investigates channel power structures of its supply chain members that describes the choice of price leadership and price followership in a decentralised supply chain. The effects of the degree of product substitutability and store substitutability to channel power structures in two-manufacturers-two-retailers scenarios by a game theoretical approach. The structures considered in previous works are sometimes suboptimal because a lots of possible leadership structures are ignored. For instance, we can consider a situation that when a new commer manufacturer enters a market dominated by a single top-level manufacturer with two retailers, the manufacturer is the single top-level price leader, and the other two retailers are the second-level leaders, and the newcomer manufacturer is the lowest follower. Several properties are derived through numerical results.

4 - Creating shared value from collaborative logistics systems
Namchul Shin

Shared value enhances the competitiveness of a company while simultaneously reducing societal burdens. By allowing companies to share their resources, collaborative logistics systems, so-called Physical Internet, provide companies with an opportunity to create shared value, namely, not only economic value by enhancing the utilization of resources, but also social value by reducing energy consumptions and greenhouse gas emission associated with logistics, production, and transportation. Emerging businesses such as ES3 and Flexe have recently demonstrated how they create shared value through collaborative logistics services, for example, ES3's collaborative warehousing and direct-to-store program, and Flexe's on-demand warehousing platform. However, the development of collaborative logistics systems is currently at a nascent stage. There are quite a few socio-technical barriers to overcome for sharing resources (data as well as infrastructure). This research, currently in progress, examines how companies create shared value from collaborative logistics systems. We highlight socio-technical barriers, particularly one set of social barriers, that is, competition-oriented conservatism prevalent among companies. Using the case study methodology and interview data, we closely investigate ES3 and Flexe, which provide collaborative logistics services, and demonstrate how social and technological barriers are addressed to create shared value from collaborative logistics systems.

■ MA-33

Monday, 8:30-10:00 - SOUTH BUILDING UV S315

Emerging Applications in Game Theory

Stream: Variational Inequalities
Chair: *Patrizia Daniele*

1 - On a family of transportation network cooperative games
Giorgio Gnecco, Yuval Hadas, Marcello Sanguineti

A natural question arising in the design and analysis of transportation networks is played by the investigation of network connectivity. In this context, a major issue concerns how one can measure the importance of each node with respect to the others. Classical approaches come from the literature about social networks and are based on the notion of node centrality. However, classical centrality measures have an intrinsic limitation: they evaluate each node's importance merely on the basis of its individual contribution to the functioning of the network. Consequently, existing centrality measures need to be refined to take into account that the network nodes do not act merely as individual entities, but as members of groups of nodes. To this end, a possible approach consists in using methods and tools from Cooperative Game Theory. In this talk, given a transportation network, a cooperative game model with transferable utility (TU game) is presented. The nodes of the network represent the players in such a game, and the Shapley values of the nodes are used to measure centrality. The model, called Transportation Network cooperative (TNc) game, integrates within the utility function of the TU game the network topology and the demand. Properties of TNc games and their associated utility functions are investigated. A special formulation of the game is used to represent public transport networks with an emphasis on transfers. Numerical results are reported.

2 - The impact of budget constraints on the interaction between fund-raising and procurement operations
Fuminori Toyasaki, Emel Arikan, Lena Silbermayr

The present work explores the interaction between an aid agency's fund-raising and its procurement decisions (prepositioning and aftermath procurement) under demand uncertainty in the presence of budget constraints. The aid agency trades off the lower procurement cost of prepositioning against the uncertainty of budget and demand aftermath of a disaster. In our two-stage stochastic model, the aid agency seeks to achieve multiple goals, including minimizing shortages and maximizing raised fund. Considering the fact that donors' contributions affect the aid agency's budget constraints, our model captures the interaction between the aid agency and donors by applying a non-cooperative sequential game.

3 - Game theoretic scenarios of cybersecurity investment models in a sellers-buyers market
Monica-Gabriela Cojocaru, Spencer Kirbyson

We develop three economic models within this work that look at online sellers in a marketplace. Formulated within this paper are a Nash game, a generalized Nash game and a cooperative game of the sellers involved in selling the same commodity to a number of buyers. The sellers compete with one another to sell a higher volume of product to the buyers in the marketplace while also investing in cybersecurity. While the Nash game existed in the literature, we add two new frameworks. The buyers are influenced by the average cybersecurity level of all sellers. We solve the games by calculating the Karush-Kuhn-Tucker (KKT) conditions for each game, given that each seller is trying to maximize its own expected utility function. We find that both the Nash and generalized Nash games show similar characteristics when varying parameters of the games. It is also shown that when sellers agree to cooperate, their expected utilities are higher than when they act noncooperatively.

4 - How to increase the impact of disaster relief: a study of transportation rates, framework agreements and product distribution
Timo Gossler, Tina Wakolbinger, Anna Nagurney, Patrizia Daniele

Due to restricted budgets of relief organizations, costs of hiring transportation service providers steer distribution decisions and limit the impact of disaster relief. To improve the success of humanitarian operations, it is important to understand this relationship in detail and to identify mitigation actions, always considering the interdependencies between many independent actors in humanitarian logistics. We develop a two-phase game-theoretic model in order to investigate the influence of transportation costs on distribution decisions and to evaluate measures for improving the fulfilment of beneficiary needs. The equilibrium of the model is a Generalized Nash Equilibrium which has had few applications in the supply chain context to date. We formulate it, utilizing the construct of a Variational Equilibrium, as a Variational Inequality and perform numerical simulations in order to study the effects of three interventions: an increase of market competition, a reduction of transportation costs and an extension of framework agreements. The results yield important implications. In situations of low market competition, increasing the number of service providers allows to significantly increase the impact of relief. In highly competitive environments, enhancements to the worst-developed parts of the logistics infrastructure should be prioritized. Finally, extending the scope of framework agreements helps to compensate high transportation rates on spot markets.

■ MA-34

Monday, 8:30-10:00 - SOUTH BUILDING UV S113

Risk Management for Insurance

Stream: Insurance and Pension Risk Management
Chair: *Susanna Levantesi*

1 - Enterprise risk management and economies of scale and scope: evidence from the German insurance industry
Thomas Berry-Stoelzle, Muhammed Altuntas, John David Cummins

Enterprise risk management (ERM) is the approach of managing all risks faced by an enterprise in an integrated, holistic fashion. This research investigates whether the utilization of the ERM approach helps firms achieve economies of scale and scope. We use detailed survey data of German property-liability insurance companies that allows us to construct continuous measures of ERM quality. We find that ERM quality positively moderates the size-scale efficiency relationship, and we find that ERM positively moderates the diversification-revenue scope efficiency relationship, indicating that ERM facilitates economies of scale and economies of scope with respect to revenue complementarities. We do not find any evidence of economies of scope with respect to cost complementarities. Our results suggest that ERM's impact on economies of scale and scope is one answer to the question how ERM can create value.

2 - Benchmark loss distributions in insurance regulation
Cosimo Munari, Valeria Bignozzi, Matteo Burzoni

We study capital requirements for insurance companies based on benchmark loss distributions (BLDs). Capital requirements are defined as the minimal capital injections that make a given insurance loss distribution acceptable. We define acceptability in terms of stochastic dominance: A loss distribution is acceptable if it stochastically dominates a given target distribution, namely the BLD. In the case of first- and second-order stochastic dominance we obtain generalizations of the standard risk measures used in practice, namely Value at Risk (Solvency 2) and Expected Shortfall (Swiss Solvency Test). Compared to these standard risk measures, our approach allows for a more flexible control on the likelihood as well as the size of potential losses. We provide a detailed comparison between capital requirements based on VaR, ES, and BLDs with a focus on the typical distributions used in insurance.

3 - Securities lending in insurance
Enrico Biffis

We provide a cross sectoral overview of securities lending, and then focus more explicitly on the insurance space, as well as discuss the perspective of regulators addressing the issue of systemic risk contribution via an activities based approach. We then outline a portfolio model to illustrate the main trade-offs at play when designing and managing securities lending programs, demonstrating in turn how a holistic, risk based approach can provide a good representation of the risk profile of such activites. Finally, we explore how a Solvency II - type framework may be used to understand the main risks channelled by securities lending operations.

■ MA-48

Monday, 8:30-10:00 - 4D UPV B.3

Optimisation Models for Humanitarian Logistics

Stream: Humanitarian Operations
Chair: *Begoña Vitoriano*

1 - Lexicographic optimization in a time-dependent evacuation model
M. Teresa Ortuno, Inmaculada Flores, Gregorio Tirado, Begoña Vitoriano

During the last decades, it has been a growing effort in the use of operational research techniques for humanitarian relief in different logistic problems, emergency evacuation among others. After the occurrence of some natural or human-made disasters, the evacuation of the population from the affected areas to safer places is a priority. The need to act quickly is not only due to the real possibility of injured people who need health care, but also to the possible effects that the disaster may imply after it has taken place (aftershocks, increasing floods, etc). In this work, a lexicographic goal-programming model for evacuation and distribution of aid is proposed. The problem is time -dependent, assuming that arrival of evacuees at sources vary with time. The model establishes different priority levels; in the first one, we minimize the evacuation time of critical people; in the second, the total evacuation time and the total cost of the operation.

2 - E-voucher distribution routing and planning for Syrian refugee camps in Turkey
Ramez Kian, Gunes Erdogan, Sibel Salman, Bahar Yetis Kara, Muhittin Hakan Demir, Ehsan Sabet, Sander de Leuw

The conflict in Syria began as an offshoot of the 2011 Arab Spring but it then turned to a civil war in the past six years. According to UNHCR report, Turkey has hosted about 2.3 million Syrian refugees that 260,000 of them reside in 25 camps, or outside the camps most in urban or peri-urban areas in the southern border of Turkey. UN seeks billions of dollars to provide humanitarian aid to 4.7 million Syrians. Besides the wide range of humanitarian aid activities, like providing food, shelter, healthcare, etc. which is called in-kind distributions, cash-based interventions also play an important role in aiding people on post-crisis period in humanitarian emergencies. In this study, we investigate the optimal way of distributing e-vouchers to the Syrian refugee camps in the southern parts of Turkey. As they are distributed, the subsequent money transfers can be performed electronically and therefore, periodic logistics costs and risks are prevented. Distribution of the e-vouchers are planned to be accomplished by three ways including (i) temporary fixed facilities, (ii) a mobile facility and (iii) a mobile vehicle within a predetermined planning horizon. We provide a mathematical programming model to maximise a reward function defined according to the amount of distributed e-vouchers and logistics costs. Our model addresses both distribution channels and vehicle routing by considering the potential en route risks, as well. Numerical results with real data are presented.

3 - Routing of mobile pharmacies to address drug stockout inequity in developing countries
Rajan Batta, Biplab Bhattacharya, Li Lin

Mobile pharmacies are an excellent tool to supplement pharmaceutical needs for rural populations in developing countries. We study the problem of routing mobile pharmacies in rural Uganda to supplement traditional pharmacies with drugs related to commonly found ailments. The goal is to route these mobile units so that the availability of drugs is equitable across the community served, and shortages are held to a minimum time span. Return to the depot is needed to restock drug supply. We develop a mathematical equation to capture equity of drug stock outs and use this equation to drive a routing algorithm that is based on well known vehicle routing principles. Computational results are presented along with results from a case study based on the situation in rural Uganda. Extensions of the model to other situations are also discussed.

4 - Strategic facility location and tactical resources allocation under uncertainty for natural disaster response
Adán Rodriguez, Begoña Vitoriano, M. T. Ortuno, Laureano Fernando Escudero, Juan Francisco Monge

Preparedness on Humanitarian Logistics is determinant, but it is complicated to prepare for an uncertainty scenario. The optimization model showed its focus on strategic decisions, taken for a long time horizon, like warehouses location. The stochasticity of the problem is modeled with scenarios which represent the possible humanitarian catastrophes that must be taken into account. Those scenarios determine the humanitarian aid demand and the road conditions. In addition a realistic case about Mozambique is presented. Historical catastrophes data, road information and demography data is utilized for scenario construction.

■ MA-49

Monday, 8:30-10:00 - 4D UPV B.4

IBM Research Applications I

Stream: IBM Research Applications
Chair: *Andrea Simonetto*

1 - Transmission-constrained unit commitment: a decomposition-based approach
Claudio Gambella, Jakub Marecek, Sara Pezic Djukic, José María Fernández Ortega, Martin Mevissen, Mustafa Pezic

Currently, models of unit commitment problems often do not incorporate transmission constraints, which present considerable challenges. Commitment schedules infeasible for the actual non-linear transmission constraints in the Alternating-Current (AC) model may have to be adjusted by experienced operators. The joint problem, known as the Transmission-Constrained Unit Commitment (TCUC) in the AC model is a challenging Mixed-Integer Non-Linear Programming problem, due to the non-convexity of transmission constraints. We present an approach based on decomposition of a Mixed-Integer Semidefinite Programming (MISDP) relaxation into a mixed-integer master problem and a continuous sub-problem. Between the master problem and the sub-problem, we pass no-good cuts and over-cost cuts. We report computational results for the approach on a test case from the Spanish transmission network.

2 - Optimal microgrid design - a piecewise linear approximation
Ramachandra Rao Kolluri, Julian de Hoog

Distributed generation and storage have a key role to play in revolutionizing the modern electricity grid. In many places, reduced feed-in tariffs and declining solar incentives are making behind-the-meter energy consumption via storage a favourable option for most domestic roof-top PV owners. Together with the financial trends, the advent of advanced electronics and communications are stimulating microgrid deployments. Energy planning and operation in microgrids can be challenging, especially when the spatial and temporal profiles of demand and generation do not align well making an integrated approach where generation and storage systems are designed together essential. In this work we provide a framework that can be used for the sizing, positioning and operating PV systems and batteries simultaneously in a way that reduces the cost of operating as a microgrid while also maintaining a high quality of service. We formulate a piecewise linear mixed integer program based optimization algorithm that accounts for several network/cost/tariff constraints along with battery degradation. We apply our framework to a realistic example and show its capability in providing operational and power quality benefits.

■ MA-50

Monday, 8:30-10:00 - 4D UPV 1.1

Logistics and Transportation in Biomass-Based Supply Chains

Stream: Biomass-Based Supply Chains
Chair: *Taraneh Sowlati*

1 - Combining dynamic vehicle routing with multiple stock size cutting stock problem in forestry harvesting
Laura Climent

We deal with a real-life sustainability application from our industrial partners: forestry harvesting. In such problem, the logs of the trees (stock) have to be cut in smaller log-pieces (types of products) by harvesting machines in order to satisfy the demands of the customers. The objective is to satisfy the demands by minimizing the trees harvested. (The parts of the logs that do not fit in the demands are wasted). First of all, we classify this problem as a variant of Multiple Stock Size Cutting Stock Problem (MSSCSPs). In MSSCSPs some sets of stock of different sizes (such as the logs of the trees) must be cut following certain patterns. The main additional difficulty of the forestry problem lies in the fact that estimates of the stock sizes differ (sometimes significantly) from real stock sizes. This implies that the cutting patterns cannot be known a priori and that the amounts of products that will be obtained from cutting the stock are uncertain. We tackle this MSSCSP in a dynamic way by re-computing solutions: 1st computing the difference between expected and obtained amounts and 2nd updating the "targeted" amounts as the cutting process progresses. In addition, we present an Integer Linear Program (ILP) that combines the dynamic MSSCSP with the Vehicle Routing Problem (VRP) in order to decide the path that the harvesting machines have to follow. In the evaluation, we show the outperformance of our approach against a metaheuristic algorithm from the literature.

2 - Searching synergies between timber production and non-wood forest products for multi-objective forest management
Mikko Kurttila, Timo Pukkala, Jari Miina

The global growth of the consumption of non-wood forest products (NWFPs) is evident due to the current trends in lifestyle and consumption. Alongside with the increased popularity and commercial use of NWFPs, their yields are more often taken into account also in forest management planning. Empirical yield models developed recently for different NWFPs enable forest managers to include their yields in multi-objective optimization calculations. However, knowledge on the synergies and trade-offs between timber production and different NWFPs is scanty. In this study, we studied these relationships through correlation matrices and production possibility frontiers in two case study forest holdings from Finland. A large number of pareto optimal forest plans were produced by multi-objective optimization. There plans formed the data for our analyses. In these calculations, empirical yield models for 12 different NWFPs, representing different berries, mushrooms and tree-based products were utilized. The results reveal possibilities for the joint-production of different NWFPs and reveal the trade-offs between NWFP and timber production. The results are valuable when the aim is to diversify the use of boreal forests and open avenues for truly multi-objective decision support services to facilitate the decision making of forest owners.

3 - Regulation and benchmarking: a formative evaluation of Portuguese wastewater services using composite indicators
Ana Camanho, Alda Henriques, Pedro Amorim, Jaime Gabriel Silva

This paper describes a framework to enhance the evaluation of performance of wastewater companies based on the indicators collected by the Portuguese water and waste services regulation authority (ERSAR). Our assessment is focused on wholesale and retail services, contributing to increased accountability in the water sector. It considers three main dimensions of performance: protection of user interests, operator sustainability, and environmental sustainability. We develop a composite indicator to provide a summary measure of utilities performance. The composite indicator is estimated using a directional distance function with weight restrictions in the form of assurance regions type I, to allow the specification of alternative perspectives concerning the importance of the different dimension of company performance. We illustrate our approach with data of 19 wholesale companies and 264 retail companies in the year 2014. In a second stage, a truncated regression model is used to analyze the impact of contextual factors on companies' activity. The information provided by this analysis constitutes the basis of a formative evaluation framework that the regulator can use to disseminate best practices and motivate continuous improvement

4 - Optimization of forest-based biomass logistics
Taraneh Sowlati, Krishna Teja Malladi

In this research, models are developed to optimize the short-term planning of a large biomass logistics company in Canada. Collection, storage, pre-processing and transportation of forest-based biomass are considered in the models and constraints related to truck-location and truck-biomass compatibilities are incorporated into the models. A decomposition-based approach is used and first a transshipment model is developed to optimize the collection, comminution, storage and transportation weekly plans. Next, a routing model is developed to optimize the daily truck routes. The results of optimization models show reduction in total average cost and fuel consumption compared to the actual routes implemented by the company. Finally, a decision support tool is developed for the company.

■ MA-51

Monday, 8:30-10:00 - 4D UPV 1.2

OR for Sustainable Development in Developing Countries

Stream: OR for Sustainable Development
Chair: *Olabode Adewoye*

1 - Measuring footprint in supply chain: an important contribution in achieving green supply chain
Rajbir Kaur, Sadia Samar Ali

Globally supply chain practices are trending towards configurations of optimal networks of functional and innovative products to achieve carbon emission reduction targets. This is achieved by integrating operational and environmental aspects into the entire length of supply chain starting from procurement, manufacturing, inventory and logistics till final disposal of products. Global organizations are bound to follow environmental regulations to maintain carbon levels because there are penalties for failures and benefits for achievers. Literature review is done to identify carbon trading and carbon credit measures as major factors for environmental sustainability as this study aims to bridge gap between these two factors for Indian industries. Primary data is collected from the industries in greater NOIDA region where logistics services provided to users are measured by American Customer Satisfaction Index (ACSI). 'Stringent industrial policies' and 'interest of foreign industrial investor' have been identified as major external factors and 'commitment of top management', and 'training of employees' as major internal factors for bringing environmental prospect into the general fabric of supply chain. A strong emphasis is given on carbon footprint assessment standards—ISO14064 and Greenhouse Gas (GHG) protocol and product carbon footprint assessment standards—PAS2050, TSQ0010, ISO14047, for reducing carbon emissions

2 - A comparison between multi-objective optimization approaches for the harmonization of surveillance requirements and maintenance
Pablo Martorell

Safe operation of nuclear power plants depends on technical specifications, which are part of the licensing basis to operate a plant. In particular, attention is paid to the role of the surveillance requirements. The goal of these is to provide adequate assurance of the availability and reliability of equipment needed to prevent and, if necessary, mitigate NPP accidents. In the last years, the U.S. NRC has been approved several initiatives for fundamentals improvements to standard technical specifications. In this way, the initiative RITS-5b (TSTF-425) aims at enabling utilities to relocate surveillance frequencies to licensee control, thus allowing utilities to change these frequencies by using an approved risk-informed approach, which is applicable to all nuclear reactor types. This work shows a comparison between several optimization criteria in the context of RITS-5b accounting for the effects of NPP aging and the maintenance rule. The multi-criteria decision-making is formulated like multiple objective optimization problems (MOPs) adopting each one of the above criteria as either an objective to be optimized or a constraint to the decision-making problem. Each MOP represents a different implementation of the RITS-5b philosophy: 1) current situation with fixed SR and dynamic maintenance, 2) flexible SR and dynamic maintenance and 3) dynamic SR and maintenance.

■ MA-52

Monday, 8:30-10:00 - 4D UPV 1.3

Health Care Management

Stream: OR for Health and Care I
Chair: *Piotr Lukasiak*
Chair: *Rommert Dekker*

1 - Queueing models in balancing hospital's capacity and patient wait times
Susan Li, Zhimin Huang

Hospitals throughout the world face long and increasing wait times for medical services. Excessive delays may be detrimental to patients' health. As a result, there is growing public and patient pressure on hospitals to reduce wait times to acceptable levels. In order for hospitals to continue surviving, solutions are needed to decrease the waiting times while maintaining an acceptable quality service. This paper develops several queuing models which provide hospital management with insights into the causes for excessive wait times and the relationship between wait times and capacity. We will show the significant benefits that can be achieved by applying our methods to healthcare management. We will provide a numerical example to illustrate the use of our methods to optimize the scheduling of patients with multiple priorities. The study shows that by applying our approaches, wait time targets can be achieved with the use of hospital capacity.

2 - Scheduling MRI appointments: a case study in Osmangazi University Hospital
Emine Akyol Ozer, Zehra Kamisli Ozturk, Asli Ergezer, Derya Bayar, Gürdeniz Hökmen

This study deals with an optimization problem which appears in the context of booking radiology appointments at the MRI department of Osmangazi University Hospital. Since MRI machines are used by all departments, one of the busiest section at hospital is radiology department and it causes long waiting time for patients. To make an effective plan with regard to operational restrictions such as emergencies and cancellations can be reduced waiting time of patients. The aim of this study is to develop a mixed integer programming model for appointment scheduling problem at the hospital. The objective of the model is to minimize waiting time of patients. The proposed model has been verified with a toy example and then it has been implemented to radiology department of Osmangazi University Hospital. The success of obtained results are discussed.

3 - A literature review on the vaccine supply chain
Rommert Dekker, Evelot Duijzer, Willem van Jaarsveld

Vaccination is one of the most effective ways to prevent and/or control the outbreak of infectious diseases. This medical intervention also brings about many logistical questions. In the past years, the OR/OM community has shown a growing interest in the logistical aspects of vaccination. However, publications on vaccine logistics often focus on one specific logistical aspect and an integral view is lacking.

We use the following classification: product, production, allocation, and distribution. We identify unique characteristics of the vaccine supply chain: high uncertainty in both supply and demand; misalignment of objectives and decentralized decision making between supplier, public health organization and end customer; complex political decisions concerning allocation and the crucial importance of deciding and acting in time.

■ MA-53

Monday, 8:30-10:00 - 4D UPV 1.4

Quality Management

Stream: OR in Quality Management
Chair: *Rafael Sanchez-Marquez*

1 - Evaluating service quality of an art museum in South Korea using a multiple assessment model
Jimin Park, Sukran Kim, Jaewoo Chung

The purpose of this study is to measure the service quality of domestic museums in Daegu, South Korea using a new assessment model combining the SERVQUAL model with the HISTOQUAL model developed for evaluating cultural heritage sites. The new model has the advantage of being able to measure whether an added value is generated through the communications of art museum information which is difficult to measure with the exiting SERVQUAL alone. The results reveal that the museum visitors' perception could be best explained by three service quality dimensions named as Quality of Exhibition, Access, and Empathy. As a result, in order to create continuous added value beyond the basic exhibition role, art museums need a unique growth model of their own, and also a competitive operational strategy is needed to make consensus with the visitors through the process of planning exhibitions reflecting the specificity of the regional area.

2 - Combination of empirical quantile forecasts to determine the safety stock
Juan Ramon Trapero Arenas, Nikolaos Kourentzes, Manuel Cardós, Ester Guijarro, Eugenia Babiloni

Traditionally, the supply chain forecasting literature has mainly focused on point forecasts. However, little attention has been paid to measure the uncertainty around those forecasts, although important applications such as determining the safety stock depend on estimating the uncertainty. Theoretical approaches, which assume that the probabilistic lead time forecast distribution can be perfectly defined as a function of the forecasting model parameters and the forecasting horizon, are employed to determine the safety stock. This methodology also implies that forecast errors are Gaussian iid. However, demand data is very complex and assuming that there exists a perfect forecasting model able to capture the demand pattern of each SKU is unrealistic. In fact, if iid assumptions are not fulfilled, several works have reported a significant deterioration of the supply chain performance. As an alternative to the theoretical approaches, empirical methods that circumvent the traditional iid assumptions can also be employed. Among those empirical methods we can find Kernel Density Estimators and GARCH models. This work proposes an optimal combination of empirical quantile forecasts based on the minimization of the asymmetric piecewise linear loss function to determine the safety stock. The results show that combining quantile forecasts yields safety stocks with a lower cost. Simulations and a case study is shown to verify the methodology proposed.

3 - Quality management system diagnosis
Rafael Sanchez-Marquez

Some Research Works have been undertaken to prove the validity and efficiency of applying multivariate techniques to simplify Balanced Scorecard (BSC) by selecting the most important Key Performance Indicators (KPIs) and even designing effective strategies to achieve goals and objectives in manufacturing environment. Those Works are based mainly on the weight of their relationships within the whole System (BSC). Some of these Works have also pointed out that details regarding the nature of relationships among those KPIs can also be used for other purposes. This Research Work is showing how Principal Component Analysis, Regression and finally Time Series can help on the diagnosis of the Quality Management System of a big manufacturing Company. The work has been carried out in a real Company with actual data as a case study approach to validate the method. As a result, several relationships between KPIs has allowed management to make decisions about important aspects of Quality such as Quality Predictability and Quality Feedback from final Costumer.

■ MA-54

Monday, 8:30-10:00 - 4D UPV 1.6

Sustainable Supply Chains

Stream: Energy Economics, Environmental Management

and Multicriteria Decision Making
Chair: *Renzo Akkerman*

1 - ToBLoOM - triple bottom line optimization modelling for sustainable supply chains under uncertainty
Ana Barbosa-Povoa, Bruna Mota, Ana Carvalho, Maria Isabel Gomes

In this work a decision support tool for the design and planning of sustainable supply chains entitled ToBLoOM (Triple Bottom Line Optimization Modelling) is presented. It encompasses support in decisions regarding: multi-facility location and capacity allocation; inventory planning; supplier selection and allocation; purchase planning; technology selection and allocation; production planning; transportation network definition (with unimodal and intermodal options); product recovery and remanufacturing planning. These decisions are supported considering the three pillars of sustainability: economic, environmental and social, using a multi-objective approach. Uncertainty is considered using a stochastic approach. This decision support tool allows the identification of sustainability hotspots and supports the definition of strategies towards more sustainable supply chains. The validity and applicability of the decision support tool is demonstrated through its application to a case-study of a European electronic components' producer. In this work: Net Present Value (NPV) is used as the economic objective function; the environmental objective function is based on the Life Cycle Analysis methodology ReCiPe; the social objective function is based on a GDP metric. Uncertainty in demand is incorporated. Managerial insights towards more sustainable supply chains are derived from this work.

2 - Quantitative modelling for resource efficient supply chains: a systematic review
Ursula Davis, Alok Choudhary, Grammatoula Papaioannou, Ravi Shankar

Resource efficient supply chains are increasingly important in the area of sustainable supply chain management. Quantitative modelling techniques have been utilised within sustainable supply chain management profusely, with a significant focus on the environmental impact of the supply chain. As such, there is a lack of literature review research, which focusses on the use of quantitative models for resource efficient supply chains. We apply a systematic review method to analyse the literature with a focus on the appropriate application of quantitative models in this research area. We analyse the research trends with regards to modelling techniques, supply chain areas and different types of resources used. Using sophisticated bibliometric analysis methods, we define research agenda for resource efficient supply chains by identifying and analysing existing analytical models. We use BibExcel and Gephi to visualise citation networks. We also identify most influential authors and research papers, widely used journals and research conducted in various countries and sectors to drive the future research. Our research should facilitate further understanding of the implications and trade-offs of resource efficient supply chain decision making for practitioners.

3 - Strategic capacity planning in process industries under water scarcity
Sai Jishna Pulluru, Paloma Aparicio Escuder, Renzo Akkerman

Water scarcity is an imminent threat for many industries. Process industries are particularly affected by this development due to their high dependence on water for their operations. Ensuring adequate water supply of desirable quality in order to meet operational and strategic goals can therefore be challenging, especially when companies would like to expand their production capacities to retain or increase their competitive advantage. Additionally, companies in the same geographic region may also compete for available water resources, which may even be diminishing at a steady rate. A possible solution to tackle these issues is to plan capacity expansions in view of water aspects such as availability, discharge limits, treatment capacity, available infrastructure, etc. We develop a mathematical modelling approach to plan capacity expansions in process industries, aiming to capture the interactions between strategic capacity planning and water management. We extend this approach to include other companies withdrawing water from a common set of resources for their daily operations. Using a game-theoretic approach, we study both competitive and collaborative behavior during capacity expansion and water use. Based on theoretical case studies, we examine various water management strategies such as waste water sharing, treatment capacity investments, shared treatment plants, etc. that can be adopted by these industries to support their individual strategic capacity planning.

■ MA-55
Monday, 8:30-10:00 - 4D UPV 2.1

Speed Networking

Stream: Making an Impact I
Chair: *Ruth Kaufman*

1 - Speed networking and EURO working group on practice of OR
Ruth Kaufman

One of the most important reasons for coming to a conference is to build your circle of professional acquaintance - with like-minded people who can encourage and inspire you, and with not-quite-so-like-minded people who can challenge and extend you, and with the many people who you can encourage, inspire, and challenge. However, it is not always easy to meet people when most of our time is spent sitting listening to presentations. The speed networking session is a supportive, managed way of meeting people you don't know: a series of short, quick-fire sharing of professional information with other participants, together with an exchange of contact details if you meet somebody you want to keep in touch with. Latecomers will be admitted but may have to wait for a few minutes before they can join in. The meeting will also include a short presentation about the EURO Working Group on Practice of OR, aimed at supporting a pan-European network of practitioners.

■ MA-56
Monday, 8:30-10:00 - 4D UPV 2.2

OR in Neuroscience

Stream: OR in Neuroscience
Chair: *Dorit Hochbaum*

1 - Voxel-MARS and CMARS: methods for early detection of Alzheimer's disease by classification of structural brain MRI
Gerhard-Wilhelm Weber, Alper Çevik

Neuroscience is of emerging importance along with the contributions of OR to the practices of diagnosing neurodegenerative diseases with computeraided systems based on brain image analysis. Although multiple biomarkers derived from Magnetic Resonance Imaging (MRI) data have proven to be effective in diagnosing Alzheimer's disease (AD) and mild cognitive impairment (MCI), no specific system has yet been a part of routine clinical practice. We introduce a fully-automated voxelbased procedure, Voxel-MARS (and CMARS), for detection of AD and MCI in early stages of progression. Performance was evaluated on a dataset of 508 MRI volumes gathered from the Alzheimer's Disease Neuroimaging Initiative database. Data were transformed into a high-dimensional space through a feature extraction process. A novel 3-step feature selection procedure was applied. Multivariate Adaptive Regression Splines method was used as a classifier for the first time in the field of brain MRI analysis. The results were compared to those presented in a previous study on 28 voxel-based methods in terms of their ability to separate control normal (CN) subjects from the ones diagnosed with AD and MCI. It was observed that our method outperformed all of the others in sensitivity with acceptable specificity values. Furthermore, the method worked for discriminating MCI patients which converted to AD in 18 months (MCIc) from non-converters (MCInc) with a sensitivity outcome better than 27 of 28 methods.

2 - Spatial separability in hub location problems with an application to brain connectivity networks
Taghi Khaniyev, Samir Elhedhli, Fatih Safa Erenay

The spatial separability of uncapacitated single assignment p-hub median problems (USApHMP) is studied. We observe that the optimal solutions to the well-known USApHMP instances can be partitioned into p allocation clusters, defined as the set of nodes which are allocated to the same hub, such that the convex hulls of the allocation clusters are disjoint. We illustrate numerically that this pattern persists over a wide range of random instances. A data-driven approach which relies on the low resolution representation of the original problem is proposed to exploit this pattern to tackle very large problem instances. Brain connectivity networks (BCN) is introduced as a new application area of hub location problems (HLP) with a dataset for the largest (998 nodes) and first 3D instances in the literature. Computational experiments corroborate the effectiveness of the proposed approach in generating high quality solutions within a reasonable amount of time. Experiments also reveal that the HLP models can successfully reproduce similar results to those in the medical literature related to hub organisation of the brain. We conclude that with certain customization and methods that allow tackling very large instances, HLP models can potentially become an important tool to further investigate the intricate nature of hub organisations in BCNs.

3 - Dynamic models of the spread of neurodegenerative diseases
Hana Tomaskova, Richard Cimler, Jitka Kühnová, Ondřej Dolezal, Dalibor Cimr, Dalibor Cimr

The main aim of this research is to compare different modeling approaches and focus on their usability for creating a vast dynamical simulation of the growth of the population and the occurrence of Alzheimer's disease (AD). The second aim of this rsearch is to predict a number of patients with different neurodegenerative diseases and evaluate it's economical and social burden within specified region. Advanced modeling techniques will be used for simulation of population growth and prediction of a number of persons with such diseases in given population. Cost models will be applied to simulation results which enable to predict financial burden. Different advanced modeling techniques will be used for prediction of population grown and prediction of the number of persons with neurodegenerative disease in the population. Numerical, agent-based and system dynamics approach enables to model and predicts different characteristics of the system. Models in an initial phase of the research will be based on data from available public databases e.g.Eurostat. Advanced models will include own algorithms for prediction of population growth of specified region - in order to be able to simulate different scenarios of population grow based on experts requirements

4 - HNCcorr: a novel combinatorial optimization approach for neuronal cell identification in calcium imaging movies
Dorit Hochbaum, Quico Spaen, Roberto Asín

Calcium imaging is a key method in neuroscience for investigating patterns of neuronal activity in vivo. Still, existing algorithms to automatically detect and extract activity signals from calcium imaging movies suffer from major shortcomings. A combinatorial optimization technique for identifying clusters that are highly similar within and highly dissimilar to their complements named HNC has been successfully employed in several data mining contexts. HNC (Hochbaum's Normalized Cut) solves the clustering problem using an efficient parametric minimum cut procedure. HNCcorr is a novel algorithm based on HNC for cell identification in calcium imaging movies which, unlike existing methodologies, guarantees an optimal solution and minimal dependence on initialization techniques. HNCcorr uses a new method for computing similarities named, "similarity squared" which associates with each pixel a vector of correlation similarities with respect to a reference set of pixels, and determines the similarities between pairs of pixels by computing the similarity of the respective two vectors. The effectiveness of the HNCcorr has been demonstrated by its leading performance or the Neurofinder cell identification benchmark. As such HNCcorr is an important addition to the toolbox for analysis of calcium imaging movies.

■ MA-60

Monday, 8:30-10:00 - 4D UPV B.5

ROADEF

Stream: EURO Special Sessions
Chair: *Eric Bourreau*

Monday, 10:30-12:00

■ MB-01

Monday, 10:30-12:00 - UPV Nexus

Optimization and Music Data Science

Stream: Keynotes
Chair: *Teresa Leon*

1 - Optimization and Music Data Science
Elaine Chew

The explosion in digital music information has spurred the developing of mathematical models and computational algorithms for accurate, efficient, and scalable processing of music information. According to the 2017 IFPI Industry Global Music Report, the total global recorded music revenue was US$15.7b in 2016, 50% of which were digital. Industrial scale applications linking recorded content to listeners include Last.fm, Pandora, Shazam, and Spotify. Shazam has over 120 million active users monthly and Spotify over 140 million. Since the launch of Shazam, users have issued 30 billion song identification requests, growing by 20 million each day. With such widespread access to large digital music collections, there is substantial interest in scalable models for music processing. Optimization concepts and methods thus play an important role in machine models of music engagement, music experience, music analysis, and music generation.

In this talk, we will show how optimization ideas and techniques have been integrated into computer models of music representation and expressivity, and into computational solutions to music generation and structure analysis. More specifically, we will report on research and outcomes on an interior-point approach to modeling tonal perception (inferring the keys and chords from note information), the idea of duality in reverse-engineering music structure analyses, constraint-based music generation to instill long-term structure, an optimization heuristic for stream segregation separating out voices from a polyphonic texture), statistical and optimization-based approaches to music segmentation, and rhythm transcription that minimizes quantization error for music and arrhythmia sequences. The talk will contain numerous music illustrations and, where appropriate, live performances of music and demonstrations of interactive visualization software on a piano or keyboard.

■ MB-02

Monday, 10:30-12:00 - SOUTH BUILDING UV S101

Scheduling Practice in Manufacturing

Stream: Scheduling Practice
Chair: *Miriam Zacharias*

1 - Dispatching rules selection for machines and AMHS scheduling
Yung-Hsun Tsai, Ken-Hsuan Chen, Gen-han Wu

Nowadays, automated material handling systems are widely introduced in wafer fabs for wafer transportation. If we can integrate material handling and production scheduling together, it will enhance overall production efficiency. Dispatching rules, which can provide satisfactory solutions, are easily and widely used for semiconductor manufacturing scheduling. However, how to select different appropriate dispatching rules for production machines and material handling vehicles is so called the dispatching scheduling problem. The composite dispatching rules need to be evaluated in detail by system simulation. In this study, we proposed four simulation-based algorithms including PSO, CSA, PSO/VNS and CSA/VNS to construct near-optimal solutions for dispatching rule allocation in a specific manufacturing environment which is similar to wafer fabrication system. The objective is to minimize total weighted tardiness. For these approaches, we also design a series of experiments to optimize the parameters of the proposed four algorithms. In computational result, it shows that the composite dispatching rules (CDRs) obtained by four algorithms outperform single dispatching rules. Moreover, the result reveals that the proposed PSO/VNS can achieve the best CDRs in most cases.

2 - Line-side material placement to minimize walking time at moving assembly lines
Helmut Sedding

Our study describes a combinatorial optimization approach on reducing worker walking time at moving assembly lines by optimizing material placement at the line side. This corresponds to sorting the material containers in a row along the assembly line. However, it differs considerably from existing sequencing problems. Already swap of adjacent containers requires a reoptimization of all following walking times. Therefore, parts of an optimum solution might be suboptimal if regarded for themselves. The only remotely related problems we are aware of are in the area of time-dependent scheduling with non-monotonous convex processing times. As the problem is novel in theory and in practice, we define a model that is quintessential in both terms and allows for extensions. In our tests, we find that with this optimization, a common material placement strategy's walking time can be reduced by a mean of 20%. As MIP formulations and existing literature only optimize small instances, we aim to understand the underlying combinatorial structures to find algorithms for larger problem sizes. In this study, we show that the problem is NP-complete in the strong sense, describe polynomial cases, and devise algorithms that outperform both generic and existing approaches. With our findings, we furthermore hope to spark further research in this novel research area.

3 - Measuring effectiveness of scheduling jobs with earliness and tardiness costs: a case study
Andrés Muñoz-Villamizar, Javier Santos, Jairo R. Montoya-Torres, María Jesús Alvarez

This paper assesses the effectiveness in scheduling jobs with earliness/tardiness costs and variable setup times using the OEE (Overall Equipment Effectiveness) metric. The OEE metric is a well-known rate used in the Lean Manufacturing framework that measure how effectively a manufacturing operation is realized. A mixed-integer linear programming formulation of the job scheduling problem with four different objective functions is developed in order to compare different scheduling configurations. Computational tests were carried out using real data from a manufacturing company of plastic containers located in the Basque country (Spain). Sensitivity analysis was performed with different production capacities and earliness/tardiness costs in order to validate the proposed approach. Results obtained show the relationship and the trade-offs between OEE measures (i.e., quality, performance, availability) and economic performance (i.e., costs). The objective of this work is to propose a guideline for managerial decisions in order to measure and improve the scheduling effectiveness contemplating earliness, tardiness and variable setup times.

4 - Machine learning in hybrid flow shop scheduling problems with unrelated machines
Miriam Zacharias

Hybrid flow shop (HFS) problems are often encountered in real world production systems. Despite their practical relevance, few generic methods exist to solve HFS problems. Hence, many approaches focus either on two-stage problems or the application of simple dispatching rules. Moreover, the majority of authors assume identical parallel machines, which reduces the complexity of machine assignment to a large extent. If a real world case is studied, solution methods are often customized and not adaptable to other settings. Lately, machine learning (ML) has been applied to different scheduling problems. A common application is the selection of best dispatching rules based on the state of system's parameters. We propose an alternative ML-based approach to makespan minimization that is suitable for different configurations regarding the number of stages and number of unrelated machines per stage. To speed up the scheduling process rapidely, we apply ML in one step of our solution method: We train Neural Networks (NN) and Support Vector Machines (SVM) with optimal machine assignments and makespan values for fixed batch sizes and randomly generated processing time matrices. Afterwards, we use the NN and SVM to predict optimal makespan values and machine assignments for all partial job sequences (batches) based on a given processing time matrix. Only sequences with close-to-optimal makespan values are evaluated further to determine a final machine assignment and overall sequence.

■ MB-03

Monday, 10:30-12:00 - SOUTH BUILDING UV S103

Facility Location II

Stream: Location Analysis and Optimization
Chair: *Mehdi Amiri-Aref*

1 - Combining three facility location problems
Ana Dolores López-Sánchez, Jesus Sanchez-Oro, Manuel Laguna, Alfredo G. Hernandez-Diaz

Facility location problems aim to locate the best locations for facilities. Depending on the considered objective, the best locations can be substantially different. This paper presents a Scatter Search algorithm for solving the multi-objective facility location problem (mo-FLP) with three different objectives. The objectives selected are those considered in the p-median problem (pMP), the maximal coverage location problem (MCLP), and the p- center problem (pCP), that is, minimize the total (or the average) weighted cost traveled, maximize the number of customers covered that will receive the service and minimize the maximum weighted cost traveled. The Scatter Search algorithm obtains the set of Pareto optimal solutions. This algorithm has been applied to a variety of optimization problems and uses two populations: a population with the best solutions and a population with the solutions more different from the best ones. Then, the algorithm combines solutions from both populations, as will be explained below, using diversification and intensification strategies in order to obtain high-quality solutions. Note that we are addressing a multi-objective optimization problem hence, the Scatter Search has been adapted to define the best and diverse solutions considering the problem characteristics. Computational results indicate that the Scatter Search algorithm is able to find the set of non-dominated solutions in a simple run within short computational time.

2 - A gradual covering location problem with different facility types & customer preferences
Hande Kucukaydin, Necati Aras

We address a gradual covering location problem where the system planner can open different types of facilities and customers have preferences represented by probabilities for visiting these facilities. It is assumed that customers at a demand point are absolutely willing to travel to a certain facility type if the facility is located within a full coverage distance and the revenue collected by that facility is determined by multiplying the buying power of customers with the visiting probability for the type of the facility. On the other hand, if the distance between the facility and demand point exceeds the full coverage distance, then the visiting probability decreases by a factor so that customers at that demand point are either partially or not covered. Furthermore, in order to bring service to more customers a minimum separation distance between facilities of different and same type is adopted. It is also assumed that a new facility can survive if the collected revenue from the customers exceeds a threshold. The aim of the system planner is to find the optimal location and type of facilities to be opened so as to maximize the profit which is computed by the annual revenue collected from the visiting customers less the fixed cost of facility establishments. We formulate a binary integer linear programming model and solve it by a Lagrangean heuristic and a local search procedure.

3 - Optimal algorithms for two variants of inverse undesirable center location models on graphs
Behrooz Alizadeh

We investigate two variants of the inverse undesirable center location problem on graphs, in which the set of vertices are considered as existing customer points. The first model aims to modify the edge lengths at the minimum total cost subject to specific modification bounds until a predetermined facility location becomes an undesirable center location on the perturbed graph. However, the other model wishes to change the edge lengths within an associated overall budget such that the predetermined facility location on the underlying graph becomes as far as possible from the customer points under the new lengths. We propose combinatorial algorithms with linear time complexities for obtaining the optimal solutions of the problems under investigation.

4 - The flood-adaptive facility location problem
Mehdi Amiri-Aref, Maliheh Hashemi Tilenoi

The purpose of this research is to determine a set of optimal flood-adaptive facility locations in the river-bank of the Seine, which is classified as the flood-prone risk zone in Paris. In the present work, these zones are considered as the regions in which neither placing the facility in nor travelling through is allowed. These regions, which have random nature in size or position in practice, are known as barrier regions in planar location theory. In the urban context, it has been widely shown that the rectilinear (or Manhattan) distance function represents an efficient continuous approximation of the travelled distance in the transportation networks. Therefore, we developed a rectilinear distance Weber location problem in the presence of polygonal barriers with the uncertain position of occurrence, which gives rise to a mixed-integer nonlinear programming formulation. This mathematical model aims to find the optimal location of a set of facilities on the feasible two-dimensional plane and to allocate all demand points to the optimal facility locations at the minimum expected travelled distance while avoiding collision with the barrier regions. This problem is then reformulated to a stochastic programming in which the uncertainty of the position of barriers is realized in scenario generation process.

■ MB-04

Monday, 10:30-12:00 - SOUTH BUILDING UV S104

Dynamic and Stochastic Scheduling in Logistics

Stream: Dynamic and Stochastic Scheduling
Chair: *Heimir Thorisson*

1 - Dynamic allocation of fire vehicles in preparedness phase for bush fires
Reena Kapoor

The impact of bushfires on communities can be devastating, resulting in loss of life and property, environmental damage, and disruption of the local economy. During periods of high fire danger, timely response to fires is essential to prevent the spread of bushfires within a community, and wide-scale devastation. One approach to decrease the time taken to respond to fire reports is to pre-allocate fire responders (and resources) within a community. In addition to fire stations, other suitable stopping locations such as roadside pull-ins or parks can be used to distribute resources more optimally within a community. In this research we developed a mixed integer program for dynamic deployment of fire resources (personnel and appliances) among the available stopping locations with the objective of minimising the total bushfire risk remaining per hour for the area. In this model we also take care of capacity and response time constraints.

2 - A honey bees mating optimization algorithm with path relinking for the vehicle routing problem with stochastic demands
Yannis (Ioannis) Marinakis, Magdalene Marinaki

Honey Bees Mating Optimization algorithm is a very efficient nature inspired algorithm. In this paper, this nature inspired algorithm is used in a hybrid scheme with other metaheuristic algorithms for successfully solving the Vehicle Routing Problem with Stochastic Demands. More precisely, the proposed algorithm for the solution of the Vehicle Routing Problem with Stochastic Demands, the Honey Bees Mating Optimization (HBMOPR), combines a Honey Bees Mating Optimization (HBMO) algorithm, the Variable Neighborhood Search (VNS) algorithm and Path Relinking (PR). A set of benchmark instances from the literature is used in order to test the proposed algorithm. The algorithm is compared with a number of algorithms from the literature (a Particle Swarm Optimization algorithm, a Differential Evolution algorithm and a Genetic Algorithm) and with two versions of the Honey Bees Mating Optimization algorithm and its results proves the efficiency of the method.

3 - A mixed integer model to dynamic deployment of traffic surveillance system

Roozbeh Ebrazi, S. Mehdi Hashemi, Mina Gholizadeh Atani

The impact of enforcement on reducing traffic offenses and accidents reveals the importance of planning for traffic surveillance system. Meanwhile, despite the advent of data gathering tools and intelligent transportation systems, there are limited studies on the systematic approach to developing strategic operational plans for surveillance resource and devices. This paper investigates dynamic deployment of stationary police patrol vehicles problem. Traffic police have two major responsibilities: (1) handling calls for services; (2) enforcing traffic laws. From the perspective of first responsibility, an emergency services allocation problem should be solved but for the second responsibility, there is a need for an enforcement programming to pay attention to site priorities while making a comprehensive risk of apprehension between drivers through the network. Therefore, a maximum coverage problem and multiples set-cover problems should be handled simultaneously. In this paper first, a MIP model is developed which improves enforcement aspect by making unpredictable police presence and explicit consideration of the halo effect. Moreover, to overcome model complexity, the column generation method was applied to solve the model efficiently. Numerical experiments are conducted on randomly generated networks to illustrate and the effectiveness of the proposed solving method in a reasonable time.

4 - Vessel berthing schedules under the influence of emergent and future conditions

Heimir Thorisson, Thomas L Polmateer, James H Lambert

This presentation introduces a scheduling method for vessel berthing at maritime container ports with two layers of emergent and future conditions: i) variable arrival and handling times during business-as-usual operations and ii) large-scale disruptions including major construction, market shifts, and others. In 2017, new alliances of major ocean carriers, sharing resources and services, were forming. This requires schedule negotiations between ports and carriers. Port authorities are concerned with avoiding congestion at their facilities and efficient equipment usage while carriers want to minimize time spent waiting for and receiving service at ports of call. In a case study with the Port of Virginia (USA), schedules are created using a mixed-integer linear program minimizing total cost for different stakeholders and coupled with a Monte-Carlo simulation to account for expected fluctuations in inputs. This process is repeated for several scenarios, representing disruptions due to market demand, extreme weather, accidents, and others. The results show potential for significant cost savings. Furthermore, resilience of each vessel terminal assignment to the various emergent and future conditions is evaluated. An original metric for the disruption potential of scenarios is applied to prioritize further risk management and research needs. Lessons learned from the study are valuable to port owners and operators, shipping lines, trucking and rail companies, and local authorities.

■ MB-05

Monday, 10:30-12:00 - SOUTH BUILDING UV S105

Vehicle Routing

Stream: Mixed-Integer Linear and Nonlinear Programming
Chair: *Inmaculada Rodríguez Martín*

1 - Dynamic parking allocation problem in urban areas

Marko Mladenovic, Thierry Delot, Gilbert Laporte, Christophe Wilbaut

In an urban environment the massive search for vacant parking slots is one of the main causes of traffic congestion, especially in small streets. A parking allocation model is proposed to tackle assigning parking slots to a set of connected vehicles. The 0-1 model is by design Totally Unimodular (TU) and can be quickly solved to optimality. However, new vehicle requests appear continuously, and the Parking Allocation Problem (PAP) must be resolved at each time step, and the new input can be handled in several ways. We therefore investigate several parking allocation policies over the proposed model. In this study we propose two policies for the Dynamic Parking Allocation Problem (DPAP) and analyze their impact on the overall parking requests in the entire city. To render the results more credible we also propose an acceptance parameter, which allows vehicles to deviate from the parking recommendations and a global objective function over the entire time period (e.g. one day). Experiments to evaluate the proposed approaches were conducted over real data collected over the year of three European cities.

2 - A selective pickup and delivery vehicle routing problem with handling cost

Yali Li, Jun Yang, Ling Zhao, Yuanyuan Zhou

This paper presents a selective pickup and delivery vehicle routing problem with handling cost (SPDVRPH).In the SPDVRPH, each delivery node can be serviced by a corresponding set of delivery nodes. And only one node in this set is to be selected to satisfy the demand of the delivery node. The SPDVRPH aims to find the minimum-cost routes for a fleet of vehicles. Based on the characteristics of the vehicle and the loading and unloading policy, the handling cost caused by additional operation is considered in our problem. The problem consists of two interacted decisions including a pickup node selection for each delivery node and the vehicle routing problem. Considering this, two algorithms are proposed to solve the SPDVRPH. One is the large neighborhood search(LNS) and the other one is a metaheuristic hybrid based on genetic algorithm and large neighbourhood search, called GA/LNS. The operators in LNS ensures that it could deal with the selecting operation and vehicle routing decision simultaneously . In GA/LNS , the selection is first determined by GA, which leaves the vehicle routing a sub-problem to be solved by LNS after hand. We compare our heuristics with CPLEX on instances adapted from instances in TSPLIB to verify the effectiveness of the algorithms. Then the two algorithms are compared in terms of efficiency.

3 - An optimization framework for one-way electric vehicle-sharing systems with the combination of operator-based and user-based relocation

Ye Zou, Chao Yang, Min Teng

This paper develops and solves a MILP model for planning station-based one-way electric vehicle-sharing systems with the case that vehicles can be dropped-off not only at designated stations run by the operator but also at specific non-cooperative social parking lots. The optimization of such a system involves a large number of strongly interacting decisions regarding the location and size of stations, the fleet size, as well as the number of relocation personnel. Unlike existing model, both operator-based relocation and user-based relocation are involved. To certify the performance of the proposed approach, the model is applied to a large scale real world problem with available data from Wuhan, China within two real world field tests. Test one represents the scenario that users return vehicles only at designated stations, and the vehicle movements between stations are conducted by the operator. Test two involves car returning in stations and parking lots, and at this point, the users are stimulated to relocate the vehicles. In addition, extensive sensitivity analysis is executed by varying demand, parking and service charge of parking lots. The results provide helpful insights regarding the efficient planning of vehicle-sharing systems. Most importantly, in test two, both profit and vehicle utilization is increased, and the mean idle time per trip end is decreased.

4 - An exact approach for the periodic vehicle routing problem with driver consistency
Inmaculada Rodríguez Martín, Juan José Salazar González, Hande Yaman

In this work we address a variant of the Periodic Vehicle Routing Problem. A fleet of homogeneous capacitated vehicles has to give service to a set of customers over a time horizon of several days. Each customer has an associated set of allowable visit schedules, and must be always visited by the same driver/vehicle. Solving the problem implies to choose a visit schedule for each customer, and to design vehicles' routes for each period of the time horizon respecting the driver consistency requirements of the customers and the capacity restriction of the vehicles, while minimising the total routing cost. We present an integer linear programming formulation for this problem and derive several families of valid inequalities. We solve it using an exact branch-and-cut algorithm, and show computational results on randomly generated instances with up to 71 nodes and different features.

■ MB-06

Monday, 10:30-12:00 - SOUTH BUILDING UV S106

Consumer Behavior and Pricing I

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Tamer Boyaci*

1 - Analyzing retail market basket data by unsupervised machine learning methods
Harald Hruschka

We compare the performance of several unsupervised machine learning methods, namely binary factor analysis, two topic models (latent Dirichlet allocation and the correlated topic model), the restricted Boltzmann machine and the deep belief net, on a retail market basket data set. We shortly present these methods and outline their estimation. Performance is measured by log likelihood values for a holdout data set. Binary factor analysis vastly outperforms topic models. Both the restricted Boltzmann machine and the deep belief net on the other hand attain a similar performance advantage over binary factor analysis. We also show how to interpret the relationships between the most important hidden variables and observed category purchases. To demonstrate managerial implications we compute relative basket size increase due to promoting each category for the better performing models. Recommendations which product categories to promote based on the restricted Boltzmann machine and the deep belief net not only have lower uncertainty due to their better predictive performance, they are also more convincing than those derived by binary factor analysis, which leave out most categories with high purchase frequencies.

2 - Flexible estimation of time-varying effects for frequently purchased retail goods
Winfried Steiner, Bernhard Baumgartner, Daniel Guhl, Thomas Kneib

In most applications of brand choice models, possible time-varying effects in consumer behavior are ignored simply by imposing constant parameters. However, it is very likely that trends and/or short-term variations in consumers' intrinsic brand utilities or in consumers' sensitivities to marketing instruments occur. We propose flexible multinomial logit models for estimating time-varying effects in brand choice behavior. Time-varying brand intercepts and time-varying effects of covariates are modeled using penalized splines, a nonparametric smoothing technique. Our estimation procedure is fully data-driven, determining the flexible functions and the corresponding degrees of smoothness simultaneously in a unified approach. Our model further allows for alternative-specific time-varying effects of covariates and is able to mimic state-space approaches with random walk parameter dynamics. In an empirical application for ground coffee, we compare the performance of the proposed approach to a number of benchmark models in terms of in-sample fit, information criteria, and in particular out-of-sample fit. Interestingly, the most complex P-spline model with time-varying brand intercepts and brand-specific time-varying covariate effects outperforms all other specifications both in- and out-of-sample. We further present results from a sensitivity analysis on how the number of knots and other P-spline settings affect the model performance.

3 - Dynamic pricing with multiunit purchases
Rouven Schur, Robert Klein

Dynamic Pricing is gaining more and more importance in other fields than the classical airline industry. Whenever there is a finite selling horizon as well as stochastic and price sensitive demand, methods of the dynamic pricing framework might be applicable and helpful for maximizing the expected revenue. One popular example is a retailer selling goods that are seasonal (e.g. charcoal), perishable (e.g. fresh food) or part of a temporary promotion (e.g. beer during the World Cup finals). In this example, all potential customers have in common that they are willing to buy more than one unit if the price is right. In this property, they differ from the standard airline customer who is assumed to buy at most one seat. To adapt the standard dynamic pricing model to multiunit purchases, we first formulate an appropriate customer choice model using stochastic willingness-to-pay with decreasing marginal utility for an increasing number of units. After stating the multiunit dynamic pricing model, we propose a tailored heuristic to solve the optimization problem. In order to demonstrate the applicability of our approach, we run a simulation study to show the improvement of expected revenue compared to other approaches.

4 - Brand positioning and consumer taste information
Tamer Boyaci, Arcan Nalca, Saibal Ray

We study how a retailer can benefit from acquiring consumer taste information in the presence of competition between the retailers store brand (SB) and a manufacturers national brand (NB). In our model, there is ex-ante uncertainty about consumer preferences for distinct product features, and the retailer has an advantage in resolving this uncertainty because of his close proximity to consumers. Our focus is on the impact of the retailers information acquisition and disclosure strategy on the competitive positioning of the brands. Our analysis reveals that acquiring taste information allows the retailer to make better SB positioning decisions. Information disclosure, however, enables the manufacturer to make better NB positioning decisions - which in return may benefit or hurt the retailer. We identify and discuss scenarios for both cases.

■ MB-07

Monday, 10:30-12:00 - SOUTH BUILDING UV S107

Analytic Hierarchy Process II

Stream: Analytic Hierarchy Process / Analytic Network Process
Chair: *Josef Jablonsky*

1 - Enhancing sustainable competitiveness of small and medium-sized enterprises using the analytic hierarchy process
Debashree De, Prasanta Kumar Dey

Small and medium sized enterprises (SMEs) contributes to GDP significantly of any economy but their cumulative negative impact on environment is also phenomenal. SMEs have limited resources and numerous competition and hence, they emphasize on economic factors over environmental and social. Therefore, for achieving sustainable competitiveness, SMEs must consider environmental and social factors along with economic aspects across the supply chain. Although competitiveness assessment of larger companies is numerous, research on SMEs supply chain is scant. Moreover, according to authors' knowledge research on SMEs' sustainable competitiveness measurement is none. The main aim of this research is to develop a robust framework for measuring sustainable competitiveness of SMEs. Through combined literature review and primary research a few constructs and sub-constructs for sustainable competitiveness of SMEs' supply chain are derived. Leadership agility, innovation in operations and logistics, sustainable supply chain, excellence in quality are considered as major constructs for sustainable competitiveness of the SMEs. The Analytic Hierarchy Process (AHP) is used as the method for deriving sustainable competitiveness of SMEs' supply chain due to the characteristics of the constructs and sub-constructs. The proposed framework is applied to six SMEs in the transport sector of the UK using multiple case study to demonstrate its effectiveness.

2 - Perception-based interval type-2 fuzzy AHP-QFD approach for evaluation of a service quality

M.Bahar Baskir

Qualitative decision-making process has uncertainty due to its subjective assessment system. The uncertainty mainly arises from concept and cognitive disparities in the subjective system. These disparities result from the perception of decision makers. In engineering applications, quality function deployment (QFD) is one of the widely used quality management method to transform qualitative costumer requirements into engineering characteristics for a product/service. QFD has the mentioned uncertainty problem owing to its evaluation procedure. QFD model is a multi-attribute decision making problem due to its qualitative and quantitative features. Hence, QFD and its uncertainty problem can be modelled using an integrated approach including fuzzy set and analytic hierarchy process (AHP). In this study, a perception-based interval type-2 fuzzy AHP-QFD approach is proposed. This approach has three phases: i) Determining components of QFD, ii) Measuring perception of decision makers in QFD using belief-subspaces (named knowledge and confidence), iii) Perception-based QFD assessments are accomplished using interval type-2 fuzzy set and AHP. This approach is applied to improving service quality of an authorized service in Turkish automotive industry.

3 - Student consumers' decision-making process

Emrah Koksalmis, Gulsah Hancerliogullari Koksalmis

Today, marketing department is the most important part of a business since it makes great efforts to understand the consumer behavior. Some of the common questions in this area are: How do consumers decide where to shop? When do consumers like shopping most? What are the factors influencing consumers' store preference? Consumer behavior includes psychological, personal and social causes, such as why consumers buy, use, dispose of, and which products they use. These decisions which are made by the consumers are based on many criteria. The aim of this study is to determine and analyze the basis of the decisions made by the student consumers. In order to solve the problem, Analytic Hierarchy Process (AHP) based model is used.

4 - Analytic hiararchy process as a ranking tool for efficient units in DEA models

Josef Jablonsky

Traditional data envelopment analysis (DEA) models assign to efficient decision making units (DMUs) identical maximum efficiency score. That is why they cannot be ranked easily according to this measure. The aim of the paper is to present an original approach for ranking of efficient DMUs based on the analytic hierarchy process (AHP). The approach runs in two basic steps. The first one is traditional DEA analysis and specification of efficient DMUs. In the second step, the AHP model with second hierarchical level containing all ratios of outputs divided by inputs is constructed. Their priorities are derived as average weights given by traditional DEA analysis. Finally, the DMUs are evaluated with respect to all criteria and their global priorities are derived. The derived priorities generate complete ranking of DMUs. The proposed approach is illustrated on a numerical example with real-world background. The results of the DEA/AHP model are compared with other DEA ranking approaches (Andersen and Petersen model, SBM model, cross-efficiency evaluation, etc.).

■ MB-08

Monday, 10:30-12:00 - SOUTH BUILDING UV S108

Complexity Aspects of Linear and Integer Linear Programming

Stream: Combinatorial Optimization I
Chair: *Sergei Chubanov*

1 - Disjunctive conic cuts: the good, the bad, and implementation

Julio Góez

In recent years, the generalization of Balas disjunctive cuts for mixed integer linear optimization problems to mixed integer non-linear optimization problems has received significant attention. Among these studies, mixed integer second order cone optimization (MISOCO) is a special case. For MISOCO one has the disjunctive conic cuts approach. That generalization introduced the concept of disjunctive conic cuts (DCCs) and disjunctive cylindrical cuts (DCyCs). Specifically, it showed that under some mild assumptions the intersection of those DCCs and DCyCs with a closed convex set, given as the intersection of a second order cone and an affine set, is the convex hull of the intersection of the same set with a parallel linear disjunction. The key element in that analysis was the use of pencils of quadrics to find close forms for deriving the DCCs and DCyCs. The first part of this talk will summarize the main results about DCCs and DCyCs including some results about valid conic inequalities for hyperboloids and non-convex quadratic cones when the disjunction is defined by parallel hyperplanes. In the second part, we will discussed some of the limitation of this approach to derive useful valid inequalities in the context of MISOCO. In the last part, we will briefly describe the software libraries that together constitute DisCO, a full-featured solver for MISOCP which we are currently used to explore the potential of DCCs and DCyCs.

2 - Pyramidally solvable cases of the bipartite TSP

Vladimir Deineko

We consider the NP-hard bipartite travelling salesman problem (BTSP). We show how certain techniques developed for the analysis of the classical travelling salesman problem can successfully be used to characterise new tractable cases of the BTSP. We describe two classes of specially structure matrices. In both cases an optimal BTSP tour with an underlying distance matrix from these classes can be found among special tours known as pyramidal tours. Our results generalize some previously published tractable cases of the BTSP. New specially structured matrices can be recognised even after permuting rows and columns with the same permutation.

3 - The load planning and sequencing problem for double-stack intermodal trains

Moritz Ruf, Jean-François Cordeau, Emma Frejinger

Intermodal freight transportation has seen a significant growth in recent decades, such that its share in rail freight nowadays is considerable. By assuring the transfer of containers from one mode of transport to rail, railway terminals play a crucial role in intermodal transport. Two operations in railway terminals mainly contribute to the efficiency of intermodal freight: the load planning and the load sequencing. The former aims at finding a subset of containers and assignments to slots on railcars maximizing the slot utilization, whereas the objective of the latter is to determine the optimal order of loading movements such that the operational costs of the cranes are minimized. As the two described problems are interdependent, tackling them sequentially might lead to disadvantageous loading sequences. Therefore, we propose an integer linear programming formulation that copes both with the load planning and the load sequencing problem for double-stack intermodal trains. First, we define loading restrictions based on diverse technical and physical restrictions. Second, we model gantry crane and reach stacker movements and discuss several ways of formulating the sequencing restrictions. Finally, we present computational results considering realistic instances. We further report the impact of the use of gantry cranes and reach stackers with respect to difficulty of solving and loading effort.

4 - Integer optimization with verification oracles
Sergei Chubanov

One of the fundamental questions when solving an optimization problem is how to verify whether a given solution is optimal. An algorithm proving or disproving optimality of a given solution for a given objective function is called a verification oracle. In this talk we consider linear optimization over finite sets and present an algorithm whose oracle complexity is polynomially bounded in the size of the problem and in the bounds on variables. The algorithm can be viewed as a variant of the simplex method applied to the convex hull of the feasible set.

■ MB-09

Monday, 10:30-12:00 - SOUTH BUILDING UV S109

The Role of Mathematical Optimization in Data Science II

Stream: European Working Group: Data Science Meets Optimization
Chair: *Vanesa Guerrero*

1 - On the construction of optimal randomized classification trees
Cristina Molero-Río, Rafael Blanquero, Emilio Carrizosa, Dolores Romero Morales

Random Forests are a powerful prediction tool obtained by bagging decision trees. Classic decision trees are defined by a set of orthogonal cuts, i.e., the branching rules are of the form variable X not lower than threshold c. The variables and thresholds are obtained by a greedy procedure. The use of a greedy strategy yields low computational cost, but may lead to myopic decisions. Although oblique cuts, with at least two variables, have also been proposed, they involve cumbersome algorithms to identify each cut of the tree. The latest advances in Optimization techniques have motivated further research on procedures to build optimal classification trees, with either orthogonal or oblique cuts. Mixed-Integer Optimization models have been recently proposed to tackle this problem. Although the results of such optimal classification trees are encouraging, the use of integer decision variables leads to hard optimization problems. In this talk, we propose to build optimal classification trees by solving nonlinear continuous optimization problems, thus avoiding the difficulties associated with integer decision variables. This is achieved by including a cumulative density function that will indicate the path to be followed inside the tree. Numerical results show the usefulness of this approach: using one single tree, we obtain better accuracies than classification trees and close to Random Forests, being much more flexible since class performance constraints can be easily included.

2 - Stochastic DCA for group feature selection in multiclass classification
Bach Tran, Hoai An Le Thi, Hoai Minh Le, Duy Nhat Phan

In this work, we consider the problem of minimizing a large sum of DC functions, which is frequently encountered in machine learning. This problem has a double difficulties due to both large-number of component functions and non-convexity of objective function. We propose an efficient Stochastic DCA (DC Algorithm) to solve it. As an application, we consider the feature selection for multiclass logistic regression problem. Numerical experiments on several datasets demonstrate the effectiveness of our method in terms of three criteria: classification accuracy, sparsity of solution and computing time.

3 - Class probability estimation for SVM with asymmetric costs
Sandra Benítez-Peña, Rafael Blanquero, Emilio Carrizosa, Pepa Ramírez-Cobo

Support Vector Machine (SVM) is a powerful tool to solve binary classification problems. However, SVM does not provide probabilities as other classifiers do in a natural way. Many attempts have been carried out in order to obtain those values, as in Sollich P. (2002) and Platt J. et al (1999). Here, a bootstrap-based method yielding class probabilities and confidence intervals is proposed for a novel version of the SVM, namely, the cost-sensitive SVM in which misclassification costs are considered by incorporating performance constraints in the problem formulation. This is important in many contexts as creditscoring and fraud detection where misclassification costs may be different in different classes. In particular, our target is to seek the hyperplane with maximal margin yielding misclassification rates below given threshold values.

4 - Some improvements of SVM and SVR for functional data
M. Asuncion Jimenez-Cordero, Rafael Blanquero, Emilio Carrizosa, Belen Martin-Barragan

Functional Data Analysis (FDA) is devoted to the study of data which are functions and Support Vector Machines (SVM) is a benchmark tool for classification, in particular of functional data. SVM is frequently used with a gaussian kernel, which has a bandwidth, usually considered as a scalar value. With the aim of preserving the advantages of the scalar bandwidth and, at the same time, exploiting the functional nature of the data, in this talk we propose a new functional kernel that is able to weight different ranges of the functional data according to their classification ability. Moreover, the selection of a subset of variables, e.g. time instants, which contain the most relevant information of the data in order to obtain a good classification is also described. The search of the most informative time points can be easily extended to the functional regression field by means of the well-known technique Support Vector Regression (SVR). Tuning the associated functional parameters is a challenging task that we express as a continuous optimization problem, solved by means of a heuristic. Our experiments with synthetic and benchmark real data sets show the advantages of using functional parameters and the effectiveness of our approach.

■ MB-10

Monday, 10:30-12:00 - SOUTH BUILDING UV S110

Decision Aiding Methods II

Stream: Multiple Criteria Decision Aiding
Chair: *Salvatore Corrente*
Chair: *Milosz Kadzinski*

1 - Measuring sustainable development in the education domain using multi-criteria methods: a case study
Marzena Filipowicz-Chomko, Ewa Roszkowska

The 2030 Agenda for Sustainable Development has given a new direction for achieving sustainable development. The agenda contains 17 goals including a global education goal (SDG 4) which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

The main aim of this study is to analyze the level of realizing the goal SDG 4 in 28 UE countries. The assessment of sustainable development in this area could be regarded as a decision-making problem handled by multi-criteria decision aiding methods (MCDA). The modified TOPSIS method including target values and the Hellwig's method to evaluate and compare the sustainable development in education area were proposed. The study used the statistics of the Eurostat's online database.

Acknowledgment: This work is supported by Bialystok University of Technology (Grant No. S/WI/1/2014) and founded by the resources for research by Ministry of Science and Higher Education.

2 - Multi-criteria decision making methods: theoretical aspects & impossibility results

Chergui Zhor, Moncef Abbas

In case of decision rules based on an aggregation function that places us in the Arrow's theorem context, it is not possible to check some mathematical properties simultaneously. Indeed, to construct a method using the same concepts, we cannot abandon the principles of unanimity, universality and non-dictatorship. Thus, the only two principles between which we have to choose are the transitivity and the independence. In other words, it is impossible to build an ordinal method verifying the transitivity and the independence at the same time. In this abstract, we introduce two impossibility results which are based upon some multi-criteria evaluation tests. More precisely, a thorough analysis has shown the impossibility to find andor define MCDM methods satisfying these tests simultaneously.

3 - On importance indices in multicriteria decision making

Mustapha Ridaoui, Michel Grabisch, Christophe Labreuche

We address in this talk the problem of how to define an importance index in multicriteria decision problems, when a numerical representation of preference is given. We make no restrictive assumption on the model, which could have discrete or continuous attributes, and in particular, it is not assumed that the model is monotonically increasing or decreasing w.r.t. the attributes. Our analysis first considers discrete models, which are seen to be equivalent to multichoice games. We propose essentially two importance indices, namely the signed importance index and the absolute importance index, both based on the average variation of the value of the model induced by a given attribute. We provide several axiomatizations for these importance indices, extend them to the continuous case, and finally illustrate them with examples.

4 - Rankings comparisons: the case of resilience assessment of countries' electricity supply

Marco Cinelli, Patrick Gasser, Milosz Kadzinski, Matteo Spada, Peter Burgherr, Stefan Hirschberg

Resilience of electricity supply has received increasing attention over the last decade due to a number of severe disruptions affecting our economies. Within the Future Resilient Systems program at the Singapore-ETH Centre, our team developed indicators representing all dimensions (i.e. resist, restabilize, rebuild, reconfigure) of nation-wide resilience of electricity supply for 41 countries worldwide. In total, 33 combinations of normalization methods and aggregation functions were applied to construct indices to rank the resilience of the countries. This presentation will focus on the (i) comparison of the agreement between these rankings and the (ii) construction of a compromise ranking. The similarity of the rankings was assessed with Kendall's and Rank Difference Measure (RDM) by exploring the pairwise preference relations as well as the actual positions of the countries. Furthermore, Rank Acceptability Index and Pairwise Winning Index were used to verify the robustness of results provided by the indices, which was eventually confirmed. The latter measures were also used to derive a univocal compromise ranking. A key finding is that pair to pair comparisons of additive average with geometric, harmonic and minimum operators (i.e. gradually less compensatory methods) indicate that the change in the ranks equals 9%, 21% and 39%, respectively. This outcome confirms the need to align the selection of the aggregation method with the preferences of the decision-makers.

■ MB-11

Monday, 10:30-12:00 - SOUTH BUILDING UV S111

DEA Theory I

Stream: DEA: Theory
Chair: *Timo Kuosmanen*

1 - BCC- and CCR-efficiencies under monoradial and biradial scaling

Andreas Kleine, Andreas Dellnitz, Wilhelm Rödder

The CCR model by Charnes, Cooper, and Rhodes (1978) together with the BCC model by Banker, Charnes, and Cooper (1984) are the most popular approaches of measuring efficiency among a group of decision making units (DMUs) in data envelopment analysis (DEA). The choice of a DEA model - CCR or BCC - often, if not always, is a difficult decision. To evaluate a DMU's efficiency for both models might be helpful, but it does not always capture the essential issues at stake. In the presentation we propose a comparative analysis of both concepts: How does activity scaling under constant BCC-efficiency influence CCR-efficiency. And inversely, how does BCC-efficiency behave when activity scaling under constant CCR-efficiency is applied. Such findings of mutual effects improve a DMU's ability to reassess upsizing and downsizing of activities. We provide optimization models for calculating these adjustments and respective stability ranges and this for both efficient as well as inefficient activities. Finally, scale efficiency turns out to be the ideal concept to control these activity changes, rather than just CCR- or BCC-efficiency. A numerical example illustrates the concept.

2 - Efficiency measurement with products and partially desirable co-products

Wanghong Li

Many operational processes that set out to create a specific set of products will often involve the creation of a set of associated co-products. A problem of interest is how to evaluate the efficiencies of a set of comparable such processes in the presence of both products and co-products. In particular, there has been an increasing interest in co-products that can be considered as playing a dual role as either outputs from or inputs to the process involved. Efficiency measurement in certain situations where both products and co-products are present, can be addressed using data envelopment analysis (DEA). For example, reclaimed asphalt coming from the resurfacing of highways in various districts, offers an opportunity to perform maintenance at a lower cost, when that reclaimed material serves as an input together with new or virgin materials. At the same time, there is an undesirable environmental impact when reclaimed asphalt (not reused) serves as an output. In the current paper we develop a DEA-based methodology to evaluate the efficiency of maintenance activities in the presence of both products and co-products. The problem concerns how to examine co-products that can have positive value, up to a certain point, but beyond this point there are disposal/environmental costs that must be considered. We use our developed model to examine the efficiency of resurfacing operations in a set of 18 districts in a Canadian province.

3 - Profitability and scale elasticity in data envelopment analysis

Alireza Amirteimoori

Profitability and scale elasticity are two important issues in the context of economics and management. Scale elasticity is a quantitative measure of the response of outputs to the change of the inputs to the boundary points of the production technology set. In this study, we are interested to know how the revenue would change when we scale the inputs up and down. Toward this end, we use profitability that is the ratio of revenue to cost and is absolutely different from profit that is the difference between revenue and cost. At first, a DEA-based model is used to calculate the profitability of the decision making units (DMUs) and then, a procedure is proposed to calculate the scale elasticity of all DMUs in DEA production technology set. To illustrate the real applicability of the proposed approach, a real case on Iranian gas companies is given.

4 - Synergies in joint production of multiple outputs
Timo Kuosmanen

Estimation of joint production technologies involving multiple outputs has proved a vexing challenge. Existing methods are unsatisfactory as they either assume away stochastic noise or restrict to functional forms that have incorrect output curvature, and hence many recent studies simply ignore production synergies. This paper builds upon recent developments in convex regression to revive the axiomatic nonparametric approach to production analysis. The semi-nonparametric approach developed in this paper is readily applicable for both estimating joint production technologies exhibiting positive or negative returns to scope and for statistical hypothesis testing of production synergies. We demonstrate the use of the estimation methods in both cross-sectional and panel data settings.

■ MB-12

Monday, 10:30-12:00 - SOUTH BUILDING UV S112

Fuzzy Optimization I

Stream: Fuzzy Optimization
Chair: *Dobrila Petrovic*

1 - A single variable method for solving min-max programming problem with addition-min fuzzy relational inequalities
Sy-Ming Guu, Yan-Kuen Wu

In this paper, we study the min-max programming problem with n addition-min fuzzy relational inequalities constraints. We prove that when the constraints are feasible, there always exists an optimal solution with identical elements. Based on this result, we propose a single-variable optimization problem whose optimal value is also the optimal one to our original optimization problem. We show that finding this optimal value only requires solving n linear piecewise functions with one variable. Our approach is new and efficient. Numerical examples are given to illustrate our method.

2 - New approach to forecast time series from a fuzzy point of view
Abel Rubio Fornés, José D. Bermúdez, Enriqueta Vercher

Here we introduce a new scheme to work with time series from a fuzzy point of view. Breaking with the classical approach of fuzzy time series, instead of fuzzyfing the time series of observed data, we apply the fuzzy logic to explain the hidden processes behind the data and we represent the uncertainty about the future behavior of the time series through a fuzzy variable.

The performance of our fuzzy methodology is verified with several time series extracted from the database of the M4 competition. We calculate some error measures for the crisp one step ahead forecast, and compare our results with those of other classic fuzzy time series methods. In addition, we obtain fuzzy forecast intervals.

3 - A new fuzzy linear programming model for aggregate production planning for a supplier in the automotive industry
Ivan Djordjevic, Dobrila Petrovic

Supplying real world car manufacturers is a complex task, because suplliers operate in the presence of various sources of uncertanty, such as uncertainty in customer demand and uncertainty in manufactured quantities which depend on work force availability and efficiency, machine breakdowns, quality of manufactured products, ect. A new fuzzy linear programming (FLP) model for solving an aggregate production planning (APP) problem at a first tier supplier in the automotive industry is proposed. We propose to use the time as a measure of performance of the APP and to minimise the total time of manufacturing the required products, storing them in the supplier warehouse and preparing them for delivery to the customer in the planning time horizon. These times are uncertain and modelled using fuzzy numbers. We adapted a method for inferring membership functions based on collected historical data on production times and subjective experience of the production manager. The FLP model includes fuzzy coefficients in both the objective function and linear constraints. It is defuzzyfied into a crisp LP model by adapting an interactive method which makes a trade off between the acceptable value of an objective function and the feasibility degree of constraints. Different experiments are carried out to analyse the performance of the supplier's APP in the presence of uncertainty. The obtained results are compared with the real world supplier's performance recorded in practice.

■ MB-13

Monday, 10:30-12:00 - SOUTH BUILDING UV S201

Supply Chain Management II

Stream: Supply Chain Management II
Chair: *Jonathan Balasingham*

1 - Service offerings via shipment consolidation in supply chain logistics
M. Ali Ülkü

Shipment ConsoLidation (SCL) is a powerful logistics strategy that combines multiple orders or shipments so that a larger quantity can be dispatched on the same vehicle, to the same delivery zone. Proper implementation of SCL not only results in considerable economies by reducing the unit transportation cost, but also helps reduce carbon footprint of the freight by enabling fewer dispatches. From a logistics service perspective, SCL can allow for faster and consistent line-haul or transit times, which in turn would result in reduced inventories without changing customer-service standards. The fundamental decision in developing an SCL policy is when to ship a consolidated load. The extant literature focuses mainly on cost minimization aspects of SCL in dyadic supply chains. With this research, I study the much-needed research related to the impact of SCL exclusively for the service performance of supply chain logistics. I explore the following critical research questions: How can we quantify logistics service performance (e.g. on-time delivery) enhancement or degradation SCL has on supply chains? What are the services offering trade-offs using common versus private carriage? Which SCL policy is more appropriate in terms of providing good levels of customer service in supply chain logistics? I will draw on analytical models, and their related managerial insights.

2 - Operational optimization of a small scale LNG supply chain
Slawomir Pietrasz, Frédéric Legrand, Gabrielle Menard, Ksenia Goloubeva

Any Small Scale Liquid Natural Gas (SSLNG) project faces complex investment decisions due to high asset costs, a multitude of supply options and consumption locations. In some cases, operations also need to take into account hub infrastructures.

ENGIE LNG Lab has developed the Optiretail software to help investment decision-makers answer convoluted questions: *how to make sure the infrastructure can handle the evolution of the delivered LNG quantity in the short, medium and long term? *how to minimize the LNG transport and supply costs? *how to minimize the infrastructure investment while still providing an acceptable level of service?

Encompassing a mathematical model and a state-of-the-art solver, the software designs the optimal LNG supply chain from LNG sourcing to delivery by minimizing the total cost of the project, which is the sum of the total CAPEX (cost of ownership) and OPEX (operational costs). It enables to quickly test new configurations and can be used for project dimensioning and real-time optimization for all SSLNG market opportunities: LNG-to-Power, LNG-as-fuel for road and marine transportation as well as LNG-for-industrials.

The software was tested on several scenarios involving 70 stations in Europe and several scenarios involving scale feeders to supply 19 LNG-to-Power stations in Indonesia. Ongoing developments aim at adapting Optiretail to Liquid Hydrogen (LH2) constraints and in particular to develop LH2 bunkering supply chains.

3 - Order fulfillment policies for ship-from-store operations
Bahriye Cesaret, Armagan Bayram

One of the recent trends in omni-channel retailing is ship-from-store which allows a retailer to fulfill online orders from a brick-and-mortar store. The benefits of this relatively new fulfillment model includes faster delivery, lower transportation costs, higher in-stock probability, increased sales and customer service, etc. Despite the many benefits, the model introduces many new operational challenges to the retailer. Retailer needs to identify which stores should be integrated as active fulfillment centers, and from which location to satisfy an online order when it arrives.

We consider a retailer having both online and store operations and each channel carrying its own inventory. Store orders are fulfilled from store inventories, but for an online order the retailer can ship either from the online distribution center or from any other store location that maximizes the overall profit. Our study investigates dynamic fulfillment decisions: from which location to fulfill an online order when it arrives. We incorporate the uncertainty both in demand and in the cost of shipment to individual customers. We develop a stochastic dynamic framework and present some results on optimal fulfillment strategies.

4 - A model for online subscription based merchandise box operations
Jonathan Balasingham, Ayca Erdogan

This study considers a subscription-based online services company, which provides customized box of merchandise directly to its customers periodically. In this new type of online business systems, the customers do not select the products to purchase, but the company decides the assortment of items to be included in the box of each subscriber at each period based on the characteristics and preferences of the customer. Thus, the demand is for the subscribed box, and not for the individual items. Such companies exist in fashion, beauty, and grocery industries to serve customers who are eager to explore new products. We propose a mixed-integer programming model for the optimal selection of products to subscription boxes while minimizing the total cost of operations while considering the customer satisfaction level above a certain threshold.

■ MB-14

Monday, 10:30-12:00 - SOUTH BUILDING UV S202

Fixed Point Algorithms in Optimisation I

Stream: Nonlinear Programming: Methods
Chair: *Matthew Tam*

1 - The asymptotic behavior of compositions of firmly nonexpansive mappings
Adriana Nicolae

In this talk we are concerned with the asymptotic behavior of compositions of finitely many firmly nonexpansive mappings defined in the setting of geodesic spaces. We focus on quantitative asymptotic regularity and convergence results which we then apply to the study of the convex feasibility problem.

2 - Optimal rates of linear convergence of the averaged alternating modified reflections method for two subspaces
Rubén Campoy García, Francisco Javier Aragón Artacho

The averaged alternating modified reflections (AAMR) method is a projection algorithm for finding the closest point in the intersection of convex sets to any arbitrary point in a Hilbert space. This method can be seen as an adequate modification of the Douglas–Rachford method that yields a solution to the best approximation problem. In this talk we consider the particular case of two subspaces in a Euclidean space. We obtain the rate of linear convergence of the AAMR method in terms of the Friedrichs angle between the subspaces and the parameters defining the scheme. We further optimize the value of these parameters in order to get the minimal convergence rate, which turns out to be better than the one of other projection methods. Finally, we provide some numerical experiments that demonstrate the theoretical results.

3 - Convergence properties of fixed point algorithms in the presence of perturbations
Rafal Zalas

Assuming that the absence of perturbations guarantees weak or strong convergence to a common fixed point, we study the behavior of perturbed products of an infinite family of nonexpansive operators. Our main result indicates that the convergence rate of unperturbed products is essentially preserved in the presence of perturbations. This, in particular, applies to the linear convergence rate of many projection methods. This is joint work with Christian Bargetz and Simeon Reich.

4 - On projection methods for phase retrieval
Hieu Thao Nguyen

We report on an ongoing project about efficient algorithms for phase retrieval problems in practice. Convergence analysis of several fundamental projection methods in the context of phase retrieval problems is investigated based on the recent analysis theory for Picard iterations of almost averaging operators. Along with convergence criteria, numerical results for phase retrieval are also presented.

Based on joint work with Michel Verhaegen (Delft Center for Systems and Control, Delft University of Technology, The Netherlands).

■ MB-15

Monday, 10:30-12:00 - SOUTH BUILDING UV S203

New Trends in Shared-connected and Low-emission Human and Freight Transportation Systems I

Stream: Vehicle Routing and Logistics Optimization II
Chair: *Francesca Guerriero*
Chair: *Luigi Di Puglia Pugliese*
Chair: *Giusy Macrina*

1 - Efficient solutions for the vehicle routing problem with occasional drivers and time windows
Paola Festa, Daniele Ferone, Francesca Guerriero

In this talk, we discuss a variant of the Vehicle Routing Problem with Time Windows in which the crowd-shipping is considered. The transportation company can make the deliveries by using its own fleet composed of capacitated vehicles and also some occasional drivers. The latter can use their own vehicle to make either a single delivery or multiple deliveries, for a small compensation. Two innovative aspects are here considered: 1) time windows for both the customers and the occasional drivers are defined; 2) occasional drivers can make multiple deliveries. To efficiently solve the problem, we propose and test several different metaheuristics.

2 - The online vehicle routing problem with occasional drivers

Giusy Macrina, Claudia Archetti, Francesca Guerriero

We investigate a new variant of the vehicle routing problem with time windows, in which customers requests can be either known in advance with respect to the planning of the distribution, or they arrive online during the distribution process. The company has a given fleet of vehicles to serve the customers, and, in addition, occasional drivers are available to perform the service. Each occasional driver specifies the time window in which he/she is available to distribute the goods to customers. The objective of the company is to determinate the distribution plan that serves all requests (static and online) and minimizes the distribution cost which is given by the sum of the cost of regular vehicles and the salary paid to the occasional drivers. We design and implement a heuristic method for our problem. In a detailed computational study we evaluate the behaviour of the proposed procedure.

3 - A savings-based model for two-shipper cooperative routing

Giovanna Miglionico, Manlio Gaudioso, Giovanni Giallombardo

We consider the classical Capacitated Vehicle Routing Problem (CVRP) that consists in finding the routes of minimum cost under the following constraints: each route must touch the depot, each customer must be visited exactly once, and the sum of the demands at nodes associated to each route must not be greater than the capacity of each vehicle. We still assume that there is a unique depot, but the N customers are partitioned into two subsets served by two different shippers. While in absence of any form of cooperation, each shipper would solve its own CVRP defined on an appropriate subgraph, here we explore the possibility of having some mutually advantageous cooperation between the shippers. Indeed, the approach we discuss is based on the iterative attempt of identifying subsets of shareable customers which can be fruitfully exchanged between shippers. We present both a heuristic and an exact approach to identify the subsets of customers to be moved in order to achieve mutual cost advantage.

4 - Cooperation among classical vehicles and drones: new opportunities for last-mile delivery process

Luigi Di Puglia Pugliese, Francesca Guerriero

The last-mile delivery process is one of the most expensive in the logistic chain. In the last two decades we have seen a continued growth of e-commerce, a rapid urbanization and a heightened customer expectations. Customers require more efficient and effective service with a lower lead-time. The drones have the potential to ask to those requests. Indeed, they are not directly affected by the urban infrastructure and the congestion, have the potential to limit the negative externality and could reduce the presence of classical vehicle leading to a reduction of the traffic. However, some drawbacks have to take into account. Drones currently offer a limited shipping capacity, the GPS is still inaccurate, regulations forbid the commercial use of unmanned aircrafts and their daily flights are still far away from public acceptance. To get advantages form the drone and overcome their limitations, the combination of truck-drone seems to be a viable alternative for delivery process. We introduce the problem, proposing new mathematical formulations with the focus of analysing the potential of implementing a new transportation model based on cooperation between classical vehicles and drones. The aim is to provide quantitative evidence on the advantages of using drones in the delivery process paying particular attention to the cost minimization, the gain in terms of duration of the routes and the quality of service in the delivery process.

■ MB-16

Monday, 10:30-12:00 - SOUTH BUILDING UV S115

Social Networks: Community Detection and Information Propagation II

Stream: Network Optimization and Social Networks
Chair: *Mario Ruthmair*

1 - A parallel algorithm using VNS with shared memory and message passing interface for community detection in complex networks

Gilles Caporossi, Eglantine Camby, Sylvain Perron

For the last decades, community detection is a well-studied problem because it has applications in various fields. Variable Neighborhood Search (VNS) is an efficient metaheuristic for solving combinatorial optimization problems. Naturally, it has been applied to community detection in networks. Even if parallel algorithms exist for finding communities in networks and parallel implementations of VNS are designed for a variety of problems, parallel VNS was not yet used for community detection. For this problem, we present a parallel algorithm using VNS with shared memory and message passing interface. Numerical results are encouraging.

2 - The expected distance based on random walks in graphs

Eglantine Camby, Gilles Caporossi, Marcia Paiva, Segatto Marcelo

Considering a graph as a network of resistances, Klein and Randic (1993) proposed the definition of a distance measure, called the resistance distance. Indeed, if each edge of the graph represents a resistance of 1 Ohm, the equivalent resistance of the graph between each pair of vertices may be used as a distance. Based upon random walks in graphs, Stephenson and Zelen (1989) built a computational model to find the probability that each edge is used. From a mathematical point of view, both articles are based upon exactly the same model and the link between random walks and the electrical representation was established by Newman (2005). In this talk, the similitude between these two processes is exploited to propose a new random walk-based distance measure that may be defined as the expected length of a walk between any pair of vertices. We call it the expected distance. From this new definition, the RW Index is proposed that sums the expected walks lengths between pairs of vertices. According to the computer aided graph theory system AutoGraphiX III developed by Caporossi (2017), we propose a conjecture on graphs minimizing/maximizing the RW Index. Even if the expected and the resistance distances are based upon a similar mathematical model, these conjectures attempts to prove that they are not equivalent.

3 - Exact IP-based approaches for the longest induced path problem

Dmytro Matsypura, Alexander Veremyev, Oleg Prokopyev, Eduardo Pasiliao

Graph diameter, which is defined as the longest shortest path in the graph, is often used to quantify graph communication properties. In particular, it provides a very intuitive measure of the worst-case pairwise distance. However, in many practical settings where vertices can either fail or be overloaded, or destroyed by an adversary and thus, cannot be used in any communication or transportation path, it is natural to consider a more general measure of worst-case distance. One such measure is the longest induced path. The longest induced path problem is defined as the problem of finding a subgraph of largest cardinality such that this subgraph is a simple path. In contrast to the polynomially computable graph diameter, this problem is NP-hard. In this paper, we focus on exact solution approaches for the problem based on integer programming (IP) techniques. We first propose three conceptually different IP models and study their basic properties. To improve the performance of standard IP solvers, we propose an exact iterative algorithm, which solves a sequence of smaller IPs in order to obtain an optimal solution for the original problem. In addition, we develop a heuristic capable of finding induced paths in larger networks. Finally, we conduct an extensive computational study to evaluate the performance of the proposed solution methods.

■ MB-17

Monday, 10:30-12:00 - SOUTH BUILDING UV S205

Accounting, Insolvency and Rating

Stream: Operational Research in Financial and Management Accounting
Chair: *Sascha H. Moells*

1 - Determinants of issuer credit ratings and the firm's decision to be rated: an international empirical study
Vladlena Prysyazhna, Sascha H. Moells

Issuer credit ratings serve as a device to inform actors on capital markets about the company's overall creditworthiness. Although a general description of the methodology applied by rating agencies is publicly available, the procedure remains intransparent due to its subjectivity and the qualitative nature of some criteria. From the perspective of a firm, the decision to be rated reflects the willingness to signal the own creditworthiness to other capital market participants. This paper aims to investigate how firm-specific characteristics affect the likelihood of receiving a (higher) rating incorporating financial, ownership, governance-related and strategic attributes. Our study is based on a panel referring to each of the biggest 100 publicly traded corporations of 15 industrialized countries covering the years 2002-2017. In contrast to much of the prior research, we apply a methodology that allows for varying effects at different rating levels. Furthermore, we take into account the non-random nature of the considered sample of rated companies. To capture the behavior on firm-level we develop a model that describes both the probability of being rated and the probability to be assigned to a certain rating category resulting. By applying such a procedure the results are corrected for a possible sample selection bias. In addition, the sensitivity of the results concerning a potential endogeneity problem is intensively analyzed by simulations.

2 - Investment and financing decisions in the presence of time-to-build
Haejun Jeon

We investigate a firm's optimal decisions on investment, financing, and default when it takes uncertain amount of time to complete a project. Due to the time-to-build, the firm can choose to default even prior to the completion of the project. Nonetheless, we show that the probability of default is lower than that in the absence of time-to-build and decreases with the expected time-to-build in most cases. Furthermore, the firm's probability of default prior to the project's completion increases as the project becomes more profitable. When the firm can choose the expected time-to-build by adjusting running costs that incur during the project is under progress, an all-equity firm puts more resources to shorten the expected time-to-build than a levered firm does.

3 - Performance evaluation of two-stage distress models
Mohammd Mahdi Mousavi

On feature selection, in addition to different types of information, i.e., accounting, market and macroeconomic variables, two-stage distress prediction studies used management performance to distinguish distress companies from those healthy ones. DEA is the programming algorithm that is used to estimate the cross-sectional and dynamic efficiency of companies. In addition to the conventional approach of considering management efficiency, this study uses the market efficiency as a measure of company efficiency. Also, it proposes the decomposition of Slack-Based Measure (SBM) into Pure Technical Efficiency (PTE), Scale Efficiency (SE) and Mix Efficiency (ME), and analyses how each of these measures contributes individually in developing distress prediction models. Further, this study provides a comprehensive comparison between static and dynamic two-stage distress prediction models that apply different types of DEA models to compute alternative DEA scores and two different efficiency measures. The results indicate that the measure of market efficiency is not superior to the managerial efficiency of a company, yet, it improves the performance of distress prediction models on some criteria. Moreover, feeding prediction models by decomposed efficiency measures enhances the performance of prediction models.

4 - Corporate insolvency prediction model in short-term perpective: the case of Lithuania
Kristina Sutiene, Kestutis Luksys, Kristina Kundeliene

In the field of risk management, the prediction of corporate insolvency that often leads to a bankruptcy is an important area of research having a crucial practical application. Being able to predict corporate failure is relevant for creditors, investors, owners, tax authorities and other stakeholders. To date, most studies have tended to focus on providing predictions for one year or more. Nowadays, it becomes vital to identify a potential risk of corporate failure for the next few months in order to diminish destructive social and economic impact caused by bankruptcy in advance. Alongside with the requirement to provide precise and expeditious predictions, it is equally important to determine what features have a discriminatory power to predict a likelihood that a corporate may go bankrupt in the short-term period. Since many models published in the literature were mainly built on yearly observations, the principal question dealt with in this research regards the handling of financial ratios and non-financial indicators that are observed monthly, as well as the reshaping various corporate governance features or any other external information diagnosing specific trends and patterns in the sector. By adopting machine learning technique, the experimental study is carried out on a real-world dataset of profit-making corporates operating in Lithuania and having minimum 3 years monthly historical observations.

■ MB-18

Monday, 10:30-12:00 - SOUTH BUILDING UV S206

Linear Programming

Stream: Convex Optimization
Chair: *Pál Burai*

1 - Locating binding constraints in LP-problems
Eirini Nikolopoulou, George Manoussakis, George S. Androulakis

A new method is presented for determining the binding constraints of a general LP maximization problem. When the number of constraints is much bigger than the number of decision variables, as in real-life problems, only a relatively small percentage of constraints are binding. The existence of redundant constraints increases significantly the computational cost. Approaches like LP methods, deterministic methods and heuristic methods identify redundant constraints but need significant computational work and time.The proposed method uses simple vector operations so the computational cost is inferior to the corresponding cost of matrix manipulation or inversion. The necessary conditions are that all constraints contribute on the definition of the convex feasible region. It is based on a recently proposed notion: the "mean" of each constraint, a kind of weighted mean of the decision variables associated with each constraint boundary. The algorithm checks for binding constraints at a single direction each time. It moves from a constraint to an adjacent one until it locates a binding constraint. In some cases, it locates also variables with zero optimal value.The method has been implemented and tested with impressive results. The number of operations required in the proposed method is small compared to other known algorithms. It produces useful results even in the presence of overlapping constraints and can be modified for other type of LP-problems and also for NLP problems.

2 - Lipschitz modulus of the optimal value function in linear programming: the relationship with calmness modulus
Maria Jesús Gisbert Francés, Maria Josefa Cánovas, Juan Parra, F. Javier Toledo-Melero

The objective of this talk consists in studying the stability of the optimal value function, associated to a general solvable linear problem, through Lipschitz' type properties. Specifically, we present some formulas, given exclusively in terms of the nominal data, for the Lipschitz and calmness moduli under different contexts of perturbations. Going further, we show the existing relationships between both moduli.

3 - Interior point methods for power flow optimization problem including wind power generation
Luciana Casacio, Aurelio Oliveira, João Batista Lopes

This work deals with power flow optimization, focusing on the short-term hydroelectric scheduling problem, called predispatch. Since the energy demand varies throughout the day, the hydro generation must satisfy daily targets, established by long-term planing models. Previous studies model the optimal predispatch problem considering that the hydroelectric plants and transmission systems must provide an optimal flow of active power, including additional constraints such as security constraints or pre-programmed network manipulations. The objective of this work is to incorporate wind-powered generators into the classical predispatch optimization problem and to investigate the resulting problem. Algebraic techniques are used to exploit the sparse structure of the problem, aiming the design of an interior point algorithm, efficient in terms of robustness and computational time. Case studies discuss the numerical results of this model for different wind scenarios.

4 - Matrix reordering and iterative methods for linear systems solving in interior point methods
Aurelio Oliveira, Wellington Rodrigues, Marta Velazco

In this work, the linear systems arising from interior point methods for linear programming are solved using the preconditioned gradient method. Two preconditioners are adopted. The controlled Cholesky factorization of the normal equations system is used in the first iterations and de splitting preconditioner is used in the final ones. The controlled Cholesky factorization performance depends upon the previous ordering of the linear programming constraint matrix rows. A comparison among different reordering methods is performed in order to verify the one more suitable for this approach. Variants of the nested dissection and minimum degree are among the considered heuristics. Computational experiments with large-scale linear programming problems from several collection sets are performed in order to determine the heuristic of choice for such particular approach.

■ MB-19

Monday, 10:30-12:00 - SOUTH BUILDING UV S207

Vector and Set-Valued Optimization II

Stream: Vector- and Set-Valued Optimization
Chair: *César Gutiérrez*

1 - On solving convex vector optimization problems
Andrea Wagner

Benson's Algorithm is an approximation method for solving multi-objective optimization problems. It was further and further developed during the last years in order to make it applicable to a greater variety of programs. Amongst others, a variant for bounded convex vector optimization problems was introduced. A problem is called bounded if there is a point y in the image space such that the image set is contained in y+C, where C is the considered ordering cone. If the problem is unbounded, to find an initial outer approximation is not always straight forward. While in case of vector linear programs this problem was solved by a two-phase method, the unbounded convex case was not treated yet. This study proposes a method that allows to find an initial outer approximation also for unbounded convex problems, provided that the image set is self-bounded. This is a necessary step for solving convex vector optimization problems.

2 - Time consistency of the mean-risk problem
Gabriela Kovacova, Birgit Rudloff

The mean-risk problem is a well known and extensively studied problem in Mathematical Finance. Its aim is to identify portfolios that maximize the expected terminal value and at the same time minimize the risk. The usual approach in the literature is to combine the two to obtain a problem with a single objective. This scalarization, however, comes at the cost of time inconsistency.

In this work we show that these difficulties disappear by considering the problem in its natural form, that is, as a vector optimization problem. As such the mean-risk problem can be shown to satisfy under mild assumptions an appropriate notion of time consistency. Additionally, the upper images, whose boundaries are the efficient frontiers, recurse backwards in time. We argue that this represents a Bellman's principle appropriate for a vector optimization problem: a set-valued Bellman's principle. Furthermore, we provide conditions under which this recursion can be directly used to compute the efficient frontiers backwards in time.

3 - Existence of approximate strict solutions of optimization problems
Juan Luis Ródenas, César Gutiérrez, Vicente Novo

In this talk, a strict fixed point theorem for a set-valued mapping on a metric space is stated, from which existence theorems for approximate strict solutions of vector optimization problems in linear spaces may be deduced. This property is illustrated in the setting of vector equilibrium problems via Ekeland variational principles for bifunctions.

4 - A Weierstrass theorem for weakly efficient solutions of vector equilibrium problems
César Gutiérrez, Vicente Novo, Juan Luis Ródenas

This talk concerns with the existence of weakly efficient solutions of vector equilibrium problems. To be precise, a Weierstrass theorem is stated in problems whose bifunction satisfies the so-called triangle inequality property. The result is obtained by scalarization via a new concept of upper semicontinuity for vector valued mappings

■ MB-20

Monday, 10:30-12:00 - SOUTH BUILDING UV S301

Group Decision Processes

Stream: Decision Analysis and Decision Support Systems
Chair: *Ricardo Ribeiro*

1 - A GDSS for evaluating the criteria weights in multi-criteria decision analysis with PROMETHEE
Pierre Kunsch

An essential but difficult issue in group multi-criteria decision making with the PROMETHEE methodology is the weight elicitation process by multiple stakeholder groups (SH). In general groups have different decisional powers, own sets of criteria and different priorities evaluated on various importance scales regarding the criteria. In this presentation, a flexible GDSS procedure not requiring excessive cognitive effort from the SH is presented. It consists in a two-step approach defining firstly importance classes on ordinal Likert scales, and secondly profiles on those scales for the criteria. It appears to be simple though rigorous; it easily allows fast sensitivity analyses when confronting different opinions. An example illustrates these properties.

2 - A novel recommendation approach for group items
Li-Ching Ma

Most recommendation systems suggest a single next-item that a customer is most likely to buy. However, a company might get a customer to spend more money to increase sales revenue if a recommendation system can suggest group items that customers are likely to buy together. This study aims to propose a novel next-group recommendation approach according to items bought in customers' baskets. Soft clustering and bit-string operations are employed to improve computational efficiency in analyzing large amount of sequential market basket data. The concept of the Borda majority count and PrefixSpan algorithm are adopted to discover priorities of items for recommendation.

3 - Participative design methodology for spatial data warehouse: application to farmland biodiversity data
Amir Sakka, Guy Camilleri, Lucile Sautot, Pascale Zaraté, Sandro Bimonte

For an accurate assessment of biodiversity trends, the only actual financially reasonable possibility to collect the necessary huge amount of standardized as well as opportunistic biodiversity observations data is by the involvement of large number of volunteer observers. The use of Spatial On-Line Analytical Processing (SOLAP) platforms allows non-experienced IT users to make easily geo-decision analysis and data exploration, which is not the case with the Volunteered Geographic Information (VGI) systems. Various overlapping VGI user categories are involved in this data collection process, each with its interests in biodiversity data, which makes problematic the design of a spatial data warehouse(SDW) model. Although various systems allow collaborative conceptual design for generic applications or for collaborative Geographical information systems(GIS), none of them supports existing DWs design methodologies; they do not consider together all decision-makers preferences. We define a new generic and participative SOLAP design methodology, which relies on a Group Decision Support System (GDSS) to support the collaboration of users engaged in the design of the SOLAP model. Intended to provide computational support to participative decision-making processes. The proposed methodology is participative since it allows groups of users to design their SOLAP models together and it is a generic methodology which is applicable in other contexts, such as environmental or health issues.

4 - Enhancing efficiency on productive processes using process and social collaborations mining
Ricardo Ribeiro, Cesar Analide, Orlando Belo

This work presents a process mining study based on real data from a company in the energy industry, proposing a methodology based on an adaptation of the "L * life-cycle model", tackling the particular characteristics of low frequency and high variance processes. We used some traditional process management techniques to understand process models and also to map them on process support systems. This mapping on an operational system allows for extracting, transforming and loading data into a data warehouse, and then exploring it for processes and social collaboration using specific process mining techniques. The data warehouse was designed for offering essential decision support data for online process mining optimization. Process mining results will be presented and discussed with a real application case, as well as the discovered process, comparing it to the initial process we have modeled. We will also discuss some performance metrics of the process model, showing process bottlenecks based on the activities' waiting and execution times, and finally we will show the social component revealing the collaboration of process resources concerning the handover of work in multiple perspectives. This provided us a more critical observation of process mining results. In short, we will show that low frequency and high variance processes can be converted to seize process mining techniques that can contribute to its enhancement by answering multiple questions and produce suggestions.

■ MB-21

Monday, 10:30-12:00 - SOUTH BUILDING UV S303

Workforce Scheduling and Line Balancing I

Stream: Project Management and Scheduling
Chair: *Sergey Kovalev*

1 - Human resources scheduling problem in a port container terminal: workload balancing and movement minimization
Kaoutar Chargui, Abdelghani Bekrar, Abdellah El Fallahi, Mohamed Reghioui

This research addresses a real problem of human resources allocation to quay cranes faced by a company managing a port container terminal. It's considered as a job shop scheduling problem, where resources are quay cranes operators and jobs are the activities of moving containers using quay cranes. In this case, operators are not always available due to the working constraints and the need for quay cranes during the planning horizon is variable. In this work, a mathematical model is proposed for the problem under original constraints. The objective is to allocate resources to quay cranes so that the workload of all operators is balanced and the distance covered by them to move between quay cranes is minimized; taking into consideration the accumulation of working hours from historical schedules and the variation of distance separating quay cranes. To find approximate solutions in reasonable time, a constructive heuristic and an Iterated Local Search algorithm are proposed. The algorithms are tested on real datasets and the computational results show that they can provide very good solutions. To measure the quality of the iterated local search, we have adapted it to solve a similar problem from the literature. The obtained results are of good quality and very competitive with the published ones. Finally, the methods presented in this work are integrated in a decision aid tool dedicated to a real port container terminal.

2 - Assembly line worker assignment and balancing problem: review, benchmark and pending issues
Cristobal Miralles, Marcus Ritt, Alysson Costa, Mayron César Oliveira Moreira

Assembly line balancing has interested researchers since the early days of Operations Research. The basic problem consists in assigning tasks to stations while respecting task-ordering constraints and optimizing some metric as the cycle time or the number of stations. These efforts gave origin to a rich literature on different variants of the problem including the Assembly line Worker Assignment and Balancing Problem (ALWABP), which in 2007 opened a wide research avenue by considering the diversity of the workforce. This problem, inspired by Spanish sheltered work centres for people with disabilities, considers a set of heterogeneous workers available and worker-dependent task execution times, aiming to find the best double assignment of tasks and workers to each station.

In this review we aim to critically review the literature on ALWABP categorizing: Mathematical formulations; Branch-and-bound methods and lower bounding procedures; Heuristic and metaheuristic methodologies; Problem variants, also with stochastic or robustness considerations; other inspired manufacturing problems. We also propose a new structured set of instances for experiments in order to make comparable past and future proposals on ALWABP. Finally, we intend to lower the entry barrier into this research area by releasing easy-to-understand codes and pointing out the main pending issues regarding the heterogeneity of workforce in the diverse assembly line scenarios.

3 - Decomposition methods for cost and tardiness reduction in aircraft manufacturing flow lines
Alexander Biele, Lars Moench

A manufacturing system consisting of at least two subsystems is considered in aircraft manufacturing. Parallel mixed-model assembly lines form the first subsystem while the remaining subsystems consist of parallel stations. The subsystems are decoupled by finite buffers. A combined objective function is used that accounts for total labor and inventory costs at the first subsystem and for makespan and total weighted tardiness (TWT) at the entire manufacturing system. The jobs have to be assigned to one of the parallel assembly lines. They then have to be sequenced at each single assembly line. Workers have to be assigned to each job and station. Assignment and sequencing decisions have to be made for the jobs at the remaining subsystems to compute the makespan and the TWT value. A random-key genetic algorithm is used to assign jobs to the assembly lines and to sequence them. It is hybridized with heuristics to determine start and completion times of the jobs at the stations. List scheduling is used for the remaining subsystem. Outsourcing is required to take into account the finite buffers between the subsystems. Results of computational experiments based on randomly generated problem instances demonstrate that the proposed decomposition scheme performs well.

4 - An optimal workforce assignment problem for a paced assembly line at the line design stage
Sergey Kovalev, Xavier Delorme, Alexandre Dolgui, Mikhail Y. Kovalyov

An assembly line from automotive industry is considered. It is composed of m stations, and n parts of k types are processed. The problem consists in minimizing the maximum required number of identical workers over all production cycles for this paced assembly line. Lower and upper bounds on the workforce requirements (number of workers) and the cycle time constraints are known. It is proved that this problem is equivalent to the same problem without the cycle time constraints and with fixed workforce requirements. It is proved that the problem is NP-hard in the strong sense if $m = 3$ and if $m = 4$ and the workforce requirements are station independent. An Integer Linear Programming model is proposed, an enumeration algorithm and a dynamic programming algorithm are developed. Polynomial in k and polynomial in n algorithms for special cases with two part types or two stations are also suggested. The relations to the Bottleneck Traveling Salesman Problem and its generalizations are discussed. It is concluded that the development of exact and approximate solution methods for the general problem and computer experiments with them are both interesting and practically relevant topics for future research.

■ MB-22

Monday, 10:30-12:00 - SOUTH BUILDING UV S304

Big Data Analytics and Smart Systems

Stream: Analytics, Data Science and Data Mining
Chair: *John Wilson*

1 - Implementation of exponential smoothing forecasting method in a GPU for big data problems
Juan Ramon Trapero Arenas, Marco Antonio Villegas García, Diego José Pedregal Tercero

Recently, GPU High Performance Computing is a potential instrument to speed up computational times. In a world where big data is becoming a revolution, such a GPU could play an important role. This work intends to analyze the performance of GPU computing by implementing an exponential smoothing forecasting method within a supply chain context. Essentially, many supply chain companies must deal with millions of forecasts of SKUs with different forecasting horizons and product aggregations. Exponential smoothing is one of the most common forecasting methods employed to cope with those forecast requirements. In this context, reducing the computational times can be a source of a competitive advantage. In the first place, this work provides an implementation of exponential smoothing in a GPU card within MATLAB. In the second place, an exhaustive experiment will be carried out to compare the GPU and the traditional CPU results in serial and parallel computing. Finally, the main results will be discussed.

2 - Prediction of frail state of elderlies in smart homes with simulation and sensor systems
Cyriac Azefack, Vincent Augusto, Raksmey Phan

The global population of elderly people aged 60 years or more was 600 million in 2000; it is expected to rise to around 2 billion by 2050. These demographic changes are increasing health care cost. Frailty affects many elderly people and requires a unique care approach. The concept of 'frailty' is used to identify elder adults at risk of death, disability, and institutionalization so that they can receive proper cares to recover their general health state and well being. Frailty is a multidimensional concept which includes physic, social, cognitive, sensory, nutritional and functional health of elderly people. Significant progress has been made in recent years on smart technologies for home care. Smart systems can help health professionals screening and monitoring the frail state of patients at home. We present a simulation-based prediction model built around the resident habits which predict his general health decline. We build the simulation model by learning the living habits of the resident and how they evolve through time. The simulation of the resident habits in a distant future allow us to screen his frail state at that point. This can be used to prevent degrading cases of cognitive impairment or physical health in elderlies living at home before it is irreversible.

3 - Development of anomaly detection and cause analysis of unmanned robot line
JaeYeol Hong, Jun-Geol Baek

The manufacturing process of modern is sensitive to the manufacturing process and the size of the data collected from the equipment is also enormous. Therefore, in order to improve the process efficiency and product yield in such a manufacturing environment, it is necessary to analyze large-volume data and to develop not only product quality and yield analysis but also process abnormality detection technology and cause analysis need. This study is aimed at the injection and discharge unmanned robot lines. There are too many CNCs to manage, and it is difficult for a person to manage them individually. In a specific situation, it is necessary to define a process status and a system that alarms the administrator before an abnormal situation occurs. Therefore, based on the data showing the state between the robots and the equipment, we performed real time operation anomaly detection and cause analysis of the operation degradation of the robot line composed of robot, equipment and materials. In order to present a logical standard for the current process state, we propose a monitoring statistic for determining the state of the process and we have judged the process abnormality based on the proposed monitoring statistic. In addition, it shows that it is possible to trace and analyze the cause of the process abnormality through the proposed method when an abnormal situation occurs.

4 - Dynamic modelling of software errors
John Wilson, Dov Teeni

Traditional models for software errors have generally assumed a finite number of errors. In a modern software setting, however, new errors can be dynamically introduced as new devices are produced and are found to be incompatible with software that is perfectly good for other devices. In addition, the number of users who can detect various errors changes dynamically. For instance, there may be new adopters of the software over time. It may also happen that an old user might upgrade and thus run into new incompatibility errors. Allowing new users and errors to enter dynamically poses considerable modeling and estimation difficulties. In a big data context it is important to have algorithms that scale up and take into account the arrival of new data. We provide a procedure for finding maximum likelihood estimators of key parameters where the number of errors and the number of users can change. The procedure, while iterative, is easy to implement for a given data set even in a big data context and provides the exact maximum likelihood estimators needed to evaluate the probability of errors in software.

■ MB-23

Monday, 10:30-12:00 - SOUTH BUILDING UV S305

Employee Timetabling

Stream: Timetabling
Chair: *Troels Martin Range*

1 - A behavioural operational research approach to workforce scheduling problem for integrated healthcare in UK: a case study on chronic kidney disease
Fang He

In this work, we apply Behavioural Operational Research (BOR) approach to the workforce scheduling problem in the integrated healthcare for patients with Chronic Kidney Disease (CKD), in conjunction with patients' perspective. We anticipate developing a better understanding of how patient perspective and behaviour influences workforce management, and then design and deliver optimised workforce scheduling and management in integrated healthcare for CKD patients. The results will generate solutions to multi-disciplinary workforce scheduling and coordination to minimise workforce management costs while delivery a satisfactory care to CKD patients as much as possible.

2 - Shift work scheduling of a 24/7 service operation considering staff well-being
Sanja Petrovic, Jane Parkin, David Wrigley

There is a large volume of literature on the staff rostering problem and many software packages have been developed for producing rosters which are based on minimising cost or maximising customer service. However, to the best of our knowledge, none of these consider the aspect of staff well-being apart from the inclusion of working hours legislation and, possibly, staff preferences. On the other hand, there are also many studies especially in the field of occupational medicine, which examine the effect of shift-working on health and well-being of staff. This study considers the inclusion of staff well-being in shift work scheduling in organisations which have to provide 24/7 service. A typical example, used here, is a call centre with the challenging target of answering 90% of calls within 20 seconds.

In this study, we define objectives based on efficiency, effectiveness and well-being to measure the merit of a roster. A number of rotating shifts with a possible range of predetermined durations are defined. The objectives are combined in a single objective function and an evolutionary algorithm is used to search for optimum solutions, i.e. optimal start and durations of shifts. Using a real-world problem instance, we investigate whether it is possible to consider and improve staff well-being without compromising the efficiency and/or effectiveness of rosters.

3 - A framework for the general employee scheduling problem
Lucas Kletzander, Nysret Musliu

In many professions, the demand for work requires employees to work in different shifts to cover varying requirements. However, many constraints like demands specified in various ways and different legal requirements as well as employee satisfaction have to be taken into account. While not each problem will require the whole set of available restrictions, it is cumbersome to develop a new specification format and corresponding solver for each problem. On the other hand, it is a challenging task to provide a general formulation and solution methods that can solve large integrated problems, as even several sub-problems on their own are known to be NP-hard. This work presents the development of a new framework for the general employee scheduling problem that allows the implementation of various heuristic algorithms and their application to a wide range of problems specified by a general format. This is realized by proposing a unified handling of constraints and the possibility to implement various moves that can be reused across different algorithms. The evaluation shows that several problems from literature in different areas of employee scheduling can be modelled in our formulation and the framework can successfully be applied to all of them. The comparison shows that the implemented general purpose algorithm provides good results building a solid foundation for the development of more specialized algorithms in the framework.

4 - Hospital-wide staff rostering: from academia to implementation
Troels Martin Range

Staff scheduling or staff rostering is the task of assigning individual employees to shifts throughout a planning horizon. It is a well-known combinatorial optimization problem and many solution approaches for the problem have been proposed. In this presentation, we describe and discuss a real-world implementation of staff rostering at the Hospital of South West Jutland in Denmark. The underlying model is a mixed integer linear program implemented in GAMS and solved by CPLEX. It encompasses constraints such as continual workload balancing, soft and hard cover constraints, and constraints satisfying collective agreements. The model is used to solve the staff rostering problem on a continual basis for a diverse set of hospital wards, each with a different number as well as types of employees. While we discuss the underlying model, the focus in this presentation is on aspects of transferring the academic rostering problem to the real-life situation. Especially we focus on which parts of the model can be reused among functions, wards, and planning periods, as well as which parts of the model that cannot. Furthermore, we discuss the temporal aspect when having to solve the rostering problem for sequential planning periods.

■ MB-24

Monday, 10:30-12:00 - SOUTH BUILDING UV S306

Financial Mathematics and OR II

Stream: Financial Mathematics and OR
Chair: *Michi Nishihara*

1 - A premium-decomposition refinement of valuing convertible bonds with continuous coupons
Toshikazu Kimura

This paper deals with valuing defaultable and non-callable convertible bonds (CBs) with continuous coupon payments. The setup is the Black-Scholes-Merton framework where the underlying firm value evolves according to a geometric Brownian motion. The valuation of CBs can be formulated as an optimal stopping problem, due to the possibility of voluntary conversion prior to maturity. We begin with the plain Laplace-Carson transform (LCT) approach that generates a complex solution with little prospect of further analysis. To improve this solution, we introduce the notion of premium decomposition, which separates the target CB value into the associated European zero-coupon CB value, the NPV of the future coupon payment stream prior to maturity, and an early conversion premium. By the LCT approach combined with this premium decomposition, we obtain a closed-form LCT solution for the CB value and a nonlinear functional equation for the LCT of an early conversion boundary. They have much simpler expressions than the plain LCT solutions without using the premium decomposition. By virtue of the simplicity, we can easily characterize asymptotic properties of the early conversion boundary close or at infinite time to expiry. From numerical experiments with LCT inversion, we see that our CB value solution performs more stably and better than the plain solution.

2 - Equilibrium execution strategies in generalized price impact models
Makoto Simoshimizu, Masamitsu Ohnishi

In this talk, we examine a game problem played by two large traders, both of whom should execute respective predetermined volumes of a same financial asset in a finite horizon. It is assumed that both large traders try to maximize the expected CARA utility of their final wealth. Constructing a generalized price impact model in a discrete time setting, we formulate the problem as a stochastic game (or Markov game) and show that there exists a distinguished Markov perfect equilibrium composed of strategies with affine forms of state variables by using a backward induction procedure of dynamic programming. We also present some numerical examples which show interactions between their execution strategies and comparative statics results with respect to problem parameters.

3 - Financing and investment strategies under information asymmetry
Takashi Shibata, Michi Nishihara

We examine the interaction between the financing and investment decisions of a firm under information asymmetry between well-informed managers and less-informed investors. We show that information asymmetry delays corporate investment and decreases the amount of debt issuance to finance the cost of investment. When the level of information asymmetry is sufficient high, the firm prefers the all-equity financing to the debt-equity financing. This result contrast with that under information symmetry where the firm always prefers the debt-equity financing to the all-equity financing.

4 - Bankruptcy, liquidation, and fire sales under asymmetric information
Michi Nishihara, Takashi Shibata

This paper develops a dynamic model in which a distressed firm optimizes an exit choice and its timing. We reveal the following effects of asymmetric information where the distressed firm is not informed about an acquirer's valuation when selling assets. With asymmetric information, a high-value acquirer may have an incentive to imitate a low-value firm and purchase assets at a low price. To avoid this imitation, the distressed firm can discount the sales price to a high-value firm and delay the sales timing to a low-value firm. Due to the screening costs under asymmetric information, the distressed firm is more likely to default rather than selling out. In the default case, assets can be liquidated at a low price, and debt holders suffer greater losses than shareholders. These results can account for several empirical findings about fire sales and acquisitions.

■ MB-25

Monday, 10:30-12:00 - SOUTH BUILDING UV S307

Economic and Financial Challenges in Cryptocurrencies

Stream: Fintech: Economic and Financial Challenges in Cryptocurrencies
Chair: *Marco Patacca*

1 - Risk analysis models for cyber insurance
Aitor Couce Vieira, David Rios

Cyber insurance has recently emerged as a complimentary measure against cybersecurity risks. As a consequence, several decision problems have become relevant around the role of cyber insurance in cybersecurity risk management. In this paper, we present risk analysis models for three of these decision problems. The purpose is to provide a framework for estimating the economic impact of cybersecurity risks that may face insurers and insured IT owners as well as calculating their optimal risk management strategies.

The first model outlines a more rigorous framework for cybersecurity risk analysis. It helps IT owners to decide the best resource allocation strategy in terms of cybersecurity controls and cyber insurance. It also helps an insurance company to design their cyber products based on parametric variations. The other two models are designed to support insurance companies. Specifically, the second model addresses the optimisation of the reinsurance portfolio and the third one the decision on whether to grant a given insurance product to a company. We describe these models in terms of influence diagrams and bi-agent influence diagrams, sketching the corresponding economical problem and outlining its general solution.

2 - Bitcoin rise and fall and market exuberance
Alessandra Cretarola, Gianna Figà-Talamanca

Motivated by the new interest in Bitcoin derivatives, in this paper we develop a bivariate model in continuous time to describe the price dynamics of one Bitcoin as well as the behavior of a second factor affecting the price itself, which represents market attention in the Bitcoin system. It is widely accepted in the current literature that Bitcoin price is affected by market sentiment and that over-confidence about the underlying technology might boost in a pricing bubble. Here, the attention factor affects Bitcoin price both directly and indirectly: through a suitable dependence of the drift and diffusion functions in Bitcoin price and possible correlation between the two sourced of randomness represented by a bivariate Brownian motion. The model is proven to boost in bubble if and only the correlation between the risk sources is above a certain threshold depending on model parameters. Then, the model is fitted to historical data of Bitcoin prices considering Google SVI index and trading volume as potential attention measures; to this aim we use the conditional likelihood method. Performing the estimation on moving windows make it possible to detect past bubble periods in historical data.

3 - Adequate modeling for the dynamics of cryptocurrencies
Oleg Kudryavtsev, Alexander Grechko, Vasily Rodochenko

At present, more and more attention is attracted to cryptocurrencies, which total market capitalization reached $470 billion. In contrast to the fiat currencies or stock prices, cryptocurrencies demonstrate a very high volatility and thus arouse the great interest among traders. It follows that traditional diffusion models are not applicable for such type of currencies. We consider the problem of modeling for the dynamics of leading cryptocurrencies such as bitcoin and ethereum. We compute log returns from time series of cryptocurrency rates with different time frames and analyze realized power variation to estimate the correspondent generalized Blumenthal-Getoor index. The analysis shows that CGMY (KoBoL) is more adequate for modeling cryptocurrencies and it gives an estimate for the parameter that describes the activity of jumps in the log returns. We fit the other parameters to the CGMY model from the observed barriers crossing frequencies for the given cryptocurrency's price. Theoretical values of the first passage probabilities under the model are calculated using numerical Wiener-Hopf factorization method. We accelerate the speed of computation by means of Fast Fourier Transform and efficient numerical Laplace transform inversion. The reported study was funded by RFBR according to the research project No.18-01-00910.

4 - Does market attention affect Bitcoin returns and volatility?
Marco Patacca, Gianna Figà-Talamanca

In this paper we measure market attention by applying several filters on time series for the trading volume or the SVI Google searches index. We analyze relative impact of these measures either on the mean or on the variance of Bitcoin returns by fitting non linear econometric models to historical data from January 1, 2012 to October 31, 2017; two non-overlapping subsamples are also considered. Outcomes confirm our conjecture that market attention has an impact on Bitcoin returns. Specifically, trading volume related measures affect both the mean and the conditional variance of Bitcoin returns while internet searches volume mainly affects the conditional variance of returns.

■ MB-26

Monday, 10:30-12:00 - SOUTH BUILDING UV S308

Innovative Urban Mobility Concepts

Stream: Public Transportation I
Chair: *Konrad Steiner*

1 - The on-demand bus routing problem: towards a more performant public transport system
Lissa Melis, Kenneth Sörensen

In the last decades, the popularity of flexible transport services (FTS) has increased considerably, as witnessed in applications such as shared taxis and on-demand carpooling. Even though public bus transport is still largely bound to fixed routes and fixed timetables, the ubiquity of mobile devices and the improved technology of automated vehicle location (AVL) systems would allow for a large-scale shift to on-demand public transport in the near future. In such an on-demand system, buses would drive along routes completely determined by the demand of passengers. To support the routing of on-demand buses we define a new optimization problem: the on-demand bus routing problem (ODBRP), which combines the dial-a-ride problem (DARP) with bus stop selection, introduced in the school bus routing problem. Given a set of requests for transportation, indicating a passenger's departure and arrival location, as well as his/her preferred arrival time, the aim of the problem is to (1) assign each passenger to a departure and arrival bus stop within walking distance, and (2) develop a set of bus routes, picking up passengers at their departure stop and delivering them to their departure stop before their preferred arrival time. In this talk, we present (a mathematical formulation of) the ODBRB, as well as a straightforward heuristic to solve it.

2 - Smart public transportation services - Morocco case
Kenza Oufaska, Khalid El Yassini, Tarik Zouadi, Mustapha Oudani

Public transport is a privileged opportunity for organizations working in the logistics sector or in the field of new information and communication technologies. These organizations must respond to a dual need for organization/rationalization and management/communication. This need has strongly collaborated to the exponential propagation of systems integrating techniques and technologies related to the exploitation, the geolocation and the fleet's piloting. In the occurrence, we can mention operating assistance systems consisting of embedded units mounted on vehicles and supervised from a control center whose role is to visualize, in real time, the any vehicle's position. This control cannot be fruitful without circumventing certain malfunctions such as vehicle failures on the corresponding transit lines while taking into account all the constraints to be met such as time, the passenger's destination to edge and as well as social and environmental restrictions. The project idea is to design and develop an intelligent system, which can be accessed in real time via various terminals, whose purposes include, among other things, helping for making appropriate decisions in adequate time by the decision-makers responsible for steering the control center and analyzing the information collected by the system. This massive amount of information constitutes a fertile field for various possible exploitations such as means of transport, economic decision-makers or urban planners.

3 - Shortest paths in public transportation networks with multiple APIs
Sean Shorten, Dominique Feillet, Alexandre Iglesias

Very efficient API have been developed to compute the best itinerary in a public transportation network. However, in many geographical areas, like big cities, several operators are available and have defined their own API, which is not combined with that of other operators. Finding the shortest path considering all possible operators then becomes hardly tractable. Developing a centralized algorithm would theoretically be possible but would require having access to all timetables, which is generally not possible with API. In this research, we are interested in the way to combine existing API to compute best itineraries. We focus on the case when API are only able to answer to single-origin single-destination requests. In this talk, we present a simplified case where a single public transportation API is combined with one API for walk both at the starting point and at the ending point. Our goal is to reduce the number of calls to the public transportation API. Our approach consists in finding important stations in the network to compute a partial distance matrix. This matrix is then used to determine a priority order for the calls to the API. Experiments conducted with real API will be presented at the conference.

4 - Integrating mobility-on-demand and urban public bus networks
Konrad Steiner, Stefan Irnich

New mobility on demand (MoD) services like Uber are currently establishing a mode of transport between the classical categories public transport and individual mobility. Its long-term role in the urban mobility landscape and within public transport systems is not fully understood as of today. If the public transport industry wants to capture the opportunities these new services offer and mitigate the risks that come with them, planning tools for integrated intermodal networks are indispensable. In this talk, we present a strategic network planning optimization model for bus lines that allows for intermodal trips with MoD as a first or last leg. For an existing public transport network, the model decides simultaneously on the structure of the fixed-route network, on the footprint of the MoD service and on the interaction between the two. We also present a path-based formulation of the problem and a branch-and-price algorithm as well as an enhanced enumeration approach to solve real-world instances to proven optimality.

■ MB-27

Monday, 10:30-12:00 - SOUTH BUILDING UV S309

Supplier Relationships

Stream: Production, Service and Supply Chain Management
Chair: *Nader Azad*

1 - After-sales emergency supply contracts with asymmetric information
Sajjad Rahimi Ghahroodi

We present an original model to study the interaction of a service provider and his emergency supplier. The service provider is responsible to repair a group of assets which subject to random failures. He needs spare parts and service engineers available to repair the failures. He can fully rely on himself in providing the resources and follow a full backlogging policy, or in case of stock-out, revert to an emergency supplier. We study price-only and revenue-sharing contracts which the emergency supplier can offer to the service provider in a Stackelberg game setting. We show that there is a set of optimal revenue-sharing contracts which always coordinate the system and give the highest supplier profit. In the presence of asymmetric information in which the supplier does not have full information on the failure rate of the assets, we investigate the optimal strategy the supplier needs to follow using single and a menu of revenue-sharing contracts. We show that finding a menu of revenue-sharing contracts is not always possible and gives not necessarily a higher profit to the supplier than using a single revenue-sharing contract. Furthermore, it is shown that under what circumstances the information asymmetry can be beneficial for the service provider and when it makes the system coordination impossible.

2 - Supplier audit information sharing and responsible sourcing
Albert Ha

We study the incentive for competing manufacturers to share supplier audit information in a market with consumers who may boycott a manufacturer if supplier responsibility violations occur. The manufacturers need to make a sourcing decision of either continues to procure from an existing non-responsible common supplier with uncertain responsibility risk, or switches to a new responsible supplier who charges a cost premium. Supplier audit information allows a manufacturer to have an updated assessment of the responsibility risk of the common supplier. We fully characterize the manufacturers' equilibrium audit sharing decisions and the subsequent sourcing strategies, and show how they depend on parameters such as the relative cost premium of the responsible supplier, the expected demand loss of sourcing from a high-risk non-responsible supplier, the probability of the non-responsible supplier to be high-risk, and the audit information accuracy. We show that the existence of an audit-sharing platform does not always lead to more responsible sourcing, even though this is a common motivation for establishing these platforms. A manufacturer who sources from the responsible supplier may benefit from a higher relative cost premium when it induces the manufacturers to cease sharing audit information. A manufacturer whose sourcing decision depends on the audit information may be hurt when the information becomes more accurate.

3 - Optimal investment decisions for recovery from disruptions in the decentralized supply chains
Nader Azad, Elkafi Hassini, Manish Verma

In this paper, we investigate the optimal supplier's and buyer's reactions to supply disruption. Upon disruption, the supplier loses the supply during the recovery period. Given a delivery time contract between the supplier and buyer, the supplier can make an investment to decrease the recovery time to benefit both parties. Because the supplier can decrease the recovery completion time, the buyer may offer a financial subsidy incentive to the supplier (sole sourcing with a financial subsidy incentive strategy) or source from two suppliers (dual sourcing strategy). In this study, we present two Stackelberg game models to highlight optimal buyer's and supplier's decisions under the mentioned strategies We also find the financial incentives levels that would coordinate the two-party supply chain. Finally, we compare the two strategies and characterize the buyer's preference as a function of the model parameters. Our work complements literature papers where they analyzed similar problems in the context of improving the suppliers' reliability so as to reduce their chances of being disrupted. In contrast, we focus on the analysis of disruption recovery strategies. In particular, we investigate the role of building long term supplier relationships, through joint investment programs, in mitigating the impact of supply disruptions.

4 - Collaboration and coordination mechanism design and practice in sustainable supply chains
Amy Zeng

The success of any supply chain depends on the collaboration of the chain partners through some form of coordination mechanism, which can range from information sharing to sophisticated contractual terms; and sustainable supply chains are of no exception. This study provides an in-depth review of the status quo of research efforts pertinent to collaboration and coordination in three types of sustainable supply chains, namely socially responsible supply chains, green supply chains, and closed-loop supply chains. In the last type, two detailed examples of reverse supply chains of electronics are provided to demonstrate how the coordination mechanism is designed and determined. For future research efforts, several common threads implied by this study, as well as some broad areas considering country-specific situations, are summarized and presented.

■ MB-28

Monday, 10:30-12:00 - SOUTH BUILDING UV S310

Multiple Classifier Systems and Applications I

Stream: Multiple Classifier Systems and Applications
Chair: *Pinar Karadayi Atas*

1 - A multi-criteria framework for ensemble learning
Nikolaos Matsatsinis, Theodore Flokos, Alkaios Sakellaris, Konstantina Miteloudi

In this paper we present a Multi-Criteria framework for Ensemble Learning. The main idea of the proposed method is that every individual trained model has a utility for the ensemble model. By assessing this utility we can derive the degree of participation in the final ensemble. The algorithm has been implemented with Python programming language. Many different datasets from UCI machine learning repository have been used for evaluation of the method. Preliminary results show that the proposed framework always produces better ensemble model than individual classifiers. Also, the method can be extended to regression problems with appropriate selection of algorithms and evaluation metrics. Some advantages from using this multicriteria analysis for ensemble learning are: (1) Comprehensibility, the knowledge learned by ensembles to be understandable to the user. (2) Adaptability, different classification problems lead to different combination of classifier and evaluation metrics, specific domain knowledge of the user can be incorporated easily to the method.

2 - Building profit-sensitive classifiers for maximum profit
Eugen Stripling, Bart Baesens, Seppe vanden Broucke

In a challenging market environment, value-centric decision making is crucial for a corporate organization in order to remain competitive. Usually, this important business requirement is expressed as profit maximization. Profit-driven business analytics acknowledges the need for the value-centric approach and aims to integrate the profit aspects into the data science application. In previous works, the Expected Maximum Profit (EMP) measure for profit-based model selection as well as a few profit-driven classification methods that directly maximize the EMP during model construction were proposed in the literature. However, as for the latter, the respective works lack a general description of the essential components needed for successful building a profit-driven prediction model.

Hence, we develop a general framework for profit-driven model building that concentrates on the EMP measure. The framework formally describes the building blocks required for constructing a profit-driven prediction model, and it can be viewed as a generalization of the previously established profit-sensitive classification methods. We illustrate the applicability of the general framework for customer churn prediction. Furthermore, we benchmark a selection of derivative-free optimization (DFO) methods, one of the essential components of the proposed framework, and determine the best-performing DFO solver through a series of state-of-the-art classifier comparison tests based on Bayesian statistics.

3 - Analysis of healthcare service utilization by mixture of hidden Markov model
Nazanin Esmaili, Massimo Piccardi, Federico Girosi

Transport injuries commonly result in significant disease burden, leading to physical disability, mental health deterioration and reduced quality of life. Classifying healthcare service utilization temporal patterns following transport injury may provide more detailed knowledge of the patient health trajectory, allow improved health system resource planning, and provide a starting point against which any future system level interventions can be evaluated. The purpose of this research is to identify groups of patients with similar patterns of service utilization, describe the characteristic of those groups and identify, in each group, the "typical" behavior of individual patients with respect to service utilization. To do so, we have proposed an analytical framework that utilizes latent variables to describe the utilization patterns over time and group time series into clusters. In order to group the patients' behaviors in terms of service utilization over time, we have used a well-established statistical approach known as Mixture of Hidden Markov Models (MHMM). We tested our model with data from one of the main insurer of third-party personal liability for road accidents in Australia and found that three clear clusters of service utilization patterns are present in the data. We use multinomial logistic regression to provide a description and understanding of the clusters in terms of demographic, injury and accident covariates.

4 - A novel ensemble pruning approach for ANN-based churn prediction ensemble models
Sureyya Ozogur-Akyuz, Koen W. De Bock, Pinar Karadayi Atas

Multiple Classifier Systems (MCS), or ensembles, have been shown to increase the performance of algorithms in many applications of the machine learning field. In the well-documented field of customer churn prediction, ample research empirically demonstrate that aggregated classifiers often achieve superior performance if their constituent member model set achieves both reasonable levels of predictive accuracy, as well as diversity. Moreover, in search for further enhancement, ensemble pruning, or the practice of a selection of the best candidates in a generated ensemble has recently received attention as a method for further enhancing prediction results. This research builds upon earlier work on MCS of artificial neural networks for customer scoring, and introduces a novel method for ensemble pruning to these ensembles based upon a simultaneous optimization of both accuracy and diversity of the ensemble members. The method is based upon solving a non-convex optimization problem by transforming it into convex- concave programming and finding a solution with Majorization Minimization approach. To accommodate the specific field, domain-specific measures are adopted for measuring and optimizing accuracy and diversity. Experimental benchmarking results on multiple datasets show that the proposed ensemble pruning algorithm is successful in enhancing the predictive accuracy of ANN-based ensemble classifiers for customer churn prediction.

■ MB-29

Monday, 10:30-12:00 - SOUTH BUILDING UV S311

Power and Influence Models

Stream: Game Theory, Solutions and Structures
Chair: *Josep Freixas*

1 - Classes of influence games

Xavier Molinero, Maria Serna

An influence game is a cooperative simple game in which a coalition of the players wins if it is able to convince enough agents to participate in the task (to vote in favor of a decision). In this vein, the linear threshold model is taken as the influence model. It is known that influence games capture the class of simple games. Influence games (as simple games) are monotonic. Now, we present some new classes of influence games under some connectivity restrictions over winning coalitions. These classes of influence games are not necessary monotonic. We characterize the computational complexity of problems on influence games over these new classes, including measures (length and width), values (Shapley-Shubik and Banzhaf) and properties (of teams and players). We also analyze those problems for some particular extremal cases, with respect to the propagation of influence.

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2 - Limit theorems for power indices

Sascha Kurz

The determination of the power distribution of the members of a shareholder meeting or a legislative committee is an important problem for many applications. In some cases it turned out that power is nearly proportional to relative weights, which is very beneficial for both theoretical considerations and practical computations with many members. We present quantitative approximation results with precise error bounds for several power indices as well as impossibility results for such approximations between power and weights.

3 - Power and bloc formation in a consociational democracy: lessons from the Lebanese republic

Frank Steffen, Mostapha Diss

The governance structure of the Lebanese Republic is characterized by its consociational nature. This finds its expression in a pre-defined representation of Christians and Muslims and its sectarian subgroups in the Lebanese Parliament, i.e., by a confessional two-layer structure. We study the effects on power and bloc formation of this particular structure and relate our results to the political debates in the Lebanon and to the general discussion on consociationalism. The ratio being used to assign seats to these sectarian subgroups has been an intensively debated issue over decades. Recently, a new electoral law has been introduced. Applying the Penrose-Banzhaf measure we investigate the confessional power distributions in the Lebanese parliament under the future, current, and prior seat distribution. This allows us to relate our findings to the general motivations for the electoral reforms underlying all studied seat distributions. Additionally, we address the implications of the existing Lebanese party blocs in the current parliament from a party and confessional perspective. Currently, their existence is put into question in the public and political discussion. We contribute to the theoretical foundation of this debate and demonstrate that in terms of parliamentary power the current bloc formation is a priori disadvantageous. Furthermore, relating our results to more general debate on consociationalism, we reveal some properties of a consociational two-layer structure.

4 - Extension and characterization of majority decision in a multiple-input multiple-output context

Josep Freixas, Montserrat Pons

Simple majority is a very common rule to make collective decisions in a voting context. Following this rule, each individual can either be in favor of the proposal, be indifferent to it, or be against it. The proposal is approved if the number of votes in favor of it is greater than the number of votes against it, it is rejected in the opposite case, and there may be a tie if the number of votes for both sides coincides. May's well-known result axiomatically characterizes simple majority rule in this context.

A more general situation is considered here: several symmetric degrees of positive and negative support for the submitted proposal are allowed to voters, so that the voting rules considered by May to characterize the simple majority rule correspond to a particular case.

The main contribution of this work provides a set of independent axioms which uniquely characterizes a function that has all the ingredients of the simple majority rule and coincides with it when the support or rejection to the proposal can only be manifested in one way. A relevant aspect is that when we are restricted to the particular case our set of axioms does not coincide with those by May, so that they constitute a new characterization of the simple majority rule.

Situations in which different degrees of voting options are possible appear in different contexts.

■ MB-30

Monday, 10:30-12:00 - SOUTH BUILDING UV S312

Local search based metaheuristics

Stream: Metaheuristics
Chair: *Omer Ozkan*

1 - Ranking-based heuristic algorithm for competitive facility location

Algirdas Lančinskas, Pascual Fernandez, Blas Pelegrin, Julius Žilinskas

The location of facilities is a strategic decision for firms that compete with other firms to provide goods or services to customers in a given geographical area. There are many facility location models proposed in the literature, which describe various properties of the model such as customers behavior, facility attraction, location space, utility function, decision variables, etc. Our research is focused on the discrete facility location problem for an entering firm planning to enter the market thus giving rise for competition with other firms already in the market. The goal is to select a given number of new facilities from a given finite set of potential locations, assuming that customers are spatially separated into demand points. Despite the well-known binary customers behavior rule in which all customers of a single demand point are served by the most attractive facility, we consider the partially binary rule in which buying power of a single demand point is proportionally divided among all firms choosing the most attractive facility per chain. We propose a new heuristic algorithm, which is based on ranking of potential locations for the new facilities and is specially adopted to solve discrete facility location problems. The algorithm was applied to solve various instances of the above facility location problem using real geographical data, and performance of the algorithm was compared with the performance of other state-of-the-art algorithms.

2 - Dynamic stochastic tourist trip design problem with clustered POI

Airam Expósito Márquez, Simona Mancini, Julio Brito, José Andrés Moreno-Pérez

Tourists visiting a touristic area, for several days, face the problem to select which points of interest (POIs) would be visited and to determine a route for each trip day. Information about POIs could be sparse, and not accessible by foreign tourists. In the literature this problem is known as the Tourist Trip Design Problem (TTDP). Each POI is characterized by several attributes as: score, minimum visit time and opening time windows. The goal of the problem is to define a set of feasible tours, that maximize the total collected score of the visited POIs. With the aim to provide a more realistic representation of the reality, we present the Dynamic Stochastic Tourist Trip Design Problem with Clustered POI, (DSTTDP-Clu), in which we consider that POIs are clustered by categories representing different types of visiting sites (museum, restaurant, etc.). A set of scenarios in which POIs fail (for different reasons such as: a restaurant is fully booked, a beach cannot be visited, etc.) is analyzed. Information about POIs failure is not known in advance but it is dynamically revealed. In order to return high quality solutions a Fuzzy Greedy Randomized Adaptive Search Procedure has been proposed. A repair heuristic has been designed to recover feasibility and to limit score loss after a POI failure. Computational experiments were carried out to assess the performance of the Fuzzy GRASP, the ability of the repair heuristic to recover feasibility and to limit score loss.

3 - A computational study on the maximum dispersion problem

Mahdi Moeini

In this study, we are interested in the Maximum Dispersion Problem (MaxDP). In the MaxDP, we have a given set of objects such that each object has its own non-negative weight. The objective consists in partitioning this set of objects into a given number of classes. The partitioning must meet some conditions. In particular, the objects of each class must have highest mutual distance. Furthermore, each class has its predefined target and the total weight of each class must belong to an interval defined by the target weight of the class and a given parameter. The MaxDP can be formulated as a 0-1 fractional programming problem and might be linearized in different ways. Since MaxDP is NP-hard, it is difficult to solve large-scale MaxDP instances by classical exact methods. In order to overcome this issue, we introduce an efficient Variable Neighborhood Search (VNS) algorithm. Through extensive computational experiments on randomly generated instances, we evaluate the performance of the proposed VNS algorithm versus the standard solver Gurobi. More precisely, we compare the computation time as well as the quality of the solutions provided by both approaches in solving each of the instances. According to the numerical results of our computational experiments, we observe that the introduced VNS algorithm outperforms the solver Gurobi and provides high-quality solutions.

4 - A memetic algorithm based matheuristic for satellite broadcast scheduling problem

Omer Ozkan, Sezgin Kilic

Low Earth Orbit (LEO) is the orbit between 99 and 1,200 miles above the Earth's surface and LEO is the cheapest, safest and simplest orbit for placing a satellite. LEO satellites have high bandwidth and resolution images with low communication time lag and power requirement advantages. However, a plenty number of LEO satellites are needed to cover up the whole Earth surface and to maintain connectivity. Therefore, the LEO satellites need to broadcast the received data to the ground terminals while passing over the terminals. The Satellite Broadcast's Scheduling (SBS) problem aims to find a valid broadcasting schedule between satellites and ground stations for time slots while satisfying the demand constraints. The problem can be represented as a Binary Integer Programming (BIP) model and has NP-complete complexity. There are neural network and metaheuristic based approaches for the SBS problem in the literature. In this paper, a Memetic Algorithm Based Matheuristic (MABM) is proposed. A simple BIP assignment model is used for each time slot seperately to generate initial population of MABM. The model and the MABM are coded in MATLAB and the BIP model is solved by CPLEX. Problem based operators and a Local Search (LS) procedure are added to the MABM. The proposed algorithm is compared with the approaches in the literature via benchmark sets. The MABM is able to find good solutions in reasonable CPU times.

■ MB-31

Monday, 10:30-12:00 - SOUTH BUILDING UV S313

Behavioural Impacts in OR-Supported Processes I

Stream: Behavioural OR
Chair: *Gilberto Montibeller*

1 - Online weight elicitation: is there really an issue?

Alice H. Aubert, Judit Lienert

In environmental management, participatory Multi-Criteria Decision Analysis (MCDA) is desired, particularly when it relies on public investments and possibly impacts citizens' daily life. Decisions concerning future urban wastewater management (UWM) are such a topic. Some alternatives might cause changes for end-users, e.g. concerning the use of toilets in their bathrooms. Decisions on future UWM also require transparency. The big issue decision analysts are then facing is the following: how to elicit reliable preferences from the stakeholders, including the end-users. An additional challenge is that the end-users are most likely not experts in UWM. A few attempts for online surveys have been proposed to collect preferences from a large number of citizens. Building on this research, we carried out an experiment in a real case study in the city of Paris. We proposed two treatments for online weight elicitation: direct rating and swing. We also collected information with pre- and post-questionnaires about learning, preference construction, and the perceived experience. In the talk, we will report on the preliminary results of the experiments: have participants learnt during the online survey? How was the weight elicitation perceived? Do the outcomes (weights) differ between direct rating and swing? We will conclude on recommendations on how to follow-up, both in practice and research.

2 - Individual differences in model comprehension and use: a study of cognitive styles and cognitive mapping

Ilkka Leppanen, L. Alberto Franco

Do cognitive styles, value orientations, and conflict in values determine how decision makers comprehend and use cognitive maps? We set out to study this question with an experiment where subjects were tested on cognitive map comprehension and asked to make linking choices between different statements. A total of 185 subjects participated in an online experiment that consisted of two parts. In Part 1 the task was to recognise linking errors in a cognitive map that was constructed at a pre-study workshop. In Part 2 the task was to make linking choices in a map that was similar to the map in Part 1. We correlated the behaviour in Part 1 to scores in Need for Cognition (NFCog) and Faith in Intuition (FI) trait scales, and the behaviour in Part 2 additionally to scores in the Allport values scale and self-reported conflictedness statements. We found that NFCog correlated positively with linking accuracy in Part 1, i.e. high NFCog subjects made less linking errors than low NFCog subjects, whereas FI did not correlate with linking behaviour. We also found that NFCog, FI and conflict were able to predict choices in some value domains and that FI had an inverse relationship to self-reported conflictedness. Our study draws a picture of how individual traits and capabilities affect cognitive map comprehension and use, and demonstrates the importance of accounting for individual differences in model-supported managerial decision making.

3 - Attractiveness bias: how the decision situation influences the willingness-to-pay for information

Jan Lenard Rother, Christian Koester, Maximilian Vincent Reimer

Most decisions in business and life involve risk. Frequently, additional information from experts can be taken into account to sharpen the understanding of the decision task. An example may be a set of alternative strategies of a company to enter a foreign market and gathering information about potential demand for each strategy from a market research company. Thus, the integration of additional information into the decision process is essential for decision making. We present an experimental study on the willingness-to-pay (WTP) for perfect information under risk. We observe that the WTP for information is not solely based on the value of the information (VOI) but depends also on the attractiveness of the choice set. Subjects overbid moderately when faced with attractive lotteries and strongly when losses can be avoided, even when final wealth positions remain constant. Due to the experimental design this effect cannot be explained by neither risk preferences, loss aversion, prospect theory, nor disappointment theory. Instead, we find regret theory to be the only tested model that can explain the observed behavior. Hence, on the one hand, it may be adventurous for information brokers, such as market research companies or business consultancies, to frame decision situations for buyers of information to increase profits. On the other hand, buyers of information should be aware of this attractiveness bias and focus solely on the value of the information.

4 - Behavioral challenges in policy analysis with conflicting objectives
Gilberto Montibeller

Public policy problems are rife with conflicting objectives: efficiency versus fairness, technical criteria versus political goals, costs versus multiple benefits. Multi-Criteria Decision Analysis provides robust methodologies to support policy makers in making tough choices and in designing better policy alternatives when considering these conflicting objectives. However, there are important behavioural challenges in developing these models, which I will cover in this talk: individual and group behavioural biases and cognitive limitations in providing judgements and interacting with decision analytic models.

■ MB-32

Monday, 10:30-12:00 - SOUTH BUILDING UV S314

Supply Chains

Stream: Routing, Logistics, Location and Transportation
Chair: *Mojtaba Araghi*

1 - Scheduling of pick-up or delivery tasks for autonomous robots via dispatching rules
Azmi Cibi, Tahir Ozdemir, Inci Saricicek, Ahmet Yazici

Automated guided vehicles started to be replaced by autonomous transfer robot systems in the fourth industrial revolution. This transformation increases the flexibility in manufacturing but requires solving scheduling problem for autonomous robots in internal transport environments. The study deals with scheduling of autonomous robots in internal transport environments. Scheduling of pick-up and delivery tasks is essential to the efficiency of the overall manufacturing systems. Dispatching rules are used to generate schedule over a certain horizon period from an hour to a day. Dispatching rules are widely used in warehouses and shop floors to control vehicles' movements. First Come First Served, Earliest Due Date, Shortest Processing Time and combined rules are used in the scheduling of pick-up and delivery tasks of autonomous robots. The performances of proposed dispatching algorithms are evaluated in Gazebo Simulation Environment for a small factory model. The performance criteria are the minimizing the tardy jobs, total tardiness and flow time. The results show that the combined rules can be used when considering multiple objective functions such as minimizing tardy job and minimizing flow times.

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2 - Coverage planning to account for acoustical properties associated with emergency warning sirens
Hiroyuki Goto, Alan Murray

An important class of facility location problems deals with service coverage. While there are many type of coverage models, among the most widely applied is the location set covering problem. It has been used to address a broad range of planning and analysis contexts, including emergency services. In this talk we consider a system consisting of omnidirectional warning sirens. Given a region, we seek the minimum number of sirens needed to alert everyone across the region of an emergency situation. In contrast to previous work, proposed is an approach to take into acoustic properties. This requires formulation of superposition associated with multiple sounds as this impacts audible distance. The developed approach can be considered a generalization of the originally defined location set covering problem. To obtain an optimal solution, a bounding-based method is adopted. Empirical results are presented for the emergency warning siren system in Huntington Beach, California, USA. The findings highlight the significance of acoustic properties, and the need to explicitly account for siren interaction in the evaluation of service coverage.

3 - The impact of sustainable packaging used in land transfer operations
Cristian Camilo Aparicio Peralta, Ana Halabi Echeverry, Cesar Augusto Bernal-Torres

This research identifies the impact of sustainable packaging used in land transfer operations focused on new conditions given by the current land transport environments. At present, logistics operations focused on food transport, faces several difficulties at transfer times in the distribution center or in the final customer point, for instance, each product has qualities that must be preserved by the supply chain (taste, smell, presentation) that can be affected in their storage specially when sharing the storage places at vehicles (perhaps not sustainable). Vehicles with specific characteristics are used for frozen or refrigerated cargo. Therefore, the research contributes to sustainable packaging solutions to the best performance of the packaging considering the transfer restrictions and changes in land transport environments; identifing restrictions in fixed capacity of vehicles, in addition to the sanitary norms, biodegradation and other new sustainable conditions for preserving the food transport.

4 - Optimizing distribution and pricing strategy for a cold chain enhanced by sensor technologies
Mojtaba Araghi, Sara Babaee

We study the problem of optimizing transportation and pricing strategies in a cold supply chain network. Delivering perishable products, the firm faces different deterioration rates depending on the chosen transportation routes. Multiple quality levels of products, resulted from the transportation, are substitutable at the final node based on the firm's pricing strategy. Enhancing the cold chain real-time traceability by using sensor technologies enables the firm to optimize the distribution policy and update it during the course of transportation. We analyze this problem by comparing the optimal transportation and pricing policies under the presence or absence of sensor technologies using mathematical modeling. We discuss how the optimal policies depend on model parameters and evaluate the benefits of integrating the sensor technology in the perishable products supply chain.

■ MB-33

Monday, 10:30-12:00 - SOUTH BUILDING UV S315

Data Mining and Statistics I

Stream: Data Mining and Statistics
Chair: *Florian Hauck*

1 - Application of machine learning-for cost estimation in customized furniture production
Virginijus Marcinkevicius, Viktor Medvedev, Olga Kurasova, Tomas Vedlūga

A cost estimate is one of the main components of many engineering projects which includes calculation of the materials, labour, sales, overhead, and other costs. The estimation is performed by construction managers through their knowledge and experience before producing, and it affects planning, bidding, design, and production management essentially. As a consequence, such process is rather complicated and takes a long time. In this paper, we investigate different automatization strategies for cost estimation in a case of customized furniture production. The research aims to estimate production cost as accurately as possible employing instance-based learning prediction techniques using the information from historical data of similar (analogous) products. In instance-based techniques, similarity measure should be identified. In our research, we propose similarity measure adapted to the customized furniture production where the principal cost features are determined; product profiles are composed by grouping similar items according the similarity measure and cost prediction models are selected respectively. The experimental investigation based on the real data is performed, results are presented, and insights given.

2 - Machine learning based feeder bus routing design
So Young Sohn, Chung Park, Jungpyo Lee

The demand for taxis during rush hour is substantial in metropolitan areas. This kind of traffic can be reduced by feeder buses connecting popular transit points. In order to design such feeder bus routes, we apply a natural language processing method based on machine learning, to real-time taxi GPS data. In addition, k-means clustering is applied to group the extracted road vectors. For each cluster, we employ an optimization model to find feeder bus route that can replace taxi rides. We apply the proposed approach to the taxi transit data of Seoul. Our approach is expected to contribute to a reduction in traffic during the rush hour.

3 - Hidden footage of fluid actors: the evolutionary process of memberships in online communities
Changwoo Suh, Habin Lee

Online communities (OCs), computer-mediated virtual space, have become one of the important parts of our lives. For example, users of Reddit.com visited 1.36 billion times in total in July 2017 that is comparable to Facebook or YouTube. While several studies explain the underlying mechanisms of members' participation and revisit behaviours, we still do not understand the evolutionary processes of members who progress from newcomers to core members. The gap mainly stems from the dominance of variance studies that deal with co-variance between variables that capture different aspects of a given phenomenon in OC literature. This study takes process-oriented approach and aims to reveal evolutionary socialisation process of OC members by applying a novel inter-disciplinary computational qualitative method based on critical realism. Critical realism is employed for the study to help explaining complex structures of the online community and interactions between its users. Especially, we analyse whole data from OC databases for two years including visible as well as invisible events to OC members. The invisible events make us analyse how a newcomer begin to assimilate in the organisation that is not yet studied so far. We find sequence of events to identify demi-regularities through clustering and visualisation. Our results can show how newcomers are assimilated into OCs visually. We discuss theoretical contribution and practical implications in conclusions.

4 - Railway delay analytics: a data-driven approach to identify systematic train delays and measure the quality of timetables
Florian Hauck, Natalia Kliewer

Delayed passenger trains are still a major issue for railway companies. Some of the delays are caused by external events and can often not be avoided. Others occur on a regular basis and can probably be avoided by improving timetables. In order to do so, one has to identify the systematic delays and understand their causes and correlations. We present an approach to identify systematic train delays by analyzing historical delay data. For this purpose, we examine a dataset of the German railway company 'Deutsche Bahn', which contains delay information about every passenger and freight train that used the German railway infrastructure in 2016. First, we show how this dataset has been extracted from different source systems and how we cleaned, prepared, and transformed the data. Next, we propose a design for a data warehouse to store delay information and define relevant facts and dimensions. In order to measure the quality of a given timetable, we identify several key performance indicators and show how the proposed data warehouse design can be used to efficiently extract the needed information to calculate those indicators. Based on the data warehouse we develop a delay mining approach enabling us to identify systematic train delays and to understand causes for and correlations between delays.

■ MB-34
Monday, 10:30-12:00 - SOUTH BUILDING UV S113

Pension Schemes and Risk Taking

Stream: Insurance and Pension Risk Management
Chair: *Massimiliano Menzietti*

1 - Peer effects in risk taking: evidence from Germany
Sophie-Madeleine Roth, Mark J. Browne, Annette Hofmann, Andreas Richter, Petra Steinorth

Empirical evidence on the impact of peer groups on individual risk preferences ("peer effects") is very limited so far as causality is hard to establish. This study uses data from the German Socio-Economic Panel to analyze peer effects in risk taking. We use an instrumental variable approach and track the impact of the East-West migration after the German reunification to address concerns about causality. We find strong evidence for peer effects.

2 - Annuity risk management by longevity swaps in minimal Martingale measure
Tadashi Uratani

Longevity derivatives market has been expanding rapidly for the risk management of pension reserve, which is deteriorated by prolonged longevity and low interest rate. We consider risk hedging by the portfolio of longevity swaps and zero-coupon bonds, whose prices depend the interest rate and mortality intensity formulated as the affine class model. We compare the hedging portfolio by local risk-minimization (LRM) of Foellmer-Schweizer on objective probability measure and the portfolio of risk-minimization based on risk-neutral probability measure (RM). By the numerical simulation we estimate expected hedging costs for LRM and RM cases. Hedging cost per annuitant is increased in the RM case under the objective probability on the contrary to law of large numbers. We observe that the hedging by risk-neutral method causes underestimation of longevity risk.

3 - Pension Schemes versus Real Estate
Valeria D Amato, Emilia Di Lorenzo, Steven Haberman, Marilena Sibillo, Roberto Tizzano

Within the context of personal pension products, a new contractual scheme is proposed where an immediate life annuity is obtained by paying a single-premium in real estate form, for example by transferring to an insurer the (full or the) bare property of a house or a similar realty. The level of the instalments depends upon the prospective value of the transferred rights which, in turn, is influenced by the insured's life expectancy (for example, the bare ownership value increases as a function of the usufructuary's aging and turns into full property at his death). Even though the insurer undergoes a financial stress due to the fact that the insurance premium is not paid in cash, on a large scale and long term basis the managerial implications of the development of this kind of contract are not expected to be much different from investing traditional cash premium payments in a real estate portfolio.

4 - Adjustment mechanisms for notional defined contribution pension systems
Susanna Levantesi, Massimiliano Menzietti

Since the mid 1990s a certain number of European countries (among them Italy) implemented a Notional Defined Contribution (NDC) pension system. A NDC system is based on pay-as-you-go (PAYG) funding, while the pension is a function of the individual lifelong contribution. Despite many appealing features, the NDC system is not without drawbacks: it could fail to guarantee adequate pension benefits to pensioners and does not redistribute income towards workers experiencing early mortality, bad health or low-income; due to the PAYG features, such a system is vulnerable to demographic and economic shocks compromising its financial sustainability in the long run. We investigate adjustment mechanisms for a NDC pension system in order to reduce its limits and to introduce some of the advantages of a defined benefit scheme.

■ MB-48

Monday, 10:30-12:00 - 4D UPV B.3

Preparedness and Response in Disaster Logistics

Stream: Humanitarian Operations
Chair: *Sibel Salman*

1 - Minimizing latency in post-disaster road clearance operations
Meraj Ajam, Vahid Akbarighadikolaei, Sibel Salman

Due to a natural disaster, roads and bridges can be damaged or blocked by debris, causing inaccessibility between critical locations such as hospitals, disaster response centers, shelters, harbors, airports and disaster-struck areas. We study the post-disaster road clearing problem with the aim of providing a fast and effective method to determine the route of a work troop responsible for clearing the blocked roads. The problem is to find an open route for the work troop starting at the depot that visits all the critical locations, which are represented by nodes in the road network. The objective is to minimize the total latency of critical nodes, where latency of a critical node is defined as the travel time from the depot to the node. We develop an exact mathematical model for this problem. However, for real-life instances with more than seven critical nodes, the exact formulation falls short of solving the problem optimally in a 3-hour time limit. Hence, in order to find a near-optimal solution in short running time, we develop both an efficient heuristic method based on solving a mixed integer programming model on a transformed network and a metaheuristic method based on Greedy Randomized Adaptive Search Procedure (GRASP) for solution construction, followed by Variable Neighborhood Search (VNS) for improvement, repeatedly. We test both the matheuristic and the metaheuristic on Istanbul data and show that optimal or near-optimal solutions are obtained within seconds.

2 - Performance of alternative linear objective functions in effectiveness fairness trade-off
Gökalp Erbeyoğlu, Ümit Bilge

The quality and the performance of a humanitarian response plan is judged by the timely and fair satisfaction of demand. These two are contradicting objectives since effectiveness ensures the needs are met in a sufficient and timely manner, whereas equity stipulates that all beneficiaries receive comparable service. In this study, we aim to provide alternative linear objective functions that can focus on effectiveness and fairness to distribute relief items to the beneficiaries in the response stage. In our response stage routing model, the vehicles are not assigned to specific depots and tours are open. Furthermore, we assume the demand occurrences are not limited to the initial period. Also demand satisfaction is guaranteed at the end of the planning horizon for all demand points, therefore the proposed objective functions capture both the timeliness and satisfaction levels in a way that their progression is important, rather than their final values. The alternative objectives are employed on a set of test instances and their performance in terms of effectiveness and fairness trade-off are investigated in comparison to various related performance measures in the literature.

3 - A multi-stage stochastic programming model for disaster response planning
Damla Kesikburun, Roozbeh Qorbanian, Sinem Özkan, Deniz Türsel Eliiyi

This study proposes a multi-stage stochastic programming model for disaster response planning. Since it is almost impossible to know the timing and the intensity of any disaster (especially earthquakes), it is very difficult to estimate the impact, damage and resource needs exactly in advance. Thus, the planning problem should be treated as a problem where the randomness arises not only from the demand but also from the supply and route capacity perspectives. Two-stage programming is the most frequently used methodology in stochastic programming for the disaster management field in literature. However, less work has been performed using multi-stage programming, where additional information can be incorporated into the model formulation, allowing more detailed decisions. A sequence of decisions that respond to outcomes evolving over a course of time should be incorporated in most practical decision problems. Hence, our study aims to incorporate a sequence of decisions into the disaster response planning decision problems, through a multi-stage stochastic programming framework. The results of computational experimentation are reported.

4 - Improving post-disaster road network accessibility by strengthening links against failures
Eda Yücel, Sibel Salman, Idil Arsik

We study a network improvement problem to increase the resilience of a transportation network against disasters. This involves optimizing pre-disaster investment decisions to strengthen the links of the network structurally. The goal is to improve the expected post-disaster accessibility. We first propose a new dependency model for random link failures to predict the post-disaster status of the network. We show that the probability of any network realization can be computed using a Bayesian network representation of the dependency model. As the computational effort grows with the network size, we use our proposed dependency model in a network sampling algorithm. We then estimate an accessibility measure, namely, the expected weighted average distance between supply and demand points by checking pre-generated short and dissimilar paths in the sample. We minimize this measure and decide on the links that should be strengthened in a two-stage stochastic programming framework. As the failure probability of a strengthened link decreases, the discrete scenario probabilities depend on the first-stage decisions. To tackle this challenge, we develop an efficient tabu search algorithm. We apply our methods to a case study of Istanbul under the risk of an earthquake, both to illustrate the use of the methods and to derive insights for decision makers.

■ MB-49

Monday, 10:30-12:00 - 4D UPV B.4

IBM Research Applications II

Stream: IBM Research Applications
Chair: *Andrea Simonetto*

1 - Correlation of multidimensional risk factors for pricing water infrastructure insurance
Samuel Chege Maina, Nathan Wangusi

The conventional approach that governments and development partners pursue in mitigating water scarcity in the arid areas of Northern Kenya has been to increase water supply by investing in water infrastructure especially decentralized systems such as boreholes and small dams to meet growing water demands. However, this approach is unsustainable as water infrastructure frequently fail after handover because the communities lack management capacity, resources for repair and maintenance, and finances for replacement of inoperative parts. It can be argued that water security risks to these communities arise predominantly due to failure to manage insurable risks that surround the water infrastructure. The impact of various common sources of risk, for example governance risk as well as endogenous risk are usually ignored or underestimated. Consequently, it would be prudent for financiers to make fewer unsecured investments and instead enable the communities to manage the exposures around existing water infrastructure through insurance. In this paper we investigate the correlation structure between these multidimensional risk factors surrounding water infrastructure. We demonstrate that understanding these interdependencies can form a basis in asset based financing for water assets in Northern Kenya.

2 - Scenario planning for enterprise risk management
Mark Feblowitz

Abstract: Scenario planning is a commonly used method for organizations to develop their long-term plans. In this talk, we show that formulating an AI planning problem, and applying AI planning and plan recognition techniques to develop scenarios, provides a unique advantage for scenario planning. We summarize our experience and the initial results from implementing, deploying, and operating the IBM Scenario Planning Advisor (SPA), a decision support system that uses lightweight semantic models to assist finance organizations in identifying and managing emerging risk, specifically those risks associated with changes in global or local economies, politics, technology, society, and others. SPA takes as input the relevant information from news and social media, representing key risk drivers, and generates scenarios that explain the key risk drivers and describe alternative possible futures. Our approach is complementary to traditional data science techniques for forecasting, in that it encodes domain expert knowledge thus enabling identification of alternatives for which there are few or no prior examples and for which there is little or no predictive data. We provide a characterization of the problem in terms of cost-optimal planning and describe the knowledge engineering methodology and aggregation of alternative future paths (plans) into scenarios.

3 - A federated optimization approach to real-time urban-scale ridesharing
Andrea Simonetto, Julien Monteil, Claudio Gambella

We propose a novel, computational efficient, dynamic ridesharing algorithm. The beneficial computational properties of the algorithm arise from casting the ridesharing problem as a linear assignment problem between fleet vehicles and customer trip requests in a federated optimization architecture. Current literature showcases the ability of state-of-the-art ridesharing algorithms to tackle very large fleets and customer requests in near real-time, but the benefits of ridesharing seem limited to centralized systems. Our algorithm suggests that this does not need to be the case. By leveraging the New York City taxi database, we show that with our algorithm, real-time ridesharing offers clear benefits with respect to more traditional taxi fleets in terms of number of used vehicles, even if one considers partial adoption of the system. In fact, the quality of the solutions obtained in the state-of-the-art works that tackle the whole customer set of Manhattan is achieved, even if one considers only a proportion of the fleet size and customer requests. This could make real-time urban-scale ridesharing very attractive to small enterprises and city authorities alike.

■ MB-50

Monday, 10:30-12:00 - 4D UPV 1.1

OR for Developing Countries I

Stream: OR for Developing Countries
Chair: *Gordon Dash*
Chair: *Nina Kajiji*
Chair: *Herman Mawengkang*

1 - Impact of world heritage site designation on tourism industry growth in developing countries: the super slack-based Malmquist index approach
Seyedkeyvan Hosseini, Agnieszka Lejkowska

This paper examines the impact of UNESCO World Heritage Site (WHS) designation on tourism industry growth in developing countries. None of the previous studies concentrated on the global scale efficiency comparison related to WHSs. In this research, by using non-radial super slack-based Malmquist Index (MI) measure, we first investigate the efficiency of tourism industry in twenty developing countries with greatest number of WHSs, to further examine the productivity change for the period of 2011-2016. To identify the impact of sites quantity on tourism, the study calculates the correlation between the MI scores and the number of WHSs. The results from this research revealed that the MI scores are positively correlated with number of WHSs. The conducted analysis indicates that WHS designation is beneficial for tourism sector in developing countries, and can be used as a promotion tool.

2 - Vaccination tour planning in remote areas of South India
Georg Gutjahr, Prema Nedungadi

We consider the problem of routing multiple teams of health workers who provide vaccinations for remote villages in Kerala, South India. Some of the villages are in mountain or jungle areas and are only accessible by foot.

In this talk, we will formulate the routing problem as a bi-objective team orienteering problem with rich constraints. The two objectives are to minimize the travel time and to maximize vaccination coverage. The model includes changes of the mode of transportation, where teams have to leave behind jeeps in villages in order to track through rough terrain. Problem specific constraints include a vaccine-cold-chain constraint and an overnight-stop constraint, requiring that each travel must not exceed a certain closing-time in the evening.

Data from a vaccination campaign organized by the Amrita Institute of Medical Science, Kochi, is used. The set of Pareto-optimal solutions is computed by an epsilon-constraint method. Small instances of the problem are solved by branch-and-cut, and larger instances are solved by a genetic algorithm.

3 - Social contact network models for measles control strategies in Tanzania
Seán McGarraghy, Herieth Rwezaura

Vaccination is a significant control measure for airborne infectious diseases such as measles. With resurgences of measles outbreaks, there is a need to find optimal (or at least improved) vaccination strategies, especially in the context of constrained health care resources, as is the case in Tanzania. We apply Operational Research techniques within a public health setting to this end. We use a SEIR (Susceptible, Exposed, Infected, Recovered) vaccination model allowing vaccination of a proportion of the population before or at any point during an outbreak of measles. We apply a social contact network epidemiological modelling approach to examine what vaccination strategies (e.g., mass or targeted) can effectively control measles. Vaccination of individuals against an infectious disease corresponds to the removal of vertices in a contact network. The social contact networks of individuals in Tanzanian villages are generated based on demographic, age, time use and other data. Computer simulations are used to study the spread of disease in various vaccination scenarios. Our findings suggest using a targeted vaccination strategy, particularly in vaccinating children of 6 months to 15 years of age, but also in vaccinating older age groups who were born before or missed the second dose schedule. Our conclusions apply to measles' vaccination theory, practice and policy not only in Tanzania but also in other developing countries that face constrained health care resources.

4 - Efficiency assessment of smart sustainable cities based on network data envelopment analysis
Sadiye Sadanoglu

City performance assessment methods are beneficial to provide support for decision making in urban development. The fast growth of urbanisation creates concerns about the sustainability of cities. The smart city frameworks are mainly focusing on modern technologies and smartness in the smart city rather than urban sustainability. Moreover, the urban sustainability frameworks focus environmental sustainability. Therefore, smart city frameworks are lack of environmental indicators while focusing on mainly economic and social aspects. However, the focus of smart cities is to improve sustainability with the support of technology. Hence there is a gap between smart city and sustainable city frameworks. To overcome this gap, we propose a framework which can explain smart sustainable city from three main perspectives: economic, social and environmental. To assess the efficiency of urban sustainability and smart city efficiencies the traditional Data Envelopment Analysis (DEA) used. However, the traditional DEA treats Decision Making Units (DMUs) as a black box by only considering initial inputs consumed and final outputs produced by them. Therefore, the traditional DEA models cannot sufficiently characterize the performance of cities. Apart from the need for a new framework, there is also a lack of understanding of how cities main three sub-systems: environment, economy, resources, and energy should be assessed, considered and their impact on the efficiency of urban sustainability.

■ MB-51

Monday, 10:30-12:00 - 4D UPV 1.2

OR for Sustainable Built Environment

Stream: OR for Sustainable Development
Chair: *Tatjana Vilutiene*

1 - Optimum design of bridges considering long-term criteria
Tatiana Garcia-segura, Víctor Yepes, Eugenio Pellicer, Laura María Montalbán Domingo

Multi-objective optimization is a commonly used tool to find multiple trade-off solutions. However, a large computational time is needed to check the solutions to certain structural problem. This communication presents a meta-model assisted multi-objective optimization to optimize bridges under multiple objectives. Artificial neural networks (ANNs) are integrated in the multi-objective optimization to reduce the high computational cost required to evaluate the constraints of a real bridge optimization problem. ANNs are trained to predict the structural response in terms of the limit states based on the design variables, without analyzing the bridge response. This methodology is applied to a continuous post-tensioned concrete box-girder road bridges formed by 34 variables regarding the geometry, the concrete grade and the reinforcing and prestressing steel. The objective is to find the optimal bridge design so that the cost of the deck is minimized and the overall safety factor with respect to the ultimate limit states and the corrosion initiation time due to chloride is maximized. The corrosion initiation time and safety criteria are included as objective functions for further deepening in the durability and safety requirements with the aim of designing for longevity and reduced long-term impacts.

2 - Integrated advanced technologies for sustainable BIM-based building refurbishment
Jovita Starynina, Leonas Ustinovichius, Mantas Vaisnoras

Building Information Modelling (BIM) is a collaborative way of working, supported by digital technologies. Computer model that has several 'dimensions' can be used for effective management of information throughout a project lifecycle - from the earliest concept of operation. BIM-based processes are 'mainstream' for new buildings and infrastructure and have potential in sustainable refurbishment projects when complementary workflows such as building scanning. Despite the fast development and spreading standards, challenging research opportunities arise from process automation and BIM adaptation for existing buildings' requirements. To aid decision-making, building simulation is widely used in the late design stages, but its application is still limited in the early stages in which design decisions have a major impact on final building performance. Using building scanning visualization in early design stage helps fully assess the environment of the future, accept design solutions, prevent mistakes and provides rapid changes of the design. 3D scanning technology is simply an incremental technological advancement of surveying, providing a safer, richer and more rapid method of spatial data acquisition for surveying applications. 3D laser scanning or 3D reality meshes from photographs data brings myriad opportunities to project managers, and engineers to monitor, assess, and analyse physical data captured from the existing environment.

3 - Empirical study of BIM-based building life cycle: case of Net-UBIEP project
Tatjana Vilutiene, Arvydas Kiaulakis

The building sector is the largest consumer of energy in Europe, accounting for nearly 40% of the total consumption (EPBD 2010/31/EU). 2030 European Energy [COM(2014)16Final] and Energy Roadmap 2050 [COM(2011) 885 final], strongly requires more focus on the energy efficiency on housing sector. The Directive 2014/24/EU on public procurement, requires that all member states introduce electronic means to exchange information and communication in procurement procedures. The integrated approach of the Net-UBIEP project, based on BIM, integrated with energy performance requirements, will be key to solve all the problems in a more effective and efficient manner. The project proposes BIM Qualification Models integrated with energy competences, to widespread a better comprehension of energy issues along all the value chain of building industry so that both existing and new building will have better energy performances. Article presents the process of identification of specific energy BIM competences for each target group needed to implement BIM models during the whole building life cycle. Data for analysis was gathered by use of direct and indirect observation and experiences of construction sector experts. During the project the "integrated" BIM Qualification Models will be validated by stakeholders and proposed for standardization to find a broader acceptance at European and international level through regulatory organizations (CEN/ISO).

■ MB-52

Monday, 10:30-12:00 - 4D UPV 1.3

Health Care Modelling (ORAHS) I

Stream: OR for Health and Care I
Chair: *Sally Brailsford*

1 - Patient flow model for the EMS in the Netherlands
Geert-Jan Kommer

The provision of emergency medical services (EMS) is an important health care activity and should be available and accessible at all times. Recent trends in the Netherlands show bottlenecks in health care provision are increasing and result in decreasing performance of health care suppliers. Longer waiting times and blocking at emergency departments (ED's), increasing ambulance response times and, in the Netherlands, long waiting times for out-of-office GP-services are typical. The bottlenecks have a regional character. In urban areas, demand for EMS per capita is higher than in rural areas, despite the high number of elderly in many rural areas. Organizational aspects also play a role in performance. EMS-providers show differences in patient flows, in terms of input, throughput and output of the (sub-)system. In our study, we developed a SD patient flow model for the EMS in the Netherlands. We used patient data of health care use over the years 2012-2015 to describe patient flows in the acute care network in time and construct a baseline scenario that shows future developments based on demographic developments and recent trends in EMS. This baseline simulation shows expected development of the current bottlenecks. Alternative scenarios in which we search for a more balanced supply of EMS are examined. The results provide policy makers insight in possible future developments and alternatives to manage the increasing bottlenecks in EMS.

2 - Developing a simulation tool to support decisions around the commissioning of anticoagulation services for patients with atrial fibrillation
Christos Vasilakis, Neophytos Stylianou

Atrial fibrillation (AF), an arrhythmia characterized by chaotic electrical activity in the atria, is a public health problem affecting countries experiencing aging population ageing. AF not only increases the risk of stoke five-fold but a stroke suffered by this group of patients are more significant and result in more serious harm and greater mortality. Historically, Warfarin and aspirin have been the treatments of choice but recent guidance states that aspirin should not be used as a monotherapy. More recently a new class of drugs was developed, Novel Oral Anti-Coagulants (NOACs), which aim to treat AF while avoiding some of the drawbacks of Warfarin. However, each treatment comes with costs and benefits for both the patient and care system which need to be taken into account when planning the organisation of stroke prevention services at a regional or national level. Our aim was to develop a prototype modelling software tool to help with decisions around the organisation of anti-coagulation and stroke prevention services at regional level. Specifically, we constructed a stochastic simulation model representing patients with AF on different treatments and their respective outcomes. We implemented a prototype software tool to allow the execution of computer simulation experiments. Finally, we experimented with a number of showcasing scenarios that evaluate the likely impact of changes of in the mixture of medication treatments on patient and system level outcomes.

3 - Medication inventory management for automatic dispensing systems
Vera Tilson, Gregory Dobson

We discuss mathematical programming formulation for optimizing inventory handling costs by setting minimum and maximum par levels for automatic dispensing machines.

4 - Hybrid simulation for healthcare
Sally Brailsford

Healthcare is the largest single application area for hybrid simulation, i.e. models that combine more than one simulation approach. Most healthcare problems are highly complex, with many different features, and it is rarely possible to capture all of them using only one approach. For example, population level aspects are better modelled using system dynamics, to account for feedback effects and the flows of patients over time, whereas the operational aspects of healthcare delivery systems to manage these patients are better represented using the detailed stochastic approach of discrete-event simulation, due to the existence of queues, resource allocation issues and individual variability. In this talk we describe some examples from the literature, and discuss other reasons for the popularity of healthcare in this rapidly growing area.

■ MB-53

Monday, 10:30-12:00 - 4D UPV 1.4

Quality Control Applications

Stream: OR in Quality Management
Chair: *Javier Neira Rueda*

1 - A metaheuristic method for quality control chart design under autonomation
U. Mahir Yıldırım, Ozgur Toy

In systems where autonomation is employed, individual machine stoppages may create an inspection opportunity for the other machines in the system. A significant decision to be made at this point for each machine is to determine whether it will be an opportunity-taker or not. In addition, this decision is directly related to the state of the machine, being under control or not. In this study, we consider the design of control charts in the presence of machine stoppages that are exogenously imposed under autonomation and propose an evolutionary algorithm to determine the control parameters that will minimize the total cost. Our findings indicate that incorporating inspection/repair opportunities into quality control chart design provides considerable cost savings.

2 - Showing the impact of processes improvements on the performance of Khorasan Regional Electricity Company (Mashhad, Iran) using the six sigma strategy
Khatere Ghorbani-Moghadam, Narjes Sabeghi, Ladan Behroozi, Hamid Reza Yousefzadeh

Six Sigma is a widely used method to improve processes from various industry sectors. This approach accepts the consumer as the focal point. Six Sigma approach is such a model that is adapted by various companies throughout the world due to its consumer-oriented approach and this model aims the continuation of company success. Six Sigma is a strategy using statistical methods to provide measure, analyze, renovate and control optimal efficiency in business processes. Six Sigma improving methodology is a reactive approach. This approach aims to identify the causes of the problems, the selection of the optimal quality control parameters and the improvement of the time spent and the profitability. In order to establish these objectives, DMAIC (Define, Measure, Analyze, Improve, Control) cycle is used. In this paper, the main aim is to analyze the effects of proposed improvements on Khorasan Regional Electricity Company (Mashhad, Iran), using the Six Sigma strategy. To demonstrate the success of the proposed improvements on the performance of the Khorasan Regional Electricity Company (Mashhad, Iran), from the five steps of DMAIC, we use the measurement step. We find Number of Defects and Number of Opportunities and then by using them we compute sigma level before and after improvements. We observe that the level of sigma increased after using improvements and this easily shows the positive effects of improvements.

3 - Control charts for highly censored observations on the left. A contribution to processes with censored observations
Javier Neira Rueda, Andrés Carrión

TThe need to monitor industrial processes, detecting changes in process parameters in order to promptly correct problems that may arise, generates a particular area of interest. This is particularly critical and complex when the measured value falls below the sensitivity limits of the measuring system or below detection limits, causing much of their observations are incomplete. Such observations are called incomplete observations or left censored data. With a high level of censorship, for example greater than 70%, the application of traditional methods for monitoring processes is not appropriate. It is required to use appropriate data analysis statistical techniques, to assess the actual state of the process at any time.

This technique has already been developed by SH Steiner and RJ Mackay and called CEV Control (Conditional Expected Value) based on replacing each observation censored by a CEV value, where the parameters of position and dispersion of a data set are estimated and subsequently monitored. Recently contributions have been made to the parameter estimation algorithm and we expose the sampling properties and the power its control graphs using the ARL (average running length) and characteristic OC curves for samples data containing censored observations.

■ MB-54

Monday, 10:30-12:00 - 4D UPV 1.6

Multiobjective Decision Support

Stream: Energy Economics, Environmental Management and Multicriteria Decision Making
Chair: *Jochem Jonkman*

1 - A multi-objective methodology applied to decision support for high-pressure thermal processes in food treatment

Benjamin Ivorra, Miriam Ruiz Ferrández, Juana Lopez Redondo, Pilar M. Ortigosa, Angel Manuel Ramos

In this work, we propose a methodology for designing High-Pressure Thermal processes for food treatment. This approach is based on a multi-objective preference-based evolutionary optimization algorithm, called WASF-GA, combined with a decision strategy which provides the food engineer with the best treatment in accordance with some quality requirements. The resulting method is compared to a mono-objective optimization algorithm called MLS-GA. To do so, we consider several mono-objective and multi-objective optimization problems. Then, considering those cases, we determine an adequate set of parameters for WASF-GA in order to obtain a reasonable compromise between solution quality and computational time. Additionally, the best solutions returned by WASF-GA are analyzed from a food engineering point of view. Finally, a sensitivity analysis regarding the impact of design parameters on the performances of those solutions is carried out.

2 - Multi-objective optimization for metering device location in water supply networks

Joaquín Izquierdo, Jorge Francés-Chust, Manuel Herrera, Idel Montalvo Arango

Advances in low powered sensors and data transmission are making their way on the creation of smarter water networks. Despite prices are getting attractive, the return on investment is far from being clear for many water company managers in the water supply industry. To arouse managers' interest in the implementation need of an adequate lattice of sensors across their water supply networks (WSNs), and to support them in the implementation, three important questions should be first answered that should be clearly perceived as main support elements in ad hoc decision-making: firstly, how many sensors are needed; secondly, where sensors should be located to get the most out of them; and, finally, what their measurements will bring in terms of improving operation and customer services. This contribution addresses the second of these questions without forgetting the other two. Because of the nature of the objectives involved, the decision about where to locate sensors in a WSN, even under a tight budgetary constraint on the number of them to be installed, is a very challenging problem. Using the Agent Swarm Optimization framework, a consolidated multi-objective optimization algorithm, we develop a solution to the problem, which enables managers to fully explore cost-benefit alternatives. On top of evolutionary search techniques, the algorithm adds rule-based agents to more efficiently explore the decision space. To illustrate the solution process, a mid-size WSN is considered.

3 - A goal-programming model for the WEEE recovery operations planning

Sule Itir Satoglu, Alperen Bal

Global concerns about climate change and its environmental consequences, social factors and economic constraints require pursuit of a new approach to the supply chain planning at the strategic, tactical and operational levels. The approach used in investigating sustainability is described as the Triple Bottom Line (TBL) accounting (Anvari and Turkay, 2017), which states that economic, environmental and social requirements must be reached at a minimum (Jeurissen, 2000). Especially, recovery of waste electric and electronic equipment (WEEE) has become an important issue, globally. Manufacturers are under pressure due to the market trend and the environmental regulations (Kumar and Putnam 2008). In this context, this paper addresses the issue of the process of collecting WEEE products from service points, transporting them to recycling facilities, and recovery of the waste material. Our framework considers TBL approach and employs goal programming to reach economic, social and environmental targets. A multi-facility, multi-product and multi-period goal programming model is proposed, considering the real conditions, for the first time in the literature. Besides, this goal programming approach is illustrated on a WEEE reverse supply chain of the household appliances. The four goals of the model are total net cost, emission, workforce balance and legal WEEE collection targets.

4 - Decision support modelling for food processing chains

Jochem Jonkman, Jacqueline Bloemhof, Albert van der Padt

The current set-up of food processing chains is one of the main causes responsible for the inefficiency of the food industry. Typically, agro-food industrial companies produce refined and standardized intermediates, which are mixed and further processed by the food assembly industry into final consumer products. These two stages in processing lead to potentially avoidable losses. A more integrated design of food processing chains avoids such losses, using for instance different intermediates, processing pathways, and supply chain configurations. For the design of such chains, the specific characteristics of food products, food processing, and food supply chains have to be taken into account, and decisions regarding the selection of intermediate and final products should be included. To deal with this design problem at the product, process, and chain level, both the fields of supply chain management and process systems engineering are required, bridging the gap between these fields. Using mixed integer programming, we show that using alternative intermediates and processing pathways leads to improved chain performance from both an economic and an environmental viewpoint. Which processing pathways are optimal is however dependent on the regional and seasonal supply chain characteristics. Additionally, aligning the activities within the supply chain requires collaboration to distribute gains and burdens in a fair way among the supply chain actors.

■ MB-55

Monday, 10:30-12:00 - 4D UPV 2.1

Measuring Impact of OR projects...and Beyond!

Stream: Making an Impact I
Chair: *Matteo Pozzi*

1 - Measuring impact of OR projects...and beyond!

Matteo Pozzi

The first conference of the Euro Working Group on Practice of OR was held in Paris-Saclay in February, resulting in an exceptional opportunity for more than 40 top level practitioners from various industies to confront each other on the issue of ""measuring the impacts of OR projects"". Starting from the key highlights of the event, this session is aimed at carrying on this discussion leading towards the next event, to be held in Bologna next winter. Come if: - you were in Paris and cannot wait to bring this forward; - you are keen to see how OR is applied in the real world; - you have been wondering about what are the best KPIs to demonstrate the impacts of your OR models; - you are curious to know what interests the most in the community of industrial & service players who use OR to innovate and improve their processes. Bring your own views, share them with us, join the community, contribute with your own experience to help OR becoming increasingly relevant in the industry.

■ MB-56

Monday, 10:30-12:00 - 4D UPV 2.2

Optimization in Renewable Energy Systems I

Stream: Optimization in Renewable Energy Systems
Chair: *Adelaide Cerveira*

1 - Techno-economic and environmental efficiency in electricity generation in Latin America: a dual DEA approach

Felipe Henao, Julián Benavides, Juan Pablo Viteri

There is an ever-growing pressure for countries all around the globe to have electricity systems less dependent on fossil fuels and technically efficient in order to be sustainable and competitive.

In this paper, we employ a Data Envelopment Analysis (DEA) approach to modelling the techno-economic and environmental performance of the electricity mix of 19 Latin American countries, over the last ten years, from the production efficiency point of view. We employed data from 2006 to 20015 that were retrieved from the International Energy Agency (IEA), the Latin American Energy Organization (OLADE) and the World Bank, in order to measure the performance of the electricity generation of these Latam countries. These included technical aspects such as power capacity, distribution losses, imports, exports, production and prices, and also environmental data like the countries' endowment on renewable resources, CO2 emissions, and the level of land and water usage for electricity generation.

Two different DEA models were computed in order to calculate the countries' performances from the techno-economic and environmental points of views. The approach allows identifying the efficiency trends within the region as well as the trade-offs between these two apparently conflicting perspectives (the techno-economic and environmental). This will inform governments and policy makers about the appropriate electricity mixes at country-level.

2 - The net demand methodology applied to wind power generation series in a long-term energy planning context

Fernando Luiz Cyrino Oliveira, Paula Maçaira, Yasmin Cyrillo, Reinaldo Souza, Gustavo Amador

In recent years, the expressive growth of wind power generation share in the Brazilian electricity matrix has increased the need of adapting the way in which the electric system is planned. In the short-term (one-day-ahead), the National System Operator (ONS) has a model that provides the wind power generation forecasts for operational purposes. Regarding the long term, the official approach calculates the expected value of monthly wind power generation and deducts it from the expected value of the load, before the optimization process is carried out by a stochastic dynamic optimization process to produce the optimal hydrothermal dispatch. In this context, our paper proposes a model that incorporates the wind power generation variability using the Frequency and Duration (F & D) method, which combines wind power generation and system load states through a Markov Chain and discrete convolution techniques in order to obtain the so called Net Demand (ND). A case study is performed on wind power generation for the Northeast and the South regions, using the current and proposed methods. The results were applied in the medium-term energy planning optimization in order to compare the impact on the reservoirs stored energy by both techniques. The results show that the ND is capable of representing a variability of the wind source and is an alternative for the improvement of the current medium to long term hydrothermal optimal dispatch methodology.

3 - Energy markets: methods for optimization of transport infrastructure

Olesya Grigoreva, Alexander Vasin

Markets of energy resources play an important role in economies of many countries. Every such market includes its own transmission network system. We consider the welfare optimization problem with account of the production costs, consumers' utilities and the costs of transmission lines expansion. A formal model for transmission system's optimization generalizes two well-known optimization problems. The first one is the transport problem. The second related problem is the social welfare optimization for a market with several goods under perfect competition. The optimal solution of our problem determines the maximal total welfare value that can further be reallocated in order to obtain any Pareto-optimal outcome. The difficulty of the problem is that an expansion of any line requires valuable fixed costs. If the optimal set of expanded lines was known, the problem would be convex. However, the efficient search of this set requires special methods. The problem in general is NP-hard since the transport problem with non-convex transmission costs is NP-hard. For a market with a tree-type network we propose the method of S-D balance transfer to the root of the tree. The method proceeds from the known Welfare Theorem and provides a precise solution of the problem without fixed costs. In general the method permits to obtain an approximate solution and estimate the welfare loss. We also determine sufficient conditions for the solution to be precise.

4 - Optimizing the design of wind farms with ditch sharing

Adelaide Cerveira, Amaro de Sousa, Eduardo Pires, José Baptista

Environmental issues have been under debate around the world. One subject that has been highlighted is the pollution derived from the energy production which is indispensable for the survival of the present population way of life. In this way, clean forms of production have been promoted. The wind energy is one of the renewable power energies with fastest growing over the last years and, hence, it is important to optimize the production efficiency of the wind farms. This work focuses on the design of the cable network connecting the wind turbines of a wind farm, that generate electric power to the central substation which collect the produced energy. The aim is to minimize not only the network setup costs (cable costs and digging costs) but also the energy costs involved in energy losses, over the farm lifetime. Several cables types, with different cross sections, are available and the ducts may be shared between several cables. Although this problem is nonlinear, integer linear programming models are proposed considering the wind farm technical constraints. The proposed models are applied to real case studies and the computation results are analyzed.

Acknowledgements: This work is partially funded by the ERDF through the COMPETE 2020 Programme within project POCI-01-0145-FEDER-006961, and by National Funds through the FCT as part of project UID/EEA/50014/2013.

■ MB-57

Monday, 10:30-12:00 - 4D UPV 2.3

Algorithms for Sequencing

Stream: Computational Biology, Bioinformatics and Medicine

Chair: *Aleksandra Swiercz*

1 - Combinatorial models for biomolecule structure alignment

Piotr Lukasiak

3D models of biomolecules exhibit deviations from the corresponding reference structures. Having that in mind, there is a need to develop structural quality assessment methods, that can be used to reliably identify limitations of structural models in order to choose native-like models. Huge variety of methods have been proposed to address this challenge in single mode assessment and consensus mode assessment to rank several models proposed for the same target molecule. Consensus-based methods perform generally well, but they are hard to use for researchers mainly focused on analysis of a single structure. Unfortunately, the performance of single model methods is relatively poor with reference to consensus methods. We proposed a novel approach for quality assessment of a single model, based on the hybrid GDT methods as well as on the paradigm of local substructures, called descriptors. Proposed methodologies can be successfully applied in the process of model quality assessment. Suggested solutions can make the evaluation process more interactive from the domain expert point of view. With the proposed algorithms also new libraries of biomolecule descriptors can be derived and applied during structure modeling experiments.

2 - Operator assignment in parallel assembly cells with cell loading and product sequencing
Yiyo Kuo, Yen-Po Chen, Yu Cheng Wang

This research proposes an operator assignment problem in which cell loading and product sequencing are taken into account in parallel assembly cells. In the assembly cells, more than one tasks can be assigned to each operator. Because the assembly procedure and time required for each assembly task are quite different for different products, when the product changes some tasks have to be transferred to keep balanced workload between operators. The less number of task transfers the more smooth of product change. A methodology with three mathematical models is proposed to minimize the total manpower required and task transfers. Moreover, another methodology which minimizes the total manpower required and task transfers hierarchically is also applied for comparison. Finally a case study from a bicycle assembly company is introduced. The results show that the proposed methodology can provided the solution with fewer task transfers under the same manpower level. However, results also show that when the number of products increases, the computation time of the proposed methodology increases rapidly.

3 - New validation methods for complex biological systems analysis based on time-dependent Petri nets
Jakub Olszak, Marcin Radom, Piotr Formanowicz

Various types of Petri nets have been used to model complex biological systems. Their intuitive graphical representation is very helpful in understanding dependencies between components in such systems. Classical (qualitative) Petri nets are frequently used to describe a structure of a modeled system. An analysis of qualitative models can lead to discoveries of important properties of the investigated biological phenomenon. However, extending the qualitative model by data concerning time dependencies between the system's components can result in a much more precise model. As a consequence, new validation methods may be proposed and more precise analysis can be performed.

In this work problems concerning Time Petri nets (TPN) and Timed Petri nets (DPN) are discussed. In TPN a transition may be fired only within a given period of time. In DPN there are specified amounts of time which firing of every transition takes. Analysis methods for both of these cases are discussed. Moreover, a new validation method for t-invariant analysis is proposed. In particular, an algorithm for a calculation of the minimal and maximal numbers of tokens (in the most optimistic and the most pessimistic cases) required for transition firing is presented. The usefulness of the proposed methods is illustrated on the basis of a real biological system.

This research has been partially supported by the National Science Centre (Poland) Grant no. 2012/07/B/ST6/01537.

4 - An OLC approach to De Novo assembly - GRASShopPER assembler
Aleksandra Swiercz, Wojciech Frohmberg, Michal Kierzynka, Pawel Wojciechowski, Piotr Zurkowski, Jan Badura, Artur Laskowski, Marta Kasprzak, Jacek Blazewicz

Next generation sequencers produce billions of short DNA sequences in a massively parallel manner, which causes a great computational challenge in accurately reconstructing a genome sequence de novo using these short sequences. We propose the GRASShopPER assembler, which follows an approach of overlap-layout-consensus. At the beginning, an overlap graph is constructed from all high quality input reads (they constitute vertices of the graph). Calculating the alignment of the reads is performed first, by a heuristic algorithm, that selects only those pairs of reads that are likely to overlap, and next, by the exact algorithm for the sequence alignment running on GPUs. In the overlap graph, arcs are created only for those pairs of reads having the number of misaligned letters on the overlapping section below a given threshold. For the constructed graph, the algorithm continues with traversal method in order to find paths. A greedy hyper-heuristic algorithm detects forks along its way and unambiguous paths are translated into contigs. The computational experiment performed on the benchmark data sets of bacteria Candidatus Microthrix, nematode Caenorhabditis elegans, and human chromosome 14 were evaluated with the golden standard tool QUAST. In comparison with other assemblers, GRASShopPER provided contigs, which covered the largest part of the genomes, at the same time, keeping the good values of other metrics, e.g., NG50 or misassembly rate.

■ MB-58

Monday, 10:30-12:00 - 4D UPV 2.4

OR in Regular Study Programs

Stream: OR Education
Chair: *Gerhard-Wilhelm Weber*

1 - Econometric modeling of the determinants of academic achievement of students of a university in Chile
Hanns de la Fuente-Mella, Laura Villalón

In this research the determinants of academic performance of undergraduate students of a career at a university in Chile will be studied. Thus, initially the variables that affect the academic performance of the students will be identified, later an econometric model of panel data will be established to determine and interpret the academic performance of the students, and finally, how the different variables affect the academic performance will be analyzed, wich to help the application of corrective measures through the simulation of scenarios. The expected results show that variables such as: school of origin, middle school grades, place of origin of the student, education of the mother and gender, have a significant effect on the expected performance of the student.

2 - Language at home and student math performance in tertiary education: evidence from a German case study
Nora Dörmann, Horst Entorf

Our case study considers the mathematics performance in tertiary education at a German university. This fundamental education is crucial for students' further studies not only in statistics but also operations research. We analyze the impact of not speaking the course language at the parental home on student performance. Moreover, we analyze whether remedial pre-courses help underachieving students to catch up. Our results suggest that the well-known language-related educational gap between migrants and native students continues to persist in tertiary education. While we find that, in general, weaker students benefit from participating in pre-courses, students with language disadvantages fall (further) behind native and non-disadvantaged migrants. This conclusion follows from the significantly negative effect of not speaking the German language at home on grade achievement.

3 - Voice recognition algorithm applied to processes of authentication in distance education
Guadalupe Pascal, Julián E. Tornillo, Oscar M. Pascal, Javier M. Moguerza, Andrés Redchuk

Since the beginning, distance education has allowed to strengthen teaching and learning processes. There are many examples that provide evidence that the virtual learning allows to bring fields of knowledge closer to sectors of society where face-to-face education has not achieved it. However, there are still unsolved problems. In fact, distance education is currently an object of study and criticism itself.

One of unresolved issues at the time corresponds to the mechanisms to assess the authentication of students at the time of conducting the evaluations.

In this work, we present a pattern recognition model based on the use of Hopfield's neural networks embedded in the Moodle environment. Hopfield's neural networks serve as associative memory systems, initially trained to recognize faces, audio and several patterns with binary threshold nodes. In our research, the model is applied to solve the authentication problem with student's voice patterns through audio recorder plugins at the beginning of the evaluations.

4 - Master's degree program on game theory and operations research
Yaroslavna Pankratova, Leon Petrosyan, Elena Gubar

Since 2014 year the two-year master's degree program in Game Theory and Operations Research prepares a student for a career in industry, science and education. The program facilitates learning in modern concepts, techniques and methods in the game theory and leads the student to different functional areas of operations research. The master's degree program on Game Theory and Operations Research was developed to study the theory and methods of operations research, game theory, econometrics, applied statistics, decision theory, queuing systems, and applications of computer technologies in operations research. The students are involved in research projects connected also with computer science, inventory and project management, joint venture, network modeling, propagation and epidemic models, bioinformatics and related topics. For the first two terms, the core courses will focus on the fundamentals of game theory, operations research, statistics and econometrics —taught from a global perspective. The second year students will then have an access to the pool of special courses correspond to individual interests and career goals. At the end of the program each student defends the final research project as master dissertation. The publication of results in scientific journals and presentations on international OR and Game Theory conferences are highly welcomed.

■ MB-59

Monday, 10:30-12:00 - 4D UPV 2.5

OR Advances in Agri-Food Systems

Stream: OR Advances in Agribusiness
Chair: *Jorge E. Hernández*
Chair: *Leandro Antonelli*

1 - A decision support model integrating quality data in fresh food supply chains
Magdalena Leithner, Christian Fikar

In order to support the management of organic food logistics operations, this work integrates food quality models in a simulation and optimization-based decision support system (DSS). The simulation model allows the incorporation of uncertain and varying supply and demand over time. The DSS analyzes the effects of varying handling temperatures and decisions along supply chain processes on food quality and losses. Sustainable deliveries of organic fresh food from farmers over distribution and storage centers to retail stores are modeled. The joint observation of product quality information and logistics operations enable decisions, well adapted to product characteristics considering interdependencies between product quality and chain design. Computational experiments of a regional strawberry supply chain in Lower Austria investigate the impacts of consolidation strategies at cold stores, the impacts of demand fluctuations as well as stock rotation schemes. Results show that tailored deliveries and consolidation strategies reduce food losses and travel distances. Furthermore, the integration of product data in supply chain decisions enables a pro-active management of product flows, which homogenizes product quality and increases product availability.

2 - How to support decision making processes in agribusiness through the GRUS system
Pascale Zaraté, Amir Sakka

This communication aims at the presentation several scenarii identified within the RUCAPS European project for which a support is developed. The Group Decision Support System (GDSS) called GRoUp Support (GRUS) is used on the basis and the defiend scenario. One scenario deals with the tomato production while anothe rone is about standard design for food security.

3 - The use of glossaries to define consistent models on agricultural contexts
Leandro Antonelli, Alejandro Fernández, Jorge E. Hernández

The agricultural practices vary in the different regions of the world. The diversity of weather conditions, soil, flora, and fauna, demands, for example, specific irrigation system and plant health check. Moreover, different countries have different regulations about the use of material (i.e., plastic and wooden), chemicals and techniques. Thus, even though the harvest cycle is the same: soil and material preparation, fertilization, disease management, and so on; every step is performed differently. In order to perform global analysis and find solutions to be applied in several contexts simultaneously, it is necessary to relate and find the equivalences among the different practices. This work proposes a technique to analyze descriptions in natural language of the different agricultural practices with the aim of finding similarities and equivalences. Thus, a unified description can be used as input to produce mathematical models. In particular, we use the Language Extended Lexicon (LEL), a glossary that defines symbols (words and phrases), through two attributes: notion and behavioral responses. The notion provides a description as a regular dictionary does, while the behavioral responses describe the tasks related to the symbol. The proposed technique consists in analyzing the similar patterns in the behavioral responses to find the equivalences. We have worked with only one language, but we think that we can extend our work to be used in a multilanguage environment.

4 - Mathematical models of food security
Natalia Meshcheryakova, Fuad Aleskerov, Sergey Shvydun

Food security has always been one of the core issues in the matter of welfare of countries. The problem of food quality, accessibility and availability should be considered properly by all countries as a huge number of them suffer from a lack of access to enough good, healthy and culturally appropriate food nowadays. There are a lot of factors that influence food safety of economics from internal factors such as their production and consumption level to external factors such as trading with other countries. Taking into account all these crucial components we analyze the problem of food security in the context of network analysis. We focus on particular products (wheat, rice and chicken meat) that are considered by experts to be most important in the field of food sufficiency. Our main focus is the analysis of how countries influence each other's food security through trading process both on individual product level and in general. We also analyze how the world trading network structure have changed over the past twenty years in the context of influence on food security, major monopolists, clustering groups, etc. Additionally, we examine the changes in trading boundaries between countries through the considered period.

■ MB-60

Monday, 10:30-12:00 - 4D UPV B.5

Meet the editors ITOR

Stream: EURO Special Sessions
Chair: *Celso Ribeiro*

1 - Meet the Editors - International Transactions in Operational Research (ITOR)
Celso Ribeiro, Kenneth Sörensen, Luk Van Wassenhove, M. Grazia Speranza

The General Editor and some Associate Editors of the International Transactions in International Research (ITOR) will present the editorial policy and some facts, characteristics, and statistics of the journal, as well as some publication trends and good publication practices. Associate Editors will present trends and current boundaries in some specific areas and will discuss the kind of contribution the journal expects in each of them. The editors will answer some general questions from the audience.

10:30 - 11:00: Celso C. Ribeiro (General Editor), "ITOR - Statistics and publication trends"

11:00 - 11:30: Kenneth Sorensen (Associate Editor), "Metaheuristics: The metaphor exposed - and revisited" (an updated vision of the most cited paper published in ITOR)

11:30 - 11: 45: Luk Van Wassenhove (Associate Editor), "Pushing the boundaries of Operations Management"

11:45 - 12:00: Maria Grazia Speranza (Associate Editor), "Trends in Transportation and Supply Chains"

Monday, 12:30-14:00

■ MC-01

Monday, 12:30-14:00 - UPV Nexus

Systems Modeling Impacting Policy: The Role Of Group Model Building In Cambodia

Stream: Keynotes
Chair: *Christos Vasilakis*

1 - Systems Modeling Impacting Policy: The Role Of Group Model Building In Cambodia
David Matchar

Health care is a prototypical example of a complex system. System modeling provides an opportunity to capture this complexity and to evaluate the potential positive and negative impacts of policy options and to gain insight into the factors that promote or inhibit success. Our experience in the health policy context has highlighted the crucial importance of engaging stakeholders from the outset so as to encourage a sense of ownership of the process; the idea is that owning the process encourages support of any resulting policy decisions and actions. In this talk, I will discuss the use of Group Model Building as the mechanism of stakeholder engagement, and describe several practical examples, focusing on current work in Cambodia to disseminate and evaluate services for chronic non-communicable diseases (NCDs). This effort is part of a 4-stage project with the ultimate goal of broadly implementing basic, efficient, and well-accepted NCD services throughout Cambodia.

■ MC-02

Monday, 12:30-14:00 - SOUTH BUILDING UV S101

Manufacturing Scheduling

Stream: Scheduling Practice
Chair: *Francesco Aggogeri*

1 - A deep learning approach for dispatching problems in large flexible manufacturing systems
Cheng-Hung Wu, Fang-Yi Zhou, Cheng-Juei Yu

A deep learning approach is presented to solve large stochastic dynamic dispatching problems in two-stage flexible manufacturing systems with uncertain demands and unreliable machines. Traditionally, dispatching problems under uncertainties are solved by stochastic dynamic programming. However, solving large dynamic control problems directly are computationally inefficient, which is known as the "curse-of-dimensionality" of dynamic programming. The main contribution of this research is to overcome the computational complexities of large stochastic dynamic programming problems and to allow near-optimal real-time dispatching in large flexible manufacturing systems. Our results indicate that the deep learning approach can generate near-optimal dispatching rules. More than 95% similarity is observed between the deep neuron network policies and the optimal policies generated from solving stochastic dynamic programming model directly. Moreover, in terms of cycle time and throughput, less than 2% difference between deep neuron network policies and the optimal dispatching policies is observed in our the discrete-event simulation results.

2 - Scheduling jobs to minimize makespan in a multiple product permutation flow shop with intermingling and learning effects
Şeyda Ilgaz, Gultekin Kuyzu, Salih Tekin

This study examines multi-product lot streaming problem in a permutation flow shop with the objective of minimizing total completion time considering job splitting and learning. This real life problem is motivated by an electronics equipments manufacturer where learning effects take place and chief technicians need to make decisions to split and assign orders to stations. The problem is computationally complex because the products are operating in 10 stations where lot intermingling is allowed. Therefore, a two-stage solution is suggested for this problem. In the first stage, a mixed integer linear programming model is presented that enables us to find optimal batch sizes as well as the optimal sequence simultaneously. However, lot intermingling and learning effects are not allowed at this stage. In the second stage, because of the learning effect, nonlinear programming model which solves small sized instances in a reasonable time and heuristic algorithm for the medium and large-sized instances are proposed. With the help of the proposed model and the heuristic algorithm, work flow rate in the assembly line is shown to increase within a weekly production schedule. Numerical results that are based on the real data taken from the manufacturer, concerning the average benefit of lot intermingling and learning effect with multiple products are presented.

3 - A multi-objective invasive weed optimization algorithm for a tri-objective dual-resource constrained flexible job shop scheduling problem

Shima Javanmard, Sasan Barak, Seyed Taghi Akhavan Niaki

This paper considers a novel tri-objective mixed-integer mathematical programing for the dual-resource constrained flexible job-shop scheduling (DRCFJS) problem with sequence-dependent setup times. The problem is to find the efficient assignment of operations to corresponding machines as well as to the workers to optimize the three objectives including makespan, machine workload, and the workers' idle cost, simultaneously. Since the DRCFJS is known as an NP-hard problem, a modified version of the multi-objective invasive weed optimization (MOIWO) algorithm is proposed to solve the problem. As there are no benchmarks available in the literature to validate the solution obtained, comparisons are performed with a non-dominated sorted genetic algorithm (NSGA-II) and a multi-objective parallel simulated annealing (MOPSA). The parameters of all solving algorithms are calibrated using the response surface methodology (RSM). Finally, for analysis of the solutions and prioritizing the algorithms, a hybrid multi-attribute decision-making method, AHP-TOPSIS, is proposed. In the applied ranking method, the combination of analytical hierarchy process (AHP) and the technique for order of preference by similarity to ideal solution (TOPSIS) is implemented, based on which the supremacy of MOIWO is revealed.

4 - Prognostics based robust design to strengthen mechanical system functionalities

Francesco Aggogeri, Angelo Merlo, István Németh, Nicola Pellegrini, Alberto Borboni, Amit Eytan, Claudio Taesi

This study aims to present the preliminary concept of a tool able to generate and update FMECA (Failure Modes, Effects and Criticality Analysis) and Criticality Matrix automatically, using system/component life data, machine/system hierarchical structure, reliability simulation & analysis and user inputs. This tool will simplify the performance of the FMECA by automating the process of collecting information from the user as a set of predefined options. In particular, the tool will lead the user through all the steps necessary to complete the analysis using an interactive "tutorial" for each phase with easy predefined options. The data gathered will be stored in a series of linked arrays which content could be successively modified (via a web based interface) whenever a change in the plant design occurs. The maintenance priority score will be calculated for each part of equipment in order to rank and prioritize the machine's component as far as the resources maintenance on a line level will be concerned. The proposed tool will also support the user in FMECA development and failure mode analysis, proposing a smart approach based on the reliability system architecture, life data by component and criticality indicators. This study is a part of the project PROGRAMS (H2020-FOF-09-2017 - 767287) - PROGnostics based Reliability Analysis for Maintenance Scheduling.

■ MC-03

Monday, 12:30-14:00 - SOUTH BUILDING UV S103

Hub Location

Stream: Location Analysis and Optimization
Chair: *Gabriel Luque*

1 - A p-hub covering location problem with elastic demand

Armin Lüer-Villagra, Víctor Larrea-Chiriboga, German Paredes-Belmar, Vladimir Marianov

Hub location concerns the design of hub-and-spoke networks to serve a set of OD demands, in a geographical area. Most of the literature assume (non)-deterministic inelastic transportation demand, leading to tractable mathematical formulations. Other studies consider non-linear demand functions, i.e. harder models. From an economic perspective, different studies show the existence of elastic transportation demand. This paper presents a model for a p-hub covering problem in a network. The problem is to design a hub-and-spoke network with p hubs, to maximize the captured demand, which depends on the service level, i.e. total travel time from origin to destination. We approximate the demand functions through discretization. We formulate the resulting problem as a MIP, solving it using CPLEX 12.8. Preliminary results, considering various demand functions, show the importance of modeling demand elasticity in hub location models. Future research includes the development of efficient solution methods.

2 - A bilevel dynamic maximal hub location problem for freight transportation

Roghayyeh Alizadeh, Tatsushi Nishi

This research motivated by the idea of designing a model for freight transportation planning problem develops a mixed integer dynamic bi-level maximal hub location problem. The studied problem maximizes the freight company's profit in the upper-level problem which allows some expansions in hubs according to increasing demand in the forthcoming periods. The model also considers the existence of competition in the market in the lower level problem, in which the customers have the power to choose the lowest price for the transportation of their demands by companies cooperating in the same business environment. We formulated the problem and applied a Benders decomposition based method that in the subproblem to convert the bi-level problem to a single level one, two reformulations based on KKT conditions and duality theory have been used and the model is solved using data from a real-life case and also randomly generated parameters to compare the results of two reformulations and extract managerial insights.

3 - A new mathematical model for multiple allocation tree-of-hubs location problem

Betul Kayisoglu, İbrahim Akgün

Hub location problems are concerned with determining the locations of hubs and the assignment of service routes between origin-destination (OD) points. Classical hub location problems assume that all hubs are fully interconnected by the hub arcs, i.e., hub-level network is complete. However, full interconnection between hub points may not be appropriate in some problems especially when hub arcs have considerably high setup costs. In this study, we address the Tree-of-Hubs Location Problem where the complete hub-level network structure is relaxed and the hubs are allowed to be connected to each other in a tree structure. We develop a new mathematical model and an effective heuristic for the problem and present computational results. Unlike most models in the literature that use a complete-network structure with distances satisfying the triangle inequality as an input, the proposed model can work directly with physical real-world network data structure (e.g., non-complete road and rail networks) as well as complete networks whose costs may or may not satisfy the triangle inequality. That is, the model do not require any specific cost and network structure. The proposed model assume that a non-hub node may get service from one or more hubs, i.e., multiple allocation. This research was supported by the Scientific and Technological Research Council of Turkey (TÜBiTAK Grant No: 114M363).

4 - Anytime algorithms for multi-objective hub location problems
Gabriel Luque, Enrique Dominguez, Francisco Chicano, Ana Belen Ruiz

In many logistic, telecommunications and computer networks, direct routing of commodities between any origin and destination is not viable due to economic and technological constraints. Hub locations problems (HLPs) are considered in that cases, where the design of these networks are optimized based on some objective(s) related on the cost or service. A huge number of papers have been published since the seminal work of O'Kelly. Early works were focused on analogue facility location problems, considering some assumptions to simplify network design. Recent works have studied more complex models that relax some of these assumptions and incorporate additional real-life features. In most HLPs considered in the literature, the input parameters are assumed to be known and deterministic. However, in practice, this assumption is unrealistic since there is a high uncertainty on relevant parameters, such as costs, demands or even distances. As a result, a decision maker usually prefer several solutions with a low uncertainty in their objectives functions. In this work, anytime algorithms are proposed to solve the multi-objective hub location problems with uncertainty. The proposed algorithms can be stopped at any time, yielding a set of efficient solutions (belonging to the Pareto front) that are well spread in the objective space.

■ MC-04

Monday, 12:30-14:00 - SOUTH BUILDING UV S104

Dynamic and Stochastic Scheduling in Production

Stream: Dynamic and Stochastic Scheduling
Chair: *Alejandro Arbelaez*

1 - Stochastic scheduling of parallel machines under processing time variability
İbrahim Akgün, Selçuk Gören, Rahime Şeyma Bekli, Muhammed Sutcu

Harsh competition in today's manufacturing sector makes it necessary for firms to generate highly efficient production schedules, so that productivity is maximized and costs are minimized. Most schedules, however, cannot be executed exactly as they are developed because of unexpected disruptions such as machine breakdowns, order cancellations, rush orders, processing time variability and so forth. This stochastic and dynamic nature led practitioners and researchers to develop robust schedules through the last three decades.

In this study, we consider a stochastic parallel machine environment with processing time variability with the objective of minimizing the expected makespan. The uncertainty in the system is captured by a discrete set of processing time scenarios. We first propose an integer programming model that can handle small problems. To handle large problems, we propose a scenario screening model and employ a stochastic dual decomposition method, where we solve many small problems rather than a very large problem. To handle even larger problems we also propose a relaxed dual decomposition method as well as a hybrid tabu search algorithm.

Our computational experiments show that the relaxed dual decomposition, scenario selection approach and the hybrid tabu search algorithm perform quite well.

2 - DQN-based dispatching method for unmanned production line composed of multiple CNC machines
Kyuchang Chang, Jun-Geol Baek

There are diverse ways of dispatching rules depending on the circumstances of the manufacturing process and line. In the simple manufacturing environment in the past, effective process management could be done with only simple dispatching rule. However, it is difficult to optimize the scheduling process of the complicated manufacturing environment with simple dispatching rules. Various dispatching methods and ML(Machine Learning)-based task allocation techniques have been developed, but there is no generally optimal algorithm for all processes. DQN(Deep Q Network) algorithm is one of the advanced Reinforcement Learning(RL) algorithm which has proven its efficacy in many different fields. This study focus on improving productivity on unmanned production line composed of multiple CNC(Computer Numerical Control) machines which are operated by robot system. Analyzing historical and real-time data of the process, DQN algorithm-based dispatching model is designed to increase the productivity of the production line. Introducing some performance measure such as average process time and cumulative waiting time, the proposed technique is compared to other allocation techniques. Simulation verification is done to demonstrate the better performance.

3 - Multi-objective optimization of job shop scheduling with risk of stablity
Shudong Sun

The performance measures, such as makespan, total completion time, are usually used in the job shop scheduling. However, in a real situation, the stability of a scheduling is more important than the other measures, simply because a stable scheduling will be more easily put into practice. In order to get a stable scheduling, the paper puts forward a new method to deal with the uncertainties in the scheduling of job shop. An approximation method for the calculation of the risk of stability of a scheduling is presented at first. Then, a multi-objective optimization model of job shop scheduling which considers the makespan, the stability and the total completion time is set up. A two-stage optimization method is developed to get the Pareto optimization frontier. An extensive simulation-based analysis of the performance of the proposed method has been conducted. The simulation results show that our method can increase the stability of the scheduling significantly while keeping the performance of the scheduling on an acceptable level.

4 - Online scheduling of combinatorial problems
Alejandro Arbelaez, Robinson Duque, Juan F. Diaz

In this work, we present and formalize the online over time problem where arriving instances are subject to waiting time constraints, e.g., processing times, waiting times, and due dates. To formalize our problem, we propose an extension of the Graham notation (alpha | beta | gamma) that allow us to represent the necessary constraints. We also propose an approach for online scheduling of combinatorial problems (e.g., SAT) that consists of the following three parts: building a machine learning model for processing time estimations; implementation of a hybrid scheduling policy SFJ and MIP; and usage of instance interruption heuristics to mitigate the impact of inaccurate predictions.

Unlike other approaches, we attempt to maximize the number of solved instances using single and multiple machine configurations. Our empirical evaluation with well-known SAT and MIP instances, suggest that our interruption heuristics can improve generic ordering policies to solve up to 21.6x and 12.2x more SAT and MIP instances. Additionally, in our hybrid approach we observed results that are close to a semi clairvoyant policy featuring perfect estimations. We observed that with very limited data to train the models our approach reports scenarios with up to 90% of solved instances with respect to the SCP.

■ MC-05

Monday, 12:30-14:00 - SOUTH BUILDING UV S105

Heuristics for Salesman and Postman Problems

Stream: Vehicle Routing and Logistics Optimization I
Chair: *Miguel Reula Martín*

1 - A variable neighborhood search with tabu conditions for the roaming salesman problem
Masoud Shahmanzari, Deniz Aksen

We present a Variable Neighborhood Search (VNS) complemented with Tabu Search (TS) conditions for the Roaming Salesman Problem (RSP). RSP is a special case of the well-known traveling salesman problem where a set of cities with time-dependent rewards and a set of campaign days are given. Each city can be visited on any day and a subset of cities can be visited multiple times, though with diminishing rewards after the first visit. The goal is to determine an optimal campaign schedule consisting of either open or closed daily tours that maximize the total net benefit while respecting the maximum tour duration and the necessity to return to the campaign base frequently. This problem arises in election logistics where there exist no fixed depots and daily tours do not have to start and end at the same city. We formulate RSP as a mixed integer linear programming problem in which we capture as many real-world aspects as possible. We also present a hybrid metaheuristic algorithm based on a VNS with TS conditions. The initial feasible solution is constructed via a new matheuristc approach based on the decomposition of the original problem. Next, this solution is improved in terms of the collected rewards using the proposed local search procedure. We consider a set of 81 cities in Turkey and a campaign period of 30 days as our largest problem instance. Computational results on actual distance data show that the developed algorithm can find near-optimal solutions in a reasonable time.

2 - Picker routing in AGV-assisted order picking systems
Maximilian Löffler, Nils Boysen, Christoph Glock, Michael Schneider

Automated guided vehicles (AGVs) are used to support human order pickers, e.g., if heavy and bulky items are to be collected from the racks of a warehouse. In the scenario considered in our work, human order pickers are accompanied by AGVs during the order picking process and put the picked items onto the AGV. Once a picking order has been completed, the AGV autonomously drives towards the shipping area, and a new AGV for the next order is requested. Thus, the picker does not have to return to a central depot after completing a picking order but continuously picks order after order. We address the routing of the AGV-assisted pickers through the warehouse as well as the sequencing of incoming orders. We prove computational complexity and present efficient solution methods. As a main contribution, we develop an exact polynomial time algorithm for the case of a given order processing sequence. Furthermore, we compare the pickers' walking distance with and without AGV support to provide decision support for practitioners that have to choose between these two options.

3 - A solution method for the traveling salesman problem (TSP) using five sequential deterministic heuristic algorithms
Luis Moreno, Javier Diaz, Julian Gonzalez

Based initially on the known priority rule for the Traveling Salesman Problem (TSP) that searches the closest not visited neighbor for each location (myopic strategy), a combination of four additional deterministic algorithms are proposed to get a very good solution for the TSP. After a solution is obtained by the priority rule, a second step (improvement) is made to the solution by using an "order n" heuristic rule that searches the longest distance in the solution circuit, removes it to obtain a chain and from the two ends, the shortest distance to one of the other nodes in the chain is searched. Using the two nodes the circuit is rebuild in an iterative process until it is not possible to do more improvements. A third step comes now that uses the known 2-opt heuristic to get a better solution. A fourth step is applied to the actual solution using the 3-opt heuristic, but selectively in order to not degrade the time solution. Finally, with the solution of the previous step an additional heuristic rule is used, in a fifth step, that splits the solution in several chains by removing the longest edges, and then an integer programming problem is solved to link them again and form a new circuit, using a reduced set of constraints. Very good results are shown for several problems of different sizes in the classical library http://comopt.ifi.uni-heidelberg.de/software/TSPLIB95/ with the deviation from the optimal solution and the time spent by the algorithm for every problem.

4 - A heuristic algorithm for the distance-constrained generalized directed rural postman problem
Miguel Reula Martín, Angel Corberan, Jose Maria Sanchis, Isaac Plana

The Generalized Directed Rural Postman Problem (GDRPP), or Close-Enough Arc Routing Problem, is an arc routing problem with some interesting real-life applications, such as routing for meter reading. In this application, a receiver in a vehicle that gets closer than a certain distance to a meter records its consumption. Hence, the vehicle does not need to traverse every street containing meters to read them, but only some streets. We consider here the extension of the GDRPP where a fleet of vehicles with distance constraints is available. Several formulations and exact algorithms for this problem, the Distance-Constrained Generalized Directed Rural Postman Problem (DC-GDRPP), were proposed in Ávila et al. (2017). Since the size of the instances solved to optimality is far from those arising in real-life problems, we propose here a heuristic capable to provide good quality solutions in medium/large instances. The heuristic basically consists of a constructive phase, an improvement phase, and an optimization procedure for each route. In order to assess the relative efficiency of our algorithm, extensive computational experiments have been carried out. The results show the good performance of the proposed heuristic, even in the instances with a very tight maximum distance.

■ MC-06

Monday, 12:30-14:00 - SOUTH BUILDING UV S106

Consumer Behavior and Pricing II

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Winfried Steiner*

1 - Dynamic pricing strategies for perishable products
Cansu Altintas, Shaunak Dabadghao, Zumbul Atan, Tarkan Tan

Around 20% of the total food produced in EU is wasted. Food waste at the retail level arises for a variety of reasons with expiry of use by date being one of the most common ones. As periodic replenishment practices give rise to the coexistence of units with different expiry dates, customers are inclined to select fresher units which provide a higher perception of quality, as long as there is no price differential. In this study, we consider dynamic discounting as a waste management strategy. We study pricing decisions faced by a retailer selling a perishable product with shelf life of more than two periods where products with different remaining shelf life can coexist.

2 - Influencing consumer shopping behavior by expiration date based pricing of fresh products
René Haijema

Many consumers at supermarkets take the product from the shelf that has the longest expiration date and thus leaving others to take the older products. This causes food waste when the older products expire. To reduce food waste, many Dutch supermarkets apply price discounts to fresh products that are near the expiration date. Providing a discount on the oldest products available will trigger some consumers to take the oldest products from stock. The quantitative effect of such discounts on sales and thus on profits and food waste is not well understood.

We investigate these effects by modelling the inventory dynamics of a product at a supermarket. The response of consumers to discounts is modelled through a willingness to pay function. Several scenarios for discount levels, timings of discounts, and willingness to pay functions are investigated by simulation. The replenishment of the supermarket is optimized by Simulation based optimization. A detailed simulation study shows that well set discounts do reduce both food waste and increase sales and profit.

3 - The effects of a promotion on store traffic, conversion, and consumer expenditures: evaluation with a prediction approach
Leonardo Epstein, Ignacio Inostroza-Quezada

Store managers conduct promotions to increase at least one of three store performance components: arrival traffic, conversion probabilities, and customer expenditures. The talk presents a new approach to evaluate these effects: it develops a 3-variate time series model, where the variables are the arrival counts, the conversion counts and the average expenditure in one-hour time-bands.

The approach uses data outside the promotion period along with regression models with independent sets of covariates for location and scale parameters, to build counterfactual baseline predictions for each sales component for the promotion period. These baselines assume that the promotion has not occurred. To evaluate the promotion effects on each component, the approach compares the observations to the corresponding baseline predictions during the promotion.

This approach has at least three strengths: first, it does not require building a model for the promotion effect. Second, it controls for covariate effects, such as time of the day, day of the week, etc. Third, it measures the effects of the promotion directly on the quantities of interest, arrival counts, conversion probabilities, and expenditures, and not on the scales of parameters which are often difficult to translate into effects on observables. An illustration with data from an actual store combines arrival data from processed video images and sales recorded at sales registers.

4 - A data mining approach to predict e-commerce customer behavior
Ebru Dilara Arslan, Büşra Altunan, Merve Seyis, Merve Birer, Fadime Üney-Yüksektepe

Watsons, established in 1841, is one of the world's leading beauty and personal care industry with more than 6300 stores in 11 different markets. In addition to 280 Watsons's stores, online shopping is also an alternative for Turkish customers. Due to current trends, many customers prefer online shopping. Among them, some of them are adding the products to their market basket but unfortunately, they are leaving the web site without a purchase. This causes an important problem for most of the e-commerce retailers.

In this project, a data mining approach will be studied to predict customer's behavior during the website visits. In the first step, website customer's demographic and behavioral data will be collected for a specific day. Secondly, the data will be preprocessed and missing values will be controlled. After determining the important attributes to predict whether a customer will purchase or not, the most accurate data classification method will be determined by using WEKA. A decision support system will be recommended to estimate the tendency of customers who visit the website. As a result, company will able to predict the customer's behavior at her first entrance to the website.

■ MC-07

Monday, 12:30-14:00 - SOUTH BUILDING UV S107

Analytic Hierarchy Process III

Stream: Analytic Hierarchy Process / Analytic Network Process
Chair: *Petr Fiala*

1 - Sustainable fixed capital's budget allocation by applying the P&S method
Majid FathiZahraei, Abolfazl Yari, Azita Asadi

Increasing a developing gap among countries become as a big concern of managers and leader. Proper resource allocation based on state and counties' potential and capability recognized as a model to reduce this gap by forward development. In the other hand, sophisticated and network relationship among involved criteria on budget allocation require a specific method. Ability of AHP&ANP approach as the methods in the field of Multi Criteria Decision Method (MCDM) by combining tangible and intangible data give the opportunity to researchers to analyses huge and rough data. However, because of network relations and interactions among criteria involved in budget allocation and weakness of AHP & ANP to handle sophisticated model this research applied Pruning & Succession (P&S) method as one of the newest subset method of Multi Criteria Decision Method (MCDM). The results present the important of network effect on fixed capital's budget allocation. And, present the ability of P&S method to tackle the interaction and network relationship between criteria.

2 - Determination of electric bus technology to improve the public transportation using AHP-TOPSIS methods
Mustafa Hamurcu, Tamer Eren

AHP and TOPSIS methods frequently used in decision making process in research is the multi-criteria decision-making techniques. Decision-making process, in terms of multiple criteria for take-over in the various alternative is a very difficult decision. Therefore, the combine method of AHP-TOPSIS can be used for decision making process that is easy and understandable method. These methods also are used transport decisions. Environmental sustainability is the most important subject for urban transport. So, it should be used electrical busses with public mass transport that is environmental sensitive. The transportation technologies based on cleaner and environmental alternative busses can play a major role for liveable cities with improving the urban air quality. This paper presents a selection study of three different types of electric buses in public transport for Ankara. The study allowed the determination, in each bus, of parameters such as required power, environment and technical features. Finally, the best selection is made for urban transport among the different three alternative electrical bus technologies and made evaluations.

3 - Selection of gas mask using an integrated intuitionistic fuzzy AHP and TOPSIS (IF-AHP&TOPSIS) method: a case study
Elif Kilic Delice, Tuba Adar

The gas masks used in dangerous places are among personal safety equipment, and their design needs to be paid attention because they have vital importance for an individual. The design having adjustable and elastic bands, less redundant complexity, and high level of perceptible information, minimizing the risks, providing an effective and comfortable usage is accepted as a universal design. All these factors should be taken into consideration in order to provide safety, comfort, resistance, and maximum efficiency. Therefore, it may be pointed out that the choice of gas mask is an important decision-making problem which has multiple qualitative and quantitative criteria. In this study, Intuitionistic fuzzy sets (IFS) were used in order to choose a gas mask. Because they are useful tool to deal with uncertainty and fuzziness of complex problems. The gas mask selection problem includes many qualitative criteria that decision makers have difficulties in making decision. Because of these features and obtain to a more complete evaluation and more precise results, the IF-AHP&TOPSIS method is appropriate for the problem of gas mask selection. In this regard, 15 criteria were determined under such 3 categories as technical, economic, and universal. At first, IF-AHP method is used to determine the criteria weights. Then, alternatives were evaluated by using the IF-TOPSIS method, and the best one was chosen.

4 - Dynamic supply network analysis by DEMATEL and ANP
Petr Fiala

Lot of professionals tried to find sophisticated way to improve techniques for supply network analysis in different ways. The paper presents an approach for dynamic supply network analysis based on a combination of DEMATEL method and the dynamic version of the ANP model. The approach proceeds in two steps. The DEMATEL method is used in the first step to filter some parts in the model based on expert threshold values. In the second step, the ANP is applied for more precise evaluation of relations in supply network by multiple criteria. The structure of the ANP model for dynamic supply network is described by clusters of elements connected by their dependence on one another. A cluster groups elements (suppliers, producers, distributers, retailers, customers, criteria, time) that share a set of attributes. At least one element in each of these clusters is connected to some element in another cluster. These connections indicate the flow of influence between the elements.

■ MC-08

Monday, 12:30-14:00 - SOUTH BUILDING UV S108

Optimal Location Problems

Stream: Combinatorial Optimization I
Chair: *Ivana Ljubic*

1 - An exact algorithm for the perfect edge domination problem
Abilio Lucena

Let G=(V,E) be an undirected graph with a set of vertices V, a set of edges E, no loops, and at most one edge between every pair of distinct vertices of V. For any subset D of E, its closed edge neighborhood, N[D], is defined by those edges that are incident to an end vertex of an edge of D. Note that N[D] therefore contains D. Set D is said to dominate all the edges of N[D] and is called an Edge Dominating Set (EDS) if N[D] = E holds. Given an EDS D, perfect edge domination applies if any edge lying outside D is dominated by a single edge of D. Accordingly, the Perfect Edge Domination Problem (PEDP) is to find a perfect EDS with cardinality as small as possible. We investigate a formulation and a Branch-and-Cut algorithm for PEDP. So far, perfect edge domination was investigated mostly in computational complexity terms and no previous exact algorithm appears to exist for the problem. Within the 7,200 CPU seconds time limit we imposed on every run of our algorithm, all but one of the 736 instances we generated were solved to proven optimality. That outcome resulted in spite of the up to 99% (optimal solution value - LP relaxation bound)/(LP relaxation bound) gaps our formulation faced.

2 - Cost and fairness optimization in facility location
Carlo Filippi, Gianfranco Guastaroba, M. Grazia Speranza

We consider a plant location problem where a supplier will be locating facilities to serve a set of customers. We assume that the location costs are in charge of the supplier, whereas each customer pays the transportation costs between its position and the serving facility. This situation, common in public services, may also be associated with a supply chain environment, e.g., in the location of retail stores. For a supplier, an effective service is expressed by two competing goals: the facility location cost and the customer satisfaction. We assume that customer satisfaction is a matter of both fair allocation of transportation cost (system equity) and minimum total transportation cost (system efficiency). Many different measures of system equity may be proposed, but we argue that equity is well captured by the minimization of the conditional mean of the transportation costs, i.e., the average unit transportation cost paid by a certain percentage of the total customer demand paying the highest costs. We embed the conditional mean in the Single Source Capacitated Facility Location Problem, obtaining a bi-objective MILP model, where the first objective is the total location cost, and the second objective is the conditional mean of the transportation cost. We discuss the relevance of the adopted measure on a set of small/medium size instances. For large size instances, we design and implement a Benders decomposition approach. Computational results are given.

3 - Benders decomposition for covering location problems
Ivana Ljubic, Jean-François Cordeau, Fabio Furini

Covering problems constitute an important family of facility location problems. These problems embed a notion of proximity (or coverage radius) that specifies whether a given demand point can be served or "covered" by a potential facility location. One of the best known members of this family is the set covering problem location problem (SCLP) in which one must choose a minimum cost set of facilities so that every demand point is covered at least once. The drawback of the SCLP is that it often leads to costly or unrealistic solutions because it gives the same importance to every demand point, regardless of its position and size. To overcome this weakness, two main variants have been proposed: i) the maximal covering location problem (MCLP), which requires choosing a subset of facilities that maximizes the demand covered while respecting a budget constraint on the cost of the facilities; ii) the partial set covering location problem (PSCLP), which minimizes the cost of the open facilities while forcing a certain amount of demand to be covered.

We study an effective decomposition approach to the MCLP and PSCLP based on the Benders-cut reformulation. We also draw a connection between Benders and submodular cuts and provide a series of computational experiments demonstrating that, thanks to this decomposition techniques, optimal solutions can be found very quickly, even for benchmark instances involving up to one million of demand points.

■ MC-09

Monday, 12:30-14:00 - SOUTH BUILDING UV S109

The Role of Mathematical Optimization in Data Science III

Stream: European Working Group: Data Science Meets Optimization
Chair: *Philipp Baumann*

1 - An optimization model for credit score based offer management in telecommunication sector
Ayse Seda Yavuz, Erinc Albey

In the telecommunication business, companies not only provide voice/text/data services but also utilize some up-sell strategies such as selling mobile phones to customers. These activities maximize customer life time value and minimize risk of churn through contractual agreements covering long time intervals. In this work we study an optimization problem that deals with deciding the most suitable device and contract setting for each customer while considering risk scores. We first consider risk scores calculation methods based on utilizing several customer specific features such as demographic information, voice/data usage history, average invoice amount, payment history, equipment usage routine. After risk score calculation, credit limits are determined, which are further used to assist on the device assignment decision. An assignment model aiming to maximize sales while maintaining the credit amount allocated to customers under certain threshold levels is constructed using mixed integer programming. The resulting problem is then solved using commercial solvers, and for large instances, heuristic methods are applied. The performance of the solution approach is analyzed under several experimental settings.

2 - A matheuristic for binary classification of data sets using hyperboxes
Derya Akbulut, Cem Iyigün, Nur Evin Ozdemirel

In this study, an optimization approach is proposed for the binary classification problem. A Mixed Integer Programming (MIP) model formulation is used to construct hyperboxes as classifiers, minimizing the number of misclassified and unclassified samples as well as overlapping of hyperboxes. The hyperboxes are determined by some lower and upper bounds on the feature values, and overlapping of these hyperboxes is allowed to keep a balance between misclassification and overfitting. A matheuristic, namely Iterative Classification procedure for Binary classes (ICB) is developed based on the MIP formulation. In each iteration of the ICB algorithm, a fixed number of hyperboxes are generated using the MIP model, and then a trimming algorithm is used to adjust the hyperboxes in a way to eliminate the misclassified samples. Some trimmed hyperboxes and sample assignments are then fixed, reducing the unclassified sample size left for the next iteration. ICB controls the number of hyperboxes in a greedy manner, but provides an overall hyperbox configuration with no misclassification by the end of the training phase. For the test phase, distance-based heuristic algorithms are also developed to classify the uncovered and overlap samples that are not classified by the hyperboxes.

3 - Particle swarm optimization based regression
Donghee Yoon, SeJoon Park, Nagyoon Song, Suemin Kim, Dohyun (Norman) Kim

Regression analysis is used for predictive and descriptive purposes in various fields. For the descriptive purpose, it very important to obtain an explicit regression function for an output variable. However, many existing regression methods including support vector regression have a difficulty in describing an explicit function that expresses the nonlinear relationship between an output variable and input variables. To resolve this problem, we propose a nonlinear regression algorithm using particle swarm optimization by which the output variable can be explicitly expressed as a function of the input variables. The experimental results show that the proposed method, even with an explicit regression function, performs slightly better than the existing methods regardless of the datasets, implying that it can be used as a useful alternative when obtaining the explicit function description of the output variable using input variables.

4 - Scaling up similarity-based machine learning models: new geometric algorithms for sparse computation
Philipp Baumann, Dorit Hochbaum, Quico Spaen

Many leading machine learning models, including mathematical programming-based models, require as input similarities between objects in a data set. Since the number of pairwise similarities grows quadratically with the size of the data set, it is computationally prohibitive to compute all pairwise similarities for large-scale data sets. The recently introduced methodology of "sparse computation" resolves this issue by computing only the relevant similarities instead of all pairwise similarities. To identify the relevant similarities, sparse computation efficiently projects the data onto a low-dimensional space that is partitioned into grid blocks. A similarity is considered relevant, if the corresponding objects fall in the same or adjacent grid blocks. This guarantees that all pairs of objects that are within a specified L-infinity distance with respect to the low-dimensional space are identified as well as some pairs that are within twice this distance. For very large data sets, sparse computation can have high running time due to the enumeration of pairs of adjacent blocks. We propose here new geometric algorithms that eliminate the need to enumerate adjacent blocks. Our empirical results on data sets with up to 10 million objects show that the new algorithms achieve a significant reduction in running time.

■ MC-10

Monday, 12:30-14:00 - SOUTH BUILDING UV S110

Decision Aiding Methods III

Stream: Multiple Criteria Decision Aiding
Chair: *Salvatore Corrente*
Chair: *Milosz Kadzinski*

1 - Ranking sensitivity-based importance measures in multi-outputs models
Claudio Miguel Rocco

Sensitivity analysis is the study of how uncertainty in the output of a model can be apportioned to different sources of uncertainty in the model input factors. Methods for SA are used to determine which subset of parameters accounts for most of the output uncertainty or to identify the subset of non-influential factors. However, there are models in which performance is evaluated by multiple outputs or multiple figures of merit (FOM). Sensitivity analysis could be performed for each FOM. As a result, for each FOM considered, there is a corresponding vector (CV) which indicates the importance of the factors with respect to a specific FOM. In general, each of these vectors takes into account different aspects of FOM and conveys different types of information: different FOM may rank the importance of factors in different way. In this case, the decision problem includes conflictive CV vectors and possibly no clear "most" important factor. In this paper two different known approaches are compared to rank factors in multiple outputs models. The first approach is based on statistic techniques. The second approach is based on the problem of determining a composite index: Copeland Score and Ordered Weighted Average are selected for obtaining a combined rank for each factor. In addition, the Hasse Diagram Technique is used as a preliminary analysis, capable to detect possible conflicts among factors. An example illustrates pros and cons of the approaches proposed.

2 - Value-focused thinking and multi-criteria group decision making for systematically valuing the energy transition
Tim Hoefer, Rüdiger von Nitzsch, Reinhard Madlener

Governments all over the world need to change their energy systems in order to decrease greenhouse gas emissions. However, the pathway for transforming the relevant sectors is still unknown. This paper aims at investigating different stakeholders' opinions towards the future energy system and at evaluating various possible pathways, so-called storylines, into a less CO2-intensive energy system. The involved stakeholders are representatives from environmental and consumer associations, trade unions, and churches, amongst others. We use Value-Focused Thinking to define and structure the objectives of stakeholders, and Multi-Attribute Utility Theory (MAUT) to evaluate individual preferences of the stakeholders towards these objectives. The first phase of the group decision making results in a hierarchical valuation system consisting of four preferentially independent fundamental objectives, which are interrelated with several means objectives. In the second phase, energy experts from the scientific, industrial and policy advisory field assess the goodness of the storylines regarding the achievement of the means objective. The stakeholders, firstly, evaluate the relative impact of the means objectives with respect to the attainment of the fundamental objectives and, secondly, assess the relative weights of the fundamental objectives. The subjective evaluations of the objectives are used to calculate and compare the aggregated utility of each of the four storylines.

3 - A study on the anonymity of individual preferences in group decision making
Matteo Brunelli

Preference relations in the form of sets of pairwise comparisons between criteria/alternatives are a well-established methodology for group decision making. Both in the literature and in real-world applications, it is common practice to average the opinions of various experts expressed as pairwise comparisons to find a compromise solution. In this research we dwell on the inverse problem: given a decision maker who knows his own preferences and the aggregate ones, one can devise optimization problems which can help him infer, in the form of intervals, the preferences of the other decision makers. Since the possibility of inferring the other participants' preferences violates the requirement of anonymity, we investigated the extent and the likelihood of this infraction. The results come from some numerical simulation and examine the effect of increasing the number of experts in the decision process on their anonymity. In addition to numerical simulations with randomly generated data, we will also experiment with a dataset of preferences which were collected in a real-world survey on factors determining technology acceptance.

4 - Multiobjective models for planning problems
Maria Barbati, Salvatore Corrente, Salvatore Greco

We consider the problem of selecting a set of facilities considering also the location where they have to be assigned and the time in which they have to be activated. The facilities are evaluated with respect to a set of criteria. The problem has to be faced respecting some constraints related to different aspects such as precedence restrictions (due to the nature of the facilities) or available budget. We consider the uncertainty related to the performances of the facilities with respect to considered criteria, and plurality of stakeholders participating to the decision. We discuss how such a model permits to handle complex problems using several methodologies including multiple attribute value theory and multiobjective optimization. With respect to the latter point, we consider the compromise programming and an interactive methodology based on the Dominance-based Rough Set Approach. We illustrate the application of our model with a simple didactic example.

■ MC-11

Monday, 12:30-14:00 - SOUTH BUILDING UV S111

DEA Theory II

Stream: DEA: Theory
Chair: *Wen-Chih Chen*

1 - Efficiency and performance assessment in DEA technique with time series data
Zohreh Moghaddas, Mohsen Vaez-Ghasemi

Nowadays one of the concerns of managers is to calculate the efficiency score and obtaining the extent of progress and regress of decision making units (DMUs) during several successive periods. As the Malmquist Productivity Index (MPI) is unable to consider more than two time periods, in this study it is tried to construct a global multi-period model and index based on Data Envelopment Analysis (DEA) axioms with which both efficiency score and the status of progress or regress of DMUs can be obtained. Considering one of the large banks in Iran as an application and rearranging the network system from 1927 to 1700 branches, the authors showed that the procedure on the basis of the efficiency and performance of branches considering the presented model in this research is effective and practical. Thus, with these results senior manager can make fundamental decisions such as merging, closing, or up-grading of branches. In regards of mathematical programming the key feature of the proposed model is that it does not combine the performances for multiple periods into one numerical value as done in some studies in literature. Also, this index can reveal the exact extent of progress and regress during the multi-period time serial which is presented for the first time in DEA literature.

2 - Competitive pricing using efficient frontier
Alireza Davoodi

The production chain of a good or a service is developed with an appropriate pricing. Optimal and efficient pricing of a novel product leads to determine the actual position of that to the other products. Moreover, the costumer attraction can be made by a suitable pricing. The pricing strategies may change according to the market type, the product and costumer's requirements. In this paper, we propose a pricing method for products having the sample and sale experience in the market. The introduced method is based on competitive strategies and the prices of other rivals. We use the mathematical programming to find the optimal price. The integrated method includes the Marketing Mix and Mathematical Optimization techniques. Finally, an application of the method will be demonstrated.

3 - A novel two-stage double bootstrapped I-distance global assurance region DEA model
Milan Radojicic, Gordana Savic, Veljko Jeremic

We present a new model of Data Envelopment Analysis (DEA) for the measurement of efficiency. Unlike previous applications of double bootstrap in DEA, where in the first-stage bootstrap is applied to efficiency scores, we use the bootstrap to obtain weight restrictions which are then used in a Global Assurance Region (GAR) DEA model. DEA does not require any prior weighting of inputs or outputs in frontier analysis. Consequently, DMUs are assessed with the most favourable set of weights, and some inputs and/or outputs may be ignored. To avoid this, a GAR DEA model is used. The main issue is to determine lower and upper bounds in the model. Usually, these bounds are determined subjectively, by consulting experts. Thus, subjective expert opinions have a significant impact on efficiency assessment. We suggest using bootstrapped Ivanovic distance for generating lower and upper bounds in GAR. In the second stage, a bootstrapped truncated regression model is used to explain efficiency. The approach is illustrated with an example from the non-profit sector.

4 - DEA performance evaluation with a dual-role factor
Wen-Chih Chen

This talk discusses the dual-role factor classification problem in Data Envelopment Analysis (DEA) based on the economic production theory. We study two approaches taking opposite directions: one (the conventional and popular approach) clarifies the roles prior to analysis, while the other incorporates the dual roles into the analysis. An axiomatic framework is presented to investigate their relationships and the underlying assumptions.

■ MC-12

Monday, 12:30-14:00 - SOUTH BUILDING UV S112

Fuzzy Optimization II

Stream: Fuzzy Optimization
Chair: *Manuel Díaz-Madroñero*

1 - Divergence measures under imprecision
Susana Montes, Ignacio Montes, Ángel Riesgo

There are several papers where the link between information theory and fuzzy logic has been described in detail. Taking into account this relationship, we could define the divergence measures as a tool for comparing two fuzzy sets, which is based on the idea of classical divergence measure between probability distributions. This is a very important tool, since the estimation of the similarity between two sets is a very important topic in many area, such that pattern recognition or decision making. In that cases, the sets represent patterns and alternatives, respectively. The way to represent this information can be modelled by fuzzy sets, but also some generalizations of them could be necessary in some environments. Thus, we have generalized this concept and also defined the divergence measure between two interval-valued fuzzy sets and between two hesitant fuzzy sets. In all the cases, some general properties are studied. Moreover, the particular case of branching or local measures is considered and analysed in detail, since it has several specific and interesting properties. We have also related them to the dissimilaries and distances, as a different tool for measuring the degree of difference between two sets. Finally, we present some examples with possible applications for these measures. For these examples we remark the different behaviour of these measures depending on the t-norm considered to define the intersection of two sets and its dual t-conorm.

2 - Mathematical properties and possible applications of IFS-IBA approach
Pavle Milosevic, Aleksandar Rakicevic, Ana Poledica, Bratislav Petrovic

Recently proposed IFS-IBA approach is based on utilization of interpolative Boolean algebra (IBA) for dealing with intuitionistic fuzzy sets (IFSs). In the approach, the expression transformation and logic operators of disjunction and conjunction are defined in accordance with the postulates of IBA, while the notion of IFSs and negation operator rely on IFS theory. In this paper, we aim to investigate mathematical properties of IFS-IBA approach that are of interest in terms of intuitionism. Namely, we will examine the validity of contradiction, excluded middle, strong double negation law and one of the De-Morgan laws in the proposed approach and compare the results with properties of conventional IFS approaches with various operators. We will also reflect on the descriptiveness and the applicability of the observed approaches. Further, we will discuss some possible applications of IFS-IBA approach. The special attention will be paid on data aggregation and similarity measuring for pattern discovery in financial decision making. Given that prices in financial time series are often presented using 2-tuples or 4-tuples (candlesticks), IFSs seem to be a convenient technique for presenting this data. Hence, the similarity measure defined in IFS-IBA approach along with suitable aggregation operator may be used to identify and assess price patterns.

3 - Computational methods for constructing a group ranking from uncertain data
María Luisa Martínez, Esther Dopazo, Mauricio Ruiz-Tagle

The problem of rank aggregation, also known as group-ranking, arises in many fields such as metasearch engines, information retrieval, recommendation systems and decision-making. In the real world applications, information is often vague and imprecise. We propose a two-stage approach to address the group-ranking problem based on uncertain preference information given by a group of individual experts. The first stage gathers group preferences from uncertain and probably conflicting information to construct an outranking matrix. In the second stage, a collective priority vector is derived. It provides a rank ordering of the alternatives based on the group preferences. Computational methods to solve the problem and some performance measures will be presented.

4 - Reducing costs by using fuzzy techniques in inventory management
Ester Guijarro, Eugenia Babiloni, Maria J. Canos, Lourdes Canos, Vicente Liern

Inventory management has become a key area in operations research. As a consequence, the characterization of different inventory systems is one of the outstanding topics. The three key questions that inventory managers need to answer for designing inventory policies are: (i) how often should the inventory status be reviewed; (ii) when should a replenishment order be placed, and (iii) how large should be this order. However, once the policy has been selected, the main issue consists of dealing with uncertainties that are inherent in real environments. Uncertainty can be found, for instance, in how inventory costs are determined, usually treated as real and known whereas they include imprecise, or in knowing customer demand, which is usually treated by a probability distribution. Hence, the difficulty resides on the representation of this uncertainty in the model. Generally, inventory models overcome this drawback by using probability theory. Nevertheless, probability-based approaches may not be enough to reflect real inventory systems. This paper suggests new approaches to categorize inventory policies in which uncertainties are modelled using fuzzy set theory. The main objective is to close inventory theory to real environments for providing models based on fuzzy theory that guarantee target service levels and reduce inventory costs.

■ MC-13

Monday, 12:30-14:00 - SOUTH BUILDING UV S201

Supply Chain Management III

Stream: Supply Chain Management II
Chair: *Ileana Perez*

1 - Competitive and cooperative decisions in distribution network
Natalia Nikolchenko, Nikolay Zenkevich

It is well known that aggregate profit in a decentralized supply chain may be lower than in a vertically integrated chain where a focal company makes decisions for both the manufacturers and the retailers. We consider a hierarchical distribution network, which includes several manufactures, single distributor and multi retailers, operated and competed in consumer markets that are functioning according to the Cournot model with the linear demand. All participants in a chain are trying to maximize their profit. Based on this network a multi-stage hierarchic game was carried out. At the first step, we construct the competitive solution for such supply network as the perfect Nash equilibrium in the multi-step hierarchical game in closed form. At the second step, we construct the cooperative solution for the network, where winnings of all participants in the found perfect Nash equilibrium are considered as a point of the status quo. As cooperative decision we calculate the weighted Nash bargaining solution, which comes down to the solution of a separable nonlinear programming problem with concave payoff function, which has a unique solution. Numerical example for the network shows that cooperative decision is more profitable than competitive decision for all participants.

The study is carried out within the framework of the projects 16-01-00805A and 17-07-00371 of the Russian Foundation for Basic Research.

2 - How should your supply chain adjust with product innovation?
Mojtaba Mahdavi, Tava Olsen

Abstract: This research explores the impact of product innovation on the supply chain strategy. The existing research suggests that innovation changes product characteristics in several ways and the supply chain should do so accordingly to stay strategically aligned with demand and market requirements. Demand volatility, short life cycle, and high contribution margin are the major characteristics of the innovative products. To be aligned with such product type, a supply chain should be responsive, which allows for reasonably quick reaction to the fast changing market. We analytically examine this alignment and provide insights into what this dictates to the supply chain decisions. More specifically, we develop a supply chain model that incorporates multiple inventory costs, including carrying inventory, ordering and shipping, obsolescence, and stockouts, and discuss how the optimal decisions, order quantity and lead time, are affected by the product characteristics.

3 - Modeling and simulation of supply chains with different risk attitudes from participants by using Petri nets
Biljana Panić, Dragana Makajic-Nikolic, Maja Hadziahmetović, Mirko Vujosevic

Causes of bullwhip effect in supply chains can be operational or behavioural. Behavioural causes include personality traits and one of them found to influence the bullwhip effect is an attitude towards risk. We examine the influence of risk preferences of participants in the supply chain on chain performances. To determine the behaviour of risk-seeking and risk-averse people when playing the beer game previous research have been used. All participants in a chain (retailer, wholesaler, distributor and manufacturer) can be risk-seeking, risk-averse or risk-neutral. Applying the Petri nets, i.e. CPN Tools, a supply chain and a beer game with different scenarios is modelled - one of the participants is risk-averse or risk-seeking and rests of them are risk-neutral. The results showed that the risk attitude of participants has an influence on supply chain performances, but it is also demonstrated the possibility of modelling behaviour by using Petri nets.

4 - Improving decisions in inventory management: a solution supported by teamwork- ABC-AHP
Ileana Perez, Julian Arias, Daniela Gallego, Rocio Poveda-Bautista

The need of organizations to maintain their competitive advantages and ensure service levels that impact on customer satisfaction has led to the design of collaborative processes, coordinated among stakeholders involved in the decision making. The increase of quantity and variety, both demand and customer expectations, is translated into a greater complexity for the process of decision making in the inventory processes, requiring effective communication and agreements between the leaders of the logistics processes. Decisions on inventory management, must guarantee a continuous flow of production, are based on management approaches conditioned only by cost or sales volume, currently obsolete approach that must be overcome by other than considers multiple criteria, involves several areas of the companies and take into account the preferences of the stakeholders involved in these decisions. This work proposes a methodology that articulates the team work, the hierarchical analytical process (AHP) and the multi-criteria ABC classification method, to align the organizational objectives in inventory management. Proposes two stages: Selection and weighting of relevant criteria for the inventory management and multi-criteria ABC classification of the products according to the selected criteria, which will serve as inputs for later stages of demand management and inventory control. Was validated as a case study in the inventory management process of a Colombian Graphic Industry company

■ MC-14

Monday, 12:30-14:00 - SOUTH BUILDING UV S202

Fixed Point Algorithms in Optimisation II

Stream: Nonlinear Programming: Methods
Chair: *Matthew Tam*

1 - An enhanced formulation for successfully solving graph coloring problems with the Douglas–Rachford algorithm
Francisco Javier Aragón Artacho

In this talk, we present a new formulation for successfully solving graph coloring problems with the Douglas-Rachford algorithm. These are highly combinatorial problems for which the convergence of the algorithm is not guaranteed. The implementation of this formulation not only results in a faster method than the one presented in [1], but it also permits to solve graph coloring problems without the knowledge of maximal clique information.

Joint work with Rubén Campoy (University of Alicante) and Veit Elser (Cornell University).

[1] F.J. Aragón Artacho, R. Campoy: Solving graph coloring problems with the Douglas–Rachford algorithm. Set-Valued Var. Anal., 27 pages (accepted Nov. 2017). DOI: 10.1007/s11228-017-0461-4

[2] F.J. Aragón Artacho, R. Campoy, V. Elser: An enhanced formulation for successfully solving graph coloring problems with the Douglas-Rachford algorithm, preprint 2018.

2 - Fixed point iterations in the context of nonnegative matrix factorization
Patrick Groetzner

The alternating projection method as a fixed point algorithm can be used to determine points in the intersection of two sets. Therefore this tool is useful for feasibility problems. In this talk I will consider questions which can be reduced to a feasibility problem and therefore be solved using alternating projection. The first application is deriving a nonnegative matrix factorization for a given matrix. Here I will show a factorization algorithm which, for a given matrix computes a nonnegative matrix factorization based on a certain feasibility problem. Moreover for symmetric matrices it is possible to derive a symmetric nonnegative matrix factorization which can be used to prove the membership to the completely positive cone, a problem which is known to be NP hard. A local convergence result can be shown for the symmetric case.

Joint work with Mirjam Duer (University of Augsburg).

3 - The steepest descent method for computing Riemannian center of mass on Hadamard manifolds
João Carlos Souza, Glaydston de Carvalho Bento, Sandro Dimy Barbosa Bitar, João Xavier da Cruz Neto, Paulo Oliveira

In this work, we perform the steepest descent method for computing Riemannian center of mass on Hadamard manifolds. To this end, we extend convergence of the method to the Hadamard setting for continuously differentiable (possible nonconvex) functions which satisfy the Kurdyka-Lojasiewicz property. Some numerical experiments computing $L1$ and $L2$ center of mass in the context of positive definite symmetric matrices are presented.

4 - Union nonexpansive operators and applications
Matthew Tam

In this talk, we consider a framework for the analysis of iterative algorithms which can described in terms of a structured set-valued operator. More precisely, at each point in the ambient space, we assume that the value of operator can be expressed as a finite union of values of single-valued paracontracting operators. Our main result, which shows that the associated fixed point iteration is locally convergent around strong fixed points, generalises a theorem due to Bauschke and Noll (2014).

■ MC-15

Monday, 12:30-14:00 - SOUTH BUILDING UV S203

New Trends in Shared-connected and Low-emission Human and Freight Transportation Systems II

Stream: Vehicle Routing and Logistics Optimization II
Chair: *Francesca Guerriero*
Chair: *Luigi Di Puglia Pugliese*
Chair: *Giusy Macrina*

1 - Optimizing vehicle relocations in one-way electric carsharing systems
Maurizio Bruglieri, Fabrizio Marinelli, Ornella Pisacane

The carsharing systems allow sharing vehicles by paying a charge according to the time of use (even minutes). In the one-way carsharing systems, users can deliver vehicles to a station different from the one of pick-up. However, this flexibility poses the problem of balancing the demand and the availability of vehicles between the stations, further complicated by their recharge needs, if the carsharing fleet is of Electric Vehicles (EVs). We address the operator-based EV Relocation Problem in urban one-way carsharing systems assuming that: the relocation requests are known; the operators directly drive the EVs from exceeding stations (pick-up requests) to needing stations (delivery requests); they move from the latter to the former by folding bikes; a revenue is associated with each relocation request and a fixed cost with each operator. The objective is to maximize the total profit, i.e., the difference between the total revenue and the total cost of the operators employed. Unlike the literature, we assume that the operators can collaborate among them, giving a lift to the others when moving an EV from a pick-up request station to one of delivery. We model this new problem via Mixed Integer Linear Programming and we design a Column Generation based heuristic to efficiently solve it. Preliminary results show that collaboration allows not only a decrement of the total distance covered via bike by the operators, but sometimes also an increment of the total profit.

2 - Impact of battery state of charge on cost optimal routes for hybrid and plug-in electric vehicles
Simgenil Arslan, Orkun Karabasoglu

Navigation systems facilitate transportation from one location to another. For the optimal route, most traditional navigation systems mainly offer options such as the shortest distance, shortest time or the highway preference. However, when the routing decisions are made for advanced vehicles, there are other factors affecting the travel cost, such as vehicle powertrain type, battery state of charge (SOC) and the change of component efficiencies under traffic conditions, which are not considered by traditional routing systems.The impact of the trade-off between distance and traffic on the cost of the trip might change with the type of vehicle technology and component dynamics. As a result, the least-cost paths might be different from the shortest-distance or shortest-time paths. In this work, we investigate the impact of initial battery state of charge on the cost optimal routes for hybrid and plug-in vehicles. We employ Vehicle Powertrain Connected Route Optimization (VPCRO) method as our route optimization strategy where the decision-making process benefits from sensory data in the vehicle sensor network. We demonstrate that the least cost paths might be different compared to the shortest paths that are found by Dijkstra's shortest path algorithm. We show that 3% and 10% of trips had different optimal paths for a plug-in hybrid electric vehicle, when initial battery SOC changed from 90% to 60% and 40%, respectively.

3 - An exact approach for routing a fleet of green vehicles with capacitated fuel stations

Simona Mancini, Maurizio Bruglieri, Ornella Pisacane

Green Vehicles (GVs), i.e., vehicles that use alternative fuel (e.g., methane, electricity, etc) have a limited driving range. Therefore, they may need to refuel one or more times at the Alternative Fuel Stations (AFSs) during their route. Since the AFSs are usually not widespread across the road network, stops at them must be scheduled in advance. In this context, the Green Vehicle Routing Problem (GVRP) consists in routing a fleet of GVs, based on a common depot, to serve a set of customers, minimizing the total travel distance. Although the GVRP has been intensively investigated in the literature, the AFSs are always assumed to have unlimited capacity. Obviously, this assumption is not realistic, since the AFSs have a limited number of chargers. In order to model this aspect, we introduce the GVRP with Capacitated AFSs (GVRP-CAFS), where, at each AFS, the number of GVs that can simultaneously refuel is limited. We address in exact way the GVRP-CAFS by proposing a semi-path based formulation with specific Capacity Constraints (CCs) at the AFSs. To solve also large instances in a reasonable amount of time, we initially solve a relaxation of the GVRP-CAFS obtained by omitting the CCs. Then, at each iteration, the violated CCs are dynamically added to the formulation until the current solution is feasible for the original problem too. Preliminary computational tests, carried out on instances of different size, show that the proposed exact approach performs very well.

4 - A column generation approach for an emission minimizing vehicle routing problem

Martin Behnke

In this talk, we consider an emission-minimizing vehicle routing problem with heterogeneous vehicles and give rise to the effects of path selection. We take into account different paths for travelling between two locations differing with respect to their emissions to exploit potentials for reducing the environmental impact especially of urban freight transportation. For solving the arising vehicle routing problem optimally, a column generation approach is presented. The backbone of the column generation procedure is an emission-oriented elementary shortest path problem on a multi-graph with load- and vehicle-dependent arc weights and resource constraints (EESPPRC) which is solved by a backwards label correcting algorithm. The EESPPRC has to be solved for each vehicle class to obtain vehicle-specific routes. The routes become columns in the associated master problem which is formulated as a set-covering problem. The column generation procedure turns out to be very effective for problem instances up to 50 nodes where CPLEX is outperformed for a variety of test sets. Computational experiments with artificial and real-world data sets illustrate the effects of path selection by considering networks with different road types like urban roads and highways. The experiments suggest an emission saving potential of about 3 - 6 %.

■ MC-16

Monday, 12:30-14:00 - SOUTH BUILDING UV S115

Network Optimization

Stream: Network Optimization and Social Networks
Chair: *Markus Leitner*

1 - Efficient algorithms for the budget-constrained minimum cost flow problem

Clemens Thielen, Michael Holzhauser, Sven Krumke

The budget-constrained minimum cost flow problem considers two cost functions on the arcs of a network and asks for a feasible flow that minimizes the cost with respect to the first cost function subject to an upper bound (budget constraint) on the total cost with respect to the second cost function. This, for instance, models situations in which the network is not already given a priory, but the arcs are considered to have an initial capacity of zero and must first be upgraded to the desired capacities subject to a budget on the total upgrade cost. The problem is NP-hard if upgrades are only possible in discrete steps, but polynomially solvable (e.g., by linear programming) in the continuous case in which arbitrary fractional upgrades are allowed.

In this talk, we consider the continuous case of the problem and show how known combinatorial algorithms for the classical minimum cost flow problem can be combined with binary or parametric search techniques in order to obtain efficient polynomial-time algorithms for this variant of the budget-constrained minimum cost flow problem. Moreover, we show that the developed techniques can be extended to a more general setting in which a budget constraint is added to an arbitrary linear program over an integral polytope.

2 - Benders cut-and-solve: a versatile tool for network optimization

Carlos Zetina, Ivan Contreras, Jean-François Cordeau

Introduced by Climer and Zhang (2006), cut-and-solve has been used to solve well-known optimization problems such as the TSP and facility location to optimality. The cut-and-solve framework can be thought of as a generalized local branching in which at each level of the enumeration tree only two child nodes exist, one corresponding to a smaller "sparse" problem and the other as its complement known as the "dense" problem.

In this study, we propose the use of Benders-based branch-and-cut as the black box MIP solver for "sparse" problems within the cut-and-solve algorithm. Two important advantages of this are the reduced problem size and the re-usability of the Benders cuts generated in previous sparse problems. We present promising computational results for a naive implementation used to solve the fixed-charge multicommodity network design problem.

3 - An exact resolution method based on adaptive partitions for the stochastic fixed charge multicommodity flow problem

Cristian David Ramirez Pico, Eduardo Moreno

We study the Stochastic Fixed Charge Multicommodity Flow (SFCMF) problem, which is a classical strategic and tactical decision problem studied in supply chain and network design. The main idea of the problem is that given a known graph, we want to find the optimal subgraph which minimizes a total cost composed by fixed cost related to build a subset of edges and a variable cost associated to the flow over the open edges, for a certain set of commodities or data. We present the SFCMF as a Two-Stage Stochastic Program including stochasticity on the commodities' demand.

We propose an adaptive partition-based resolution method where using a relaxation of the original problem exploits some special features of its solution, yielding an algorithm converging in a finite number of iterations to the optimal solution. Mainly, the method is based on the aggregation of an exponential number of constraints and variables, since a partition includes a subset of added constraints, one per scenario. Also, each is scenario variable is added with the other ones belonging to the same partition. Furthermore, the partitions are built using scenarios which are related in a closed way. At each iteration, the algorithm refines quality of the partitions, improving the lower bound by solving a master problem and, also, enhances the upper bound by solving the subproblems generated once we fix the first stage solutions. The experimental results and benchmark against classical methods will be shown.

4 - Variables aggregation and Benders decomposition for solving large-scale extended formulations
Markus Leitner, Bernard Fortz

Many optimization problems involve simultaneous decisions on high-level strategic decisions such as the location and/or dimensioning of facilities or devices, as well as operational decisions on the usage of these facilities. Moreover, these decisions often have to be taken for multiple demand sets over time or in an uncertain setting where multiple scenarios have to be considered. Hence, a large number of variables (and constraints) is often necessary to formulate the problem. Although sometimes more compact formulations exist, usually their linear relaxations provide much weaker lower bounds, or require the implementation of problem-specific cutting planes to be solved efficiently. A lot of research has focused in recent years on strong extended formulations of combinatorial optimization problems. These large-scale models remain intractable today with traditional solvers, but Benders decomposition gained attention as successful applications of it have been reported. An alternative to these large-scale models is to use more compact formulations, often based on variable aggregations. We propose an intermediate strategy that consists of projecting the extended formulation on the space of aggregated variables with a Benders decomposition scheme, applicable to a large class of problems. We discuss possible advantages of this strategy over a classical Benders decomposition approach and present computational results obtained for selected benchmark problems.

■ MC-17

Monday, 12:30-14:00 - SOUTH BUILDING UV S205

Stochastic Optimization Problems - Theory and Applications

Stream: Stochastic and Robust Optimization
Chair: *Milos Kopa*

1 - Multistage multivariate nested distance: an empirical analysis
Sebastiano Vitali, Milos Kopa, Vittorio Moriggia

Multistage stochastic optimization requires the definition and the generation of a discrete stochastic tree that represents the evolution of the uncertain parameters through the time and the space. The dimension of the tree is the results of a trade-off between adaptability to the original probability distribution and computational tractability. Moreover, the discrete approximation of a continuous random variable is not unique. The concept of best discrete approximation has been widely explored and many enhancements have been proposed to adjust and fix a stochastic tree in order to represent as well as possible the real distribution. Still, an optimal definition is practically not achievable. Therefore, the recent literature investigates the concept of distance between trees which are candidate to be adopted as stochastic framework for the multistage model optimization. The contribution of this paper is to compute the nested distance between a large set of multistage and multivariate trees and, for a sample of basics financial problem, to empirically show the positive relation between the tree distance and the distance between the corresponding optimal solutions and the optimal objective values. Moreover, we prove that the Lipschitz constant that bounds the optimal value distance is relatively weak.

2 - Dynamic model of market with uninformed market maker
Martin Smid, Milos Kopa

We model a market with multiple liquidity takers and a single market maker maximizing his discounted consumption while keeping a prescribed probability of bankruptcy. We show that, given this setting, spread and price bias (a difference between the midpoint- and the expected fair price) depend solely on the MM's inventory and his uncertainty concerning the fair price. Tested on ten-second data from ten US electronic markets, our model gives significant results with the price bias decreasing in the inventory and increasing in the uncertainty and with the spread mostly increasing in the uncertainty.

3 - Pharmaceutical R&D pipeline management under uncertainty
Elvan Gokalp, Juergen Branke

We present an Approximate Dynamic Programming (ADP) approach to the pharmaceutical pipeline management problem. We consider two significant uncertainties: the outcomes of clinical trials and their duration. Given an initial list of potential drug candidates, the approach suggests the trials to be performed at each decision epoch and state. For the classical R&D pipeline planning problem with deterministic trial duration, we compare our ADP approach with other methods in the literature, and find that our proposed algorithm has a comparatively smaller computational time and optimality gap than existing solution methods, especially for larger portfolio size. For the case with stochastic trial duration, we compare the ADP algorithm with a myopic approach often used in practice. Our analysis shows that the expected net profit obtained by ADP policy is higher (almost 20% for a 10-product portfolio) than that obtained by the myopic heuristic.

4 - Stochastic optimization with endogenous randomness - contamination techniques
Milos Kopa

Results of stochastic optimization problems are often influenced by the model misspecification and simplifications, or by errors due to approximations, estimations, and incomplete information. The obtained optimal solutions, recommendations for a decision maker, should be then carefully analyzed. We shall deal with output analysis, robustness, and stress testing with respect to uncertainty or perturbations of input data. We focus on stochastic problems with decision dependent randomness. Applying the contamination techniques we present lower and upper bonds for optimal value function for several different decision dependent randomness problems.

■ MC-18

Monday, 12:30-14:00 - SOUTH BUILDING UV S206

Theoretical Investigations in Convex Optimization

Stream: Convex Optimization
Chair: *Attila Gilanyi*

1 - Cyclically antimonotone vector equilibrium problems
Mihaela Berchesan(Miholca)

In this paper, we extend the notion of cyclic antimonotonicity (known for scalar bifunctions) to the vector case, in order to obtain a vectorial equilibrium version of the Ekeland's variational principle. We characterize the cyclic antimonotonicity in terms of a suitable approximation from below of the vector bifunction, which allows us to avoid the demanding triangle inequality property, usually required in the literature, when dealing with Ekeland's principle for bifunctions. Furthermore, a result for weak vector equilibria in the absence of convexity assumptions is given, without passing through the existence of approximate solutions.

2 - generalized derivatives of the optimal value of a linear program with respect to matrix coefficients
Daniel De Wolf

In the framework of linear programming, we consider the problem of estimating the variation of the objective function resulting from changes in some matrix coefficients. Our objective is to extend results already available for the right-hand-side to this more general problem.

The interpretation of the dual variables as derivatives of the optimal value of the objective function with respect to the elements of the right-hand-side is well known in mathematical programming. This result can be extended to the case of multiple dual solutions. The set of all dual solutions is then the subdifferential of the optimal value of the objective function, seen as a convex function of the right-hand side.

The object of this paper is to extend these well known results to the derivative of the optimal value of the objective function with respect to matrix coefficients.

It is easy to show on a simple example that the objective function value of a linear program is not a convex function of the matrix coefficients. The subdifferential concept is thus inappropriate here. One must therefore resort to Clarke's notion of a generalized derivative.

We present here in a not (too) mathematical manner the generalized derivative of the optimal value of the objective function of a linear program as a function of matrix coefficients. We generalize the result of Freund (1985) to the cases where derivatives may not be defined because of the existence of multiple primal or dual solutions.

3 - Bilinear programming: a robust optimization perspective
Ahmadreza Marandi, Jianzhe Zhen, Dick den Hertog, Lieven Vandenberghe

We show that a bilinear problem with disjoint polyhedral feasible regions can be cast as a two-stage fixed-recourse robust linear optimization problem, and techniques for adjustable robust optimization can be used to solve the resulting problems. Numerical experiments on bimatrix games and norm maximation problems show that the proposed method is superior to the existing solvers SCIP and CPLEX in more than 70%. Theoretically, we extend McCormick relaxation to bilinear problems with a general convex feasible region and show a close relation between McCormick relaxation and linear decision rules. This result provides a new theoretical result on the tightness of the McCormick relaxation!

4 - Bernstein–Doetsch type theorems for set-valued functions
Attila Gilanyi, Carlos Gonzalez, Kazimierz Nikodem, Zsolt Pales

During the last more than one hundred years, generalizations of the well-known Bernstein–Doetsch Theorem were investigated by several authors. In this talk, we consider strongly as well as approximately Jensen convex (and also Jensen concave) set-valued maps and we present Bernstein–Doetsch type theorems with so-called Tabor type error terms for them.

■ MC-19

Monday, 12:30-14:00 - SOUTH BUILDING UV S207

Vector and Set-Valued Optimization III

Stream: Vector- and Set-Valued Optimization
Chair: *Marius Durea*

1 - Necessary conditions in set optimization
Truong Q. Bao

Set optimization means optimization of sets or set-valued mappings, where sets are compared to select the most efficient set in contrast to find the best element of the union of all sets. In this talk, we show how to use Gerterwitz' scalarization functional to convert a set optimization problem with respect to Kuroiwa's solution concepts into a scalar one. Then, we derive necessary optimality conditions for these solutions in terms of generalized differentiation.

2 - On the stability of the directional regularity
Marian Dumitru Pantiruc

We select two tools of investigation of the classical metric regularity of set-valued mappings, namely the Ioffe-Fabian-Preiss criterion and the Ekeland Variational Principle, which we adapt to the study of the directional setting. In this way, we obtain in a unitary manner new and generalized results concerning sufficient conditions for directional metric regularity of a mapping, with applications to the stability of this property at composition and sum of set-valued maps. In this process, we introduce as well new directional tangent cones and the associated generalized differentiation objects and concepts on primal spaces. Moreover, we underline several links between our main assertions by providing alternative proofs for several results.

3 - Henig efficiency in vector optimization problems with variable ordering structure
Elena-Andreea Florea, Marius Durea, Radu Strugariu

Proper efficiency was very much investigated in the case of Pareto optimality defined by a fixed ordering structure, and in last years, with the appearance in the literature of some applications in image registration, the efficiency notions have also begun to be studied in the case of vector optimization problems with a variable ordering structure. In this talk, we propose an extension of Henig proper efficiency from fixed order structure, to variable ordering structure, in the case where the order is expressed by means of a set-valued map acting between the same spaces as the objective mapping. In order to get an appropriate concept, we have to explore first the case of a fixed ordering structure and to observe that, in certain situations, the well-known Henig proper efficiency can be expressed in a simpler way. Then, we observe that the newly introduced notion can be reduced, by a Clarke-type penalization result, to the notion of unconstrained robust efficiency. We show that this penalization technique, coupled with sufficient conditions for weakly openness, serves as a basis for developing necessary optimality conditions for our Henig proper efficiency in terms of generalized differentiation objects lying in both primal and dual spaces.

4 - Optimality conditions and a barrier method in convex optimization without convex representation
Marius Durea

In this talk we consider, following some questions raised by Lasserre, several issues concerning the preservation of the conclusions of some results in smooth convex optimization with inequalities constraints to the case where the feasible set is convex, but has no convex representation. The main results we discuss concern some relations between various qualification conditions, and a barrier method based only on the geometric representation of the feasible set.

■ MC-20

Monday, 12:30-14:00 - SOUTH BUILDING UV S301

Advances in Modeling Uncertainty and Incomplete Preference Information

Stream: Decision Analysis and Decision Support Systems
Chair: *Eeva Vilkkumaa*

1 - Preferences in spatial decision making
Jay Simon, L. Robin Keller

Decision maker preferences for spatial decisions can be challenging both to model and to assess. When outcomes occur over a geographic space, the decision maker must consider not only uncertainty, risk, relative preferences for different levels of an attribute, and tradeoffs between attributes, but also the geographic areas in which each attribute level is realized. We provide representation theorems ensuring the existence of value and utility functions for spatial decisions, and discuss the forms of these functions as well as the relevant preference conditions. We also explore a range of viable elicitation techniques that can be applied to spatial preferences.

2 - Spatial multi-attribute decision analysis: axiomatic foundations and incomplete preference information
Juuso Liesiö, Mikko Harju, Kai Virtanen

This paper advances the theoretical foundations and the methodology of spatial decision analysis in which multi-attribute consequences of decision alternatives vary over a spatial region. First, we introduce necessary and sucient conditions for representing the decision maker's preferences among such decision alternatives with an additive spatial value function. This new axiomatization allows for the representation o of preferences when the spatial region consists of an infinite number of locations, which is often the case in practical applications. Moreover, we show that spatial value functions suggested in the existing literature can be interpreted as special cases of our additive spatial value function. Second, motivated by the high eort required to elicit preferences in spatial decision problems, we develop a method for utilizing the additive spatial value function with incomplete preference information about spatial weights describing the importance of locations and attribute weights. This method provides defensible decision recommendations through the use of dominance concepts and decision rules. The applicability of the developed value function and analysis method is illustrated with a real-life application in air defense planning.

3 - A portfolio approach for optimizing safety measures in dynamic Bayesian networks
Alessandro Mancuso, Michele Compare, Ahti Salo, Enrico Zio

We develop a method of portfolio optimization for selecting cost-efficient safety measures in dynamic systems consisting of components which have discrete states whose realizations evolve probabilistically over a finite number of stages. Specifically, we model such systems as Dynamic Bayesian Networks (DBN) in which nodes correspond to components and links indicate dependencies between them. The decision alternatives consist of component-specific safety measures which modify (un)conditional probability distributions over component states, thus impacting the residual risk, represented by the probabilities of the critical states of one or several target nodes. In contrast to the use of conventional risk importance measures, our method provides a systemic approach to risk management in that it uses an implicit enumeration algorithm to compute all non-dominated portfolios of safety measures for different levels of costs of risk management. Moreover, the method identifies which safety measures are contained in all or some of these portfolios, thus guiding the cost-efficient allocation of resources to safety measures. The method is illustrated by revisiting the accident scenario of a vapour cloud ignition which occurred at Universal Form Clamp in Bellwood, Illinois, U.S. on 14 June 2006. Extensive sensitivity analyses are presented to show the impacts of uncertainties about model parameters.

4 - Scenario-based multicriteria portfolio model for building a robust and proactive strategy
Eeva Vilkkumaa, Petri Rikkinen, Juuso Liesiö

In the fall of 2017, a leading cards provider company operating in Europe was looking to revisit its scenario-based strategy work. In particular, the company wanted to develop a strategy that would be robust across different scenarios of the future operational environment on two criteria: impact on revenue and alignment with customers' needs. Yet, because of the company's leading market position, its strategy was seen to have a potential impact on which of the futures scenarios would be realized.

We developed a scenario-based, multicriteria portfolio model to help select a combination of strategic actions that would be (i) robust in that it would perform relatively well across the possible future scenarios on both evaluation criteria and (ii) proactive in that it would help steer the course of change toward the desired scenario. In this model, (i) information about criterion weights and scenario probabilities may be incomplete and (ii) some actions can affect the scenario probabilities. This model supported the strategy building process by helping to identify those strategic actions that the company should pursue immediately as well as those actions in which they should make smaller, initial investments to be possibly expanded later.

■ MC-21

Monday, 12:30-14:00 - SOUTH BUILDING UV S303

Workforce Scheduling and Line Balancing II

Stream: Project Management and Scheduling
Chair: *Evgeny Gurevsky*

1 - A new mathematical formulation with search-space reduction techniques for the multi-manned assembly line balancing problem
Adalberto Sato Michels, Thiago Cantos Lopes, Celso Gustavo Stall Sikora, Leandro Magatão

Multi-manned assembly lines are commonly found in industries that manufacture large-size products (e.g. automotive industry), in which multiple workers are assigned to the same workstation in order to perform different operations simultaneously on the same product. Although the balancing problem of multi-manned assembly lines had been modelled before, the previously presented exact mathematical formulations are only able to solve few small-size instances. This work presents a new Mixed-Integer Linear Programming (MILP) model with stronger lower bounds and symmetry break techniques to solve more instances optimally. Our model minimises the total number of workers along the line and the number of opened stations as weighted primary and secondary objectives, respectively. Besides, stronger lower bound cuts and symmetry break constraints based on the model's parameters are applied to reduce search-space. Tests on a literature data-set yielded 25 optimal results out of 26 small-size instances, whereas previously presented models could only solve 12 of them to optimality. Moreover, in the instances that both models were observed to reach optimality (12 out of 26), the computational processing time had been reduced by approximately 95%. Nonetheless, the formulation still cannot solve medium and large-size instances satisfactorily. For that purpose, further cutting-plane generation methods should be implemented alongside with the model.

2 - Supplying assembly lines: a case study
Aida Saez-Mas, Angel Ruiz, José P. Garcia-Sabater, Julio J. Garcia-Sabater

Progressively adoption of mass-customization strategy in industry is leading to an increasing product variety, so that a larger number of different parts or subassemblies have to be handled to feed the assembly workstations. Since areas beside assembly lines are scarce and they are not designed to hold a lot of inventory, a continuous supply of parts from the storage areas to workstations is requested to ensure that the production flow remains constant. Indeed, this in-plant logistics has become one of the most critical tasks to ensure that assembly lines run smoothly and efficient. The management of in-plant flows is a complex and challenging problem which encompasses several decisions, including the assembly line's layout, inventory and replenishment policies, storage space assignment, and the election of specific handling equipment, among others. This research, which inspires by the situation faced by a large manufacturing facility, discusses the difficulties and challenges related to the problem of how to feed the assembly line. In particular, the already scarce available space beside the assembly line has been progressively exhausted so a new storage space has been added to the plant. Managers are now concerned not only by how to use the new space, but by a whole redesign of the plant's logistics. The problem is formulated as a location allocation model where the total time required to satisfy the daily parts' demand is minimize.

3 - Mixed model sequencing in two-sided assembly lines
Mary Kurz, Anas Al-Ghazi

Mixed-model assembly is used to produce a variety of related products on the same assembly line. Such a setting requires line balancing (the assignment of tasks to workers at stations) and sequencing (the release of work pieces down the line). When the tasks differ based on model, the line balance and sequence can interact to induce work overload in some stations. Assuming a line balance is fixed, the sequence can be adjusted to try to minimize work overload. One mechanism is to assume a utility worker can double the speed of the worker at the overload station. In contrast, in the skip policy, the utility worker takes over the work piece that is expected to cause the overload while the normal worker instead starts working on the next work piece. Additionally, "swimming" allows the worker to move into adjacent stations, in effect, getting ahead or keeping up with incoming work. Previous work has considered the impact of skipping with swimming on work overload, though it was limited to one worker per station. However, large products, such as vehicles, are assembled at stations which may have one or more workers per station. In this research, we address the sequencing problem with skipping and swimming in a two-sided assembly line.

4 - Optimality-based cuts generation for robust balancing of paced production lines with blocks of uncertain parallel tasks and space restrictions
Aleksandr Pirogov, Evgeny Gurevsky, André Rossi, Alexandre Dolgui

This communication deals with a robust design of paced production lines having a restricted number of machines, equipped with sequentially activated blocks, where each of which is able to execute simultaneously a set of tasks assigned to it. The design goal is to allocate a given set of production tasks to blocks and then blocks to machines so as to hedge against as much as possible the presence of a subset of tasks, whose processing time is likely to be uncertain. Some restrictions are taken into account as well such as precedence and cycle time constraints. In order to model the uncertainty part of this optimization problem, a robust approach is used. It is based on the concept of the so-called stability radius, which carries out the role of robustness measure to be maximized.

In this paper, an optimality-based cuts generation method, founded on MILP formulation, is proposed in order to solve the described problem to optimality. Based on structural properties of the precedence constraints, the nominal value of task processing times and the objective function value of current best integer feasible solution, the studied cuts aim to reduce the set of blocks of potential assignment for each task and consequently speed up enumeration process in search space.

The implementation of the proposed above technique within the framework of GUROBI, enhanced by an initial heuristic feasible solution and combinatorial upper bounds, will be reported during presentation.

■ MC-22

Monday, 12:30-14:00 - SOUTH BUILDING UV S304

Efficient Algorithms for Optimization Problems

Stream: Multiobjective Optimization
Chair: *Pascal Halffmann*

1 - Scalarization in vector optimization with arbitrary domination sets
Petra Weidner

Usually, vector optimization problems are defined with domination sets that are ordering cones. In the presentation, the necessity to study problems with more general domination sets will be illustrated. Vector optimization problems with arbitrary domination sets are studied. Scalarization results for efficient and weakly efficient elements of these problems are given, where especially the Gerstewitz functional is used. A surrogate for the weakly efficient point set is investigated, which is of special interest for domination sets with empty interior. The study includes statements for perturbed problems and problems under uncertainty. In general, we do not assume convexity or any topology.

2 - Column generation in biobjective linear programming
Andrea Raith, Siamak Moradi, Matthias Ehrgott

Biobjective LPs can be solved by the biobjective simplex method which iteratively moves between efficient basic solutions by selecting a variable to enter the basis with maximum ratio of improvement of one objective and deterioration of the other. We show that a column generation approach can be integrated with this simplex method to dynamically identify which decision variables to include in the problem. New variables to enter the basis are generated by solving a column generation subproblem that finds the required variable of maximum ratio. We explore how to formulate the required column generation subproblems for a particular biobjective LP, and compare the performance of the different approaches.

3 - The job sequencing and tool switches problem: properties of its solution and bounds
Horacio Yanasse

In this work, we address a simple case of the job sequencing and tool switches problem (SJSTSP). The SJSTSP consists in finding an order to process a set of N jobs in a single flexible manufacturing machine so that the total number of tool switches is minimized. Each job requires a set of tools that must be in the machine in order to process it. We assume that the position or order of any tool in the magazine is irrelevant. The time to remove or insert a tool in the magazine is significant compared to the time to process the jobs and it is constant and equal to all tools. We assume that the machine is able to change one tool at a time. The N jobs require a total of M different tools with M > C, where C is the capacity of the machine. Since M > C, tool switches are necessary in order to process all N jobs. A tool switch consists in removing a tool from the machine and inserting another in its place. We relate this problem with the minimization of open stacks problem and we identify properties of its solutions. We use these properties to derive upper and lower bounds for the SJSTSP.

4 - Can we approximate a weight set decomposition?
Pascal Halffmann, Stefan Ruzika

The Weighted Sum Method is a well-known and commonly used scalarization technique not only for solving multi-objective optimization problems but also for quantifying the preferences of a decision maker. In order to analyse either these preferences or the set of so-called (extreme) supported nondominated images, the Weight Set Decomposition can come into play: This tool decomposes the set of all normalized positive weights into components such that for each component one extreme supported nondominated image is optimal for all weights in this component. Hence, one can deduce a „quality"-measure for the chosen solution or the chosen weights. However, computing the whole weight set decomposition can be time consuming or not necessary. In this talk, we introduce the idea of an approximation for computing the weight set decomposition. To the best of our knowledge, this has not been done before, hence we lay the foundation for further development in this research. First, we state what we can understand as an approximate weight set decomposition and we list requirements and conditions from which we construct a proper definition. Further, we present various measures in order to state the quality of the approximation such as an approximation factor. Last, we present an approximation algorithm that iteratively decomposes the weight set using simplex similar polytopes. We examine this algorithm regarding correctness, approximation quality, convergence rate, running time and bounds.

■ MC-23

Monday, 12:30-14:00 - SOUTH BUILDING UV S305

Shift and Task Scheduling

Stream: Timetabling
Chair: *Ferdinand Becker*

1 - A column generation approach for the shift design and rostering problem in airport ground handling
Joost van Twist, Murat Firat, Cor Hurkens

In this study we propose a Column Generation based solution method that simultaneously solves a shift design- and rostering problem. In our problem setting, we consider a heterogeneous workforce demand of ground handling staff that is derived from a flight schedule in a given planning horizon. The pricing problem amounts to finding a shift schedule of a worker that corresponds to a longest path problem in the corresponding graph. In our case, several labour rules should be respected in the worker schedules which brings extra complexity to the pricing problem. Besides worker availabilities, we also consider worker preferences while constructing schedules. The instances contain around 200 workers and span a one-month planning horizon. Two types of workers are considered: First, we have workers with a fixed target amount of working hours each month. Second, we consider flexible workers that have no required target of working hours, but have a preferred number of working hours that can change each month based on preference. Each worker, when on duty, can cover the demand of various workloads. Our solution approach produces timetables and employee schedules with the goal of minimizing all labour costs while satisfying the workload demand. We introduce heuristics that employ graph theory for the pricing problem. Our approach is successfully tested on real life data of a ground handling company in an airport situated in the Netherlands.

2 - A rough set approach to the multinational chain multi-skilled staff scheduling problem with supporting cooperation
Teng-Sheng Su

Nowadays, the multinational chain has an impact on the issue of manpower shortage worldwide. In order to have the members of the supply chain approach workload balance, the multinational supply chain system is required to solve not only the staff scheduling problem, but also the inter-organization supporting cooperation problem. This paper presents an efficient procedure for designing a rough set theory-based multi-skilled staff scheduling and supporting cooperation model under diverse product and service requirements. To resolve the stochastic problem, a penalty function integrated mixed integer linear programming under the supporting cooperation satisfaction is proposed to minimize the service quality lost. An empirical example from the industrial case is to illustrate the proposed solution procedure and capable of producing a managerial shift arrangement applied for multinational service chain.

3 - Staff rostering for check-in counters with both period-based and task-based demands
Lishun Zeng, Mingyu Zhao, Shuai Tian

We address the problem of staff rostering for check-in counters, which is part of a large business project aimed at developing a ground handling resource management system for a major airline in China. For a given multi-skill heterogeneous workforce, the objective is to minimize the total assignment cost along a weekly planning horizon with respect to a wide range of flexible shift rules from shift start times and lengths to personal preferences and fairness. Besides the time varying yet homogeneous period-based demand as considered in the relevant literature, our problem also involves a set of non-preemptive tasks with predefined times, locations, and skills, e.g. according to service-level agreements with external customers. The resulting model is a very challenging one which simultaneously considers most of the typical modules in the rostering process, i.e. days off scheduling, shift scheduling, line of work construction, task assignment, and staff assignment. We propose a column generation approach with graph-based pricing subproblems for the model. Following the idea of the well-known RINS scheme, we also devise a MIP-based large neighborhood search heuristic in which the sub-MIP is defined based on an aggregate value of each task-employee pair in the current LP solution. The approach is able to produce good quality solutions for real-world demand data and already in use in the system.

4 - Planning cross-docking operations - integrating truck and workforce scheduling
Ferdinand Becker, Hagen Salewski, Hans Corsten

Cross-docking is a logistics concept, which synchronizes suppliers' shipments and thereby enables a fast turnover of the products at minimum stock levels. In this context, planning tasks concerning the coordination of product flows and the synchronization of the in- and outbound trucks are important. In particular, the resulting truck schedules determine the succession of the trucks' processing at the dock doors, and thus, govern the internal cross-docking processes. Since these operations are labor intensive, staffing issues become relevant. However, published cross-dock planning approaches rarely take internal processes, e.g., loading, unloading, and consolidation tasks, into account. We propose a model which integrates the planning of truck and workforce schedules in a cross-dock. Our approach allows a logistics service provider to deal with the fluctuating demand using part-time workers. The model determines the allocation of the employees to tasks and shifts while minimizing the number of engaged part-time workers. We derive representative test instances and solve the problem. Due to the high problem complexity, we propose a decomposition approach and evaluate its performance compared to the integrated model. Furthermore, we perform computational experiments to analyze different workforce coordination policies in a cross-dock.

■ MC-24

Monday, 12:30-14:00 - SOUTH BUILDING UV S306

Financial Mathematics and OR III

Stream: Financial Mathematics and OR
Chair: *Masanori Ozawa*

1 - High frequency sampling and international continuous-time stochastic processes
A. Can Inci

In today's world of global integration, non-stop trading, ultra-high speed transaction and transmission setting, continuous time stochastic processes provide an ideal starting point for designing theoretical financial models. The empirical performance of such models should be superior primarily if the data used for the tests reflect reality with high sampling frequencies. Such high frequency data (e.g., intraday data) would demonstrate the better utilization of the continuous and jump components of a stochastic process. On the other hand, low frequency data such as those with weekly, monthly, or quarterly sampling may not demonstrate the advantages of the dynamic stochastic processes with jumps since these jumps may be smoothed out unintentionally. Even data sampled at daily frequency may suffer from this problem and not necessarily reflect the true nature of the currency and interest rate dynamics. This study investigates various two-country multi-state nonlinear and affine stochastic models using currency and interest rate data with different sampling frequencies. The impact of high frequency sampling on the forecasting performance of the stochastic models is explored.

2 - CPPI-STAR: triggered insurance portfolio strategies with time varying multiples based on regime switching asset dynamics
Jean-Luc Prigent, Hachmi Ben Ameur, Fredj Jawadi, Farid Mkaouar

In this paper, we propose and analyze an important extension of one of the two main portfolio insurance strategies, namely the standard Constant Proportion Portfolio Insurance (CPPI) method. For this purpose, we assume that the risky asset price follows a general autoregressive regime switching model. To control the gap risk of such portfolio strategies, we introduce several risk measures based on various quantile conditions. We illustrate the advantages provided by such strategies, using in particular a STAR STGARCH model, while taking account of transaction costs. This leads us to introduce triggered insurance portfolio strategies with time varying multiples conditioned by the regime switching of the risky asset dynamics. Our empirical analysis is mainly conducted on S&P 500 data. We also backtest these strategies, using a sliding window method to dynamically estimate the parameters of the models based on the last two years of weekly returns. Our results emphasize the very significant interests of introducing time varying multiples based on regime switching models, from both the theoretical and operational points of view.

3 - Exploring negative variance in logistics cost for FMCG e-tailer in India
Nilanjan Chattopadhyay

E-tailing in India is booming with multinational and home-grown companies fighting to gain consumer eyeballs. Logistics cost is typically 12 % of total cost of any e-tailing organisation in India. Management of logistics cost for e-tailers dealing in FMCG products is further complicated since it is costly and tough to trace. In a country like India with its large population and wide spread geography, unplanned logistics cost often turn out to be deciding factor in survival of a firm. Purpose of this study is to estimate non-budgeted expenditure incurred by one FMCG e-tailer in logistics operations for a selected product category, for a specific period. The study also attempts to estimate the scope for improvement in logistics operations in terms of cost efficiency. The study was done using action research approach with primary data collected from one e-tailer for FMCG shipments. Later a quantitative model was developed to estimate the logistics cost to the firm. The study could successfully identify the lack of coherence between planning and implementation stage logistics, resulting in negative variance in budgeted expenditure. The study could determine the Out-of-matrix cost for the e-tailer to be as high as 38% of the total transportation cost for the period studied.

4 - A risk evaluation of the Japanese public pension and the long-term personal pension
Masanori Ozawa, Michael Krause

Recently, the Japanese public pension finance is concerned that a bankruptcy will occur because low fertility and longevity is projected in long-term years. Therefore, the Japanese government has introduced a specific reform policy which is called the automatic balancing mechanism.(ABM) Moreover, financial problems in old age life have been rising a insurant of personal pension has been on an increasing trend because of longevity. In this study, we evaluate sustainability of the public pension system by calculation the probability of bankruptcy of each termination year of ABM under some population scenarios and economic scenarios. Furthermore, we evaluate and compare the public pension and the personal pension by calculating expected consumption for life after retirement. The results show that the expected value of the personal pension benefit is higher than that of public pension benefit under any scenario. On the other hand, the personal pension is better for retirement life at the high indicators and the public pension is better at the low indicators.

■ MC-25

Monday, 12:30-14:00 - SOUTH BUILDING UV S307

Model-based Decision Support

Stream: Combinatorial Optimization II
Chair: *Jan van Vuuren*

1 - Simulating the movement of forcibly displaced Syrians using agent-based modelling
Christa de Kock, Brian van Vuuren, Sara S Grobbelaar

Over the past decade, civil wars and similar calamities within the international community have led to conflict-induced forced displacement of individuals all around the world. The challenge posed by managing sudden migration of large groups of people is the ability to accurately portray and predict the scale and dynamics of such movement. Furthermore, data pertaining to large-scale migration patterns are largely incomplete or untrustworthy, adding further complexity to the management of this issue.

In this study, agent-based simulation is employed to model the outbreak of conflict and the consequent movement patterns of forcibly displaced individuals, based on their associated decision-making, with reasonable accuracy. An empirical case study is performed on Syria, considering population characteristics associated with Syrian people. The proposed model aims to address the lack of complete data by providing estimates, generated as model outputs, pertaining to the number of refugees, undocumented migrants and internally displaced persons fleeing conflict-affected Syria. Furthermore, the anticipated destinations of these people, based on their personal characteristics and associated anticipated decision-making, are also provided in an attempt to assist with planning and management of refugee intake by neighbouring countries.

2 - Planning model of machinists' work in passenger trains
Izabela Dziaduch, Pawel Hanczar

Making decisions regarding the planning and organization of transport processes in railway companies is an important issue from the perspective of efficiency of their activities.

Planning of passenger transport in rail transport consists of the following stages: 1. Trains timetables planning, 2. Rolling stock circulation planning, 3. Train team service planning, i.e.: machinists and conductors, 4. Support team work planning.

The planning of the transport process is realized in stages given above and according to the hierarchical approach, in which a higher-level plan (timetable) provides a framework for plans of lower levels, i.e. planning of rolling stock circulation, planning of train team service and properly allocating the employees to planned services.

The article focuses on the problem of planning of machinists' work. Basic requirements, which should be considered in the presented topic, are characterized. Literature overview in terms of existing planning models of machinists' work is done as well. In the main part of the work, the decision model, which will allow in a given time to plan a crew for a train, is proposed. The article also contains the assessment of the possibility to use the presented model in the planning of machinists' work in practice.

3 - An exact tree search algorithm for the hot sheet stacking problem
Philipp Fath, David Sayah, Stefan Nickel

One of the core challenges of steel producers is the steel milling process. The output of the steel milling process are steel sheets of different sizes. These steel sheets are still very hot when leaving the mill. For quality reasons a slow cooling step is desirable. In practice, one way to achieve a decelerated cooling speed is to build compact stacks of steel sheets. The slow cooling of compact stacks eliminates hydrogen induced cracks in the steel. The underlying optimization problem is to assign steel sheets to stacks and to position each sheet inside its stack in such a way as to build stacks with maximum compactness. The problem has a dynamic nature since steel sheets arrive sequentially. Also, geometric and physical aspects restrict the positioning of steel sheets. First, we present a MINLP formulation for the hot sheet stacking problem (HSSP) with a single stack. A linearization of the MINLP formulation can be solved to optimality for instances with up to 15 sheets using a standard MIP solver. Real world instances contain around 50 sheets per stack. These instances cannot be solved within reasonable time. This motivates a different approach for solving this problem. We propose an exact tree search algorithm. Different node selection strategies are discussed. Problem-specific dominance rules speed up solution times. The performance of several upper and lower bounds is evaluated. Finally we compare the two solution approaches of the HSSP.

4 - Model-based decision support for subjective preference selection
Johan Kellermann, Jan van Vuuren

Aiding with subjective preference selection problems we propose a decision support system facilitating a solution iteratively. The decision maker is initially presented with a set of alternative combinations to evaluate. The preference of the decision maker is portrayed by scores for each alternative. By construction of a value function (hyper) surface fitting through all alternative scores considered, the user may be temporarily "replaced" by a preference learning model, which seeks to predict the decision maker's preference by generating a new set of alternatives that perform well in terms of the estimated value function of the DM. These newly generated solution alternatives are again presented and evaluated by the decision maker, which hopefully contain alternatives of better subjective quality. The new set of alternatives contain a representative remnant of the previous set of solutions called an anchor alternative, which allows for each alternative combination set's value score to be adjusted according to all alternatives considered, reducing the required pairwise comparisons. Further reduction of workload is incorporated by a trade-off between exploiting well-performing areas of the decision space and exploring unknown regions with the aim of avoiding DM's efforts in respect of decision alternatives that are known to be of poor relative quality. The learning cycle is repeated iteratively, hopefully evolving according to the user's subjective criteria.

■ MC-26

Monday, 12:30-14:00 - SOUTH BUILDING UV S308

Network Design and Equilibrium Concepts in Transportation and Location

Stream: Public Transportation I
Chair: *Claus Gwiggner*

1 - Public network design with analytical Benders cuts
Arthur Mahéo, Robin Pearce, Michael Forbes

Transportation problems tend to get very complex when applied to real-life scenarios. But they are often an assemblage of well-known problems with efficient algorithms. Our idea is to use decomposition to get to these easy parts. We propose to apply a variant of Benders decomposition on a public network design problem in Canberra, Australia. In this case, our sub-problem becomes a shortest path. Many efficient algorithms exist for this problem, but they don't produce the dual information required to generate the Benders cuts. The typical way to get dual information is to use a linear solver. And using a general purpose solver is always slower than a dedicated method. First, we show how to extract dual costs from the solution of a shortest path. Second, we prove that the cuts generated are Pareto optimal. Finally, we compare this approach to a MIP and a classic Benders.

2 - Route planning for fixed route transit by maximizing OD flow capture
Daisuke Hasegawa, Tsutomu Suzuki

In recent years, the local public transit system is reconsidered in the suburbs of Japan to cope with the economic and social condition. Fixed-route transit (FRT) such as bus or tram has been providing access connecting urban area and suburbs so far. However, it is required to diversify into more forms, such as the circle route that enhance the mobility in downtown, and the combination with the flexible-route-transit such as Dial-a-Ride system that changes route according to fluid demands. This study aims to develop the model for constructing the FRT network for maximizing the quantity of captured OD flow by FRT network. First, the locations of the start and end points of FRT route are decided by facility location problem considering the quantity of OD flow. Second, the routes connecting these points that maximize the quantity of captured OD flow are constructed under the length constraint of the route. Third, the circle route is built by the problem that selects the edge with high edge-betweenness-centrality while maintaining the connectivity. Fourth, we evaluate several solutions of FRT network created by our models regarding the economic, environmental, and health aspects of whole stakeholders and clarify the plans to be balanced. Fifth, we apply our model to several suburban areas in Japan to clarify the difference of optimized FRT according to different condition and necessity of flexible-route-transit.

3 - Modelling inbound demand and congestion with Poisson and pre-scheduled random arrivals
Carlo Lancia

Congestion is a persistent phenomenon at major airports in both the US and Western/Central Europe. Airport operations have historically attracted the interest of the scientific community in the attempt to alleviate congestion. In particular, a lot of effort has been devoted to studying congestion through queue models, and Poisson arrivals is a key assumption for developing those due to their mathematical tractability and consistency with observed inbound stream. However, this assumption has been validated only in more recent times using arrival data at major US airports.

This talk will present a dataset of inbound arrivals at 8 important European airports and show how to construct models of Poisson and Pre-scheduled random arrivals (PSRA) in a data-driven fashion. In a Poisson process, arrivals are independent and follow a Poisson law, whose intensity can be time-dependent; PSRA are negatively autocorrelated and obtained by summing random delays to a deterministic schedule.

Looking at the prediction of future inbound demand, I will show that PSRA achieves higher accuracy scores than Poisson arrivals.

Then, I will focus on the inbound congestion in situation of heavy load. Using a single-server queue model with deterministic service time, I will show that PSRA arrivals produce better performance metrics than Poisson even when the variability of PSRA delays is very large.

4 - Descriptive analysis of sequential location games
Claus Gwiggner

One class of competitive location problems consists of sequential decisions, where several players act, one after the other, possibly in several rounds. A solution for such games, that is, the prediction of their outcomes, is often associated with the subgame perfect Nash equilibrium. The naive computation of such equilibria consists of a full enumeration of all possible combinations of actions.

In this work, results of a descriptive data analysis of equilibrium strategies for the leader, i.e., the first mover, are presented. In more detail, the question whether the equilibrium strategy is greedy or not is answered by a data-driven classifier.

■ MC-27

Monday, 12:30-14:00 - SOUTH BUILDING UV S309

Simulation Models

Stream: Production, Service and Supply Chain Management
Chair: *Dimitris Zissis*

1 - Towards quantitative risk evaluation for supply chains
Birgit Mösl, Dietmar Neubacher, Nikolaus Furian

In recent years Supply Chains (SC) have been subject to major changes. They evolved from classical intra-SCs to inter-SCs and beyond to flexible and more complex SC-networks. Because of globally distributed SC-networks, dynamic environments and constantly increasing customer expectations, managers are facing new challenges. The emerging complexity of SCs leads to new dimensions of risks (variable, uncertain, global), that have to be considered and managed. Hence, managers are required to assess these new risks and make decisions in a dynamic environment. Therefore, methods and tools are needed to support managers in evaluating scenarios and making decisions. Models and simulations are suitable for latter purposes as these techniques are frequently used to describe, shape and investigate problems. Moreover they are used to improve the problem understanding, to test and compare different scenarios and to conduct 'what-if' analyses without influencing the real world. In this study the focus is the evaluation of risks along the entire SC, especially on the quantification of risks for further evaluation. Three different dimensions of risks are considered, with respect to country, transportation routes and SC participants. Appropriate risk indicators are identified and discussed. In the course of conceptual modeling the evaluation of influencing factors and their measurability is discussed.

2 - Simulating storage policies for an automated grid-based warehouse system
Michaela Wissing, Kevin Tierney, Christoph Weskamp

Robotic fullfillment systems are becoming commonplace at warehouses across the world. High-density, grid-based storage systems in particular, such as the AutoStore system, are being used in a variety of contexts, but very little literature exists to guide decision makers in picking the right policies for operating such a system. Storage policies can have a large effect on the efficiency and storage capacity of robotic fullfillment systems. We therefore introduce a discrete event simulation for grid-based storage and examine input storage policies under a couple of storage scenarios. Our simulation provides decision makers with an easy way of testing policies before implementing them in a real system, and shows that selecting the correct policy can lead to up to a 7 % input performance improvement, and 60 % better box utilization.

3 - A hybrid simulation based approach to optimize organizational structures of maintenance operations
Nikolaus Furian, Dietmar Neubacher, Clemens Gutschi

The improvement of maintenance operations, especially by the use of predictive maintenance systems, has recently gained significant attention within the scientific community. However, most of recently published studies focus on the reliability and performance of prediction algorithms. Thus, they neglect potentials arising from re-organizing maintenance operations and resources with respect to new technological possibilities. In this paper, we present a hybrid simulation model of an engine production site, including a vast number of production lines, machines and their failure behavior based on real data. Besides production operations, the model consists also of the entire maintenance workforce and the corresponding organizational structures, i.e. hierarchical structures, chains of commands and escalation processes. Several scenarios were defined that reflect different combinations of decentralized maintenance workforce levels, placed at production lines, and centralized workforce levels, placed at a central service unit. In addition to physical staff allocation, investigated scenarios also include settings with decentralized placed and centrally steered maintainers, as also alterations in escalation processes. Results show that optimal organizational structures and process definitions yield a significant increase in overall production output and decrease of maintenance staff response times.

4 - Coordination in decentralized models through multi-stage games
Dimitris Zissis, Panagiotis Kyriazis, George Ioannou, Apostolos Burnetas

We consider a decentralized logistics system with a 3PL provider that subcontracts transportation activities to a haulage company. Both parties are rational and make their decisions (levels of investments and prices), trying to maximize their own profits without thinking the global optimum. Our main objective is to examine how coordination of the parties' decisions can be reached so that the individual gains of each party are (at least) slightly increased, without signing any contracts between them. Hence, we develop a two-stage game to examine how the latter can improve the profit levels of the parties. Analytical expressions of the optimal investments levels, service prices and expected profits under specific assumptions of demand and cost functions are derived. We prove that coordination is attainable under our proposed model and both parties achieve a better pay-off. Numerical examples and sensitivity analysis illustrate the applicability of our proposed approach to real-life logistics systems.

■ MC-28
Monday, 12:30-14:00 - SOUTH BUILDING UV S310

Multiple Classifier Systems and Applications II

Stream: Multiple Classifier Systems and Applications
Chair: *Koen W. De Bock*

1 - Unsupervised feature selection for autoencoder
Suemin Kim, Donghee Yoon, Dohyun (Norman) Kim

Autoencoder is one of the popular unsupervised learning algorithms to learn a representation for unlabeled data. Autoencoder is a family of neural networks whose input is equal to their output and it trains the neural network by compressing the input into a compressed representation and then reconstructing the output from the representation. Autoencoder obtains sparse representations of data by imposing sparsity on the hidden units during training, which is called sparse autoencoder. While sparse autoencoder can be useful in computational efficiency, it does not reduce the number of input variables. In this work, we propose a unsupervised feature selection method for autoencoder, which selects the 'best' subset of input variables for the 'best' representation of the data. Experimental results show that the proposed approach, even with a subset of input variables, obtain a compressed representation of data effectively, implying that it can be used as a useful nonlinear dimensionality reduction algorithm.

2 - Segmentation of media users according to life value
Kuratomo Oyo, Takako Yamada, Hiroaki Sandoh

This study aims to clarify how people use media in their lives and what their common life values are. For this purpose, we selected features for classifying media usages based on Random Forest (RF) from a single source dataset consisting of 47,236 questionnaire responses by 14,529 Japanese and proposed a classification method that uses the features. The questionnaire was designed so that we could collect information about demographics, psychographics (life value) and media usages. We dealt with eight types of media: Twitter, Facebook, LINE, Google, YouTube, niconico DOUGA, newspaper, and TV. A list of responses to each individual questionnaire item of the respondents to the questionnaire was, in this study, concentrated upon and analyzed. In the preprocessing stage, we examined correlations of responses between two questionnaire items, and consequently several media were found to have some sort of correlation with certain life values. In the next stage, media classification was carried out by means of RF, which is known as one of effective machine learning algorithms. We extracted several features of users' life values from the importance of questions represented by Gini coefficients after the classification. We could indicate differences between paid media and other digital media applications. We also applied Kullback-Leibler divergence to the RF results, and could recognize the eight types of media usage with similar degree of accuracies to the RF-based method.

3 - Automatic forecasting support system for business analytics applications based on unobserved components models
Diego José Pedregal Tercero, Marco Antonio Villegas García, Diego Villegas

For many companies, automatic forecasting has come to be an essential part of Business Analytics applications. In this study, an Automatic Forecasting Support System is developed based on a family of forecasting models, namely Unobserved Components (UC), that have been systematically overlooked in the forecasting literature along many years. Nevertheless, they have proven to be very efficient regarding forecasting accuracy. There are many reasons for this omission, but three seem most important: i) they have been cherished in a theoretical environment far from day to day practice, ii) no automatic identification strategy has been developed to make them useful on a daily basis when applied to bundles of time series, and iii) there is not any easy to understand software package available. The automatic system proposed in this study consists of different combinations of trends, seasonal and irregular components that have not been fully exploited in the UC literature. Three important novel aspects provide the method with additional flexibility: i) different parameters estaimated for each of the harmonics in the seasonal component, ii) coloured noises are allowed, and iii) automatic outliers identification may be tried out. The system works well in practice with ample databases when compared to other widespread, well-known methods, like Exponential Smoothing or ARIMA. The method is implemented using the SSpace toolbox written for the Matlab environment and is freely available.

4 - Measuring customer lifetime value with a zero-inflated inverse Gaussian model
Mee Chi (Meko) So, Christine Currie, Christopher Bayliss

Customer lifetime value (CLV) is an important metric in customer relationship management and has been used successfully in markets in which customers have frequent transactions. Little work has been done in markets where there is a mix of frequent and infrequent customers, our focus in this article. This is despite their being widespread, particularly in the travel and tourism sectors. We develop a new probabilistic model for estimating the CLV of customers and we demonstrate our method using real data. The zero-adjusted model we introduce here (ZAIG) is based on generalized additive models for location, scale and shape (GAMLSS) with the probability of future inactivity being modelled explicitly. ZAIG is found to out-perform ordinary least squares regression and provide an effective classification of customers into the top 20% and bottom 80% by CLV, which is essential for marketing activity.

■ MC-29

Monday, 12:30-14:00 - SOUTH BUILDING UV S311

Game Theoretical Models and Applications I

Stream: Game Theory, Solutions and Structures
Chair: *Joaquin Sánchez-Soriano*

1 - Measurement of indirect control in corporate shareholding structures
Izabella Stach, Cesarino Bertini, Gianfranco Gambarelli, Jacek Mercik

In a corporate shareholding networks firms exercise control over each other by owning each other stocks. Control can be direct and indirect. In complex corporate shareholding structures with many firms, direct and indirect linkages, loops, and cross-shareholdings, it is difficult to detect who controls whom and to assess the level of control power of a particular firm or coalition of firms. The first approach to the problem of measuring indirect control power were due to Gambarelli and Owen in 1994. Since then, other models have been proposed. In our research, we analyze several game-theoretic approaches from different points of view to model and measure the control power proposed by different authors. In this work, we pay particular attention to those methods that measure the control power of all firms involved in corporate networks (and not only of investors). In the literature, there are only three such approaches: those introduced by Karos and Peters in 2015, Mercik and Lobos in 2016, and Levy and Szafarz in 2017. Comparing the various methods, we also discuss some desirable properties that could be satisfied by measuring the control power of a firm in shareholding networks. Some results are presented.

2 - The pairwise egalitarian contribution set for multi-choice transportation games
Natividad Llorca, Mariana Rodica Branzei, Elisabeth Gutierrez, Joaquin Sánchez-Soriano

In this paper, we introduce the model of multi-choice transportation games related to two-sided market situations. Associated with them we study two new solution concepts: The Owen core and the pairwise egalitarian contribution set.

3 - Tax federalism and cooperative games
Emilio Calvo

We analyze the problem of how to distribute the public spending between the regions of a country given the total collected taxes in it. We model the problem as a cooperative game in coalitional form. For that we need to specify how much taxes collect every region and coalition of regions in the country. In this way we obtain the tax game of the problem, and its core is given by the set of stable tax allocations. With this approach, we can analyze the stability of a particular tax financing system. The Spanish case is considered and we show that it is unstable from this perspective. Two tax rules are proposed: the balanced tax rule, and the redistributive balanced tax rule. Both rules have the property of being stable for every tax problem.

4 - Profit allocation in transportation systems under bounded rationality
Joaquin Sánchez-Soriano, Natividad Llorca

Transportation problems are well-known operations research models. In this paper, we deal with two-sided transportation problems which can be used to describe a wide variety of logistic problems. We approach the problem from the perspective of cooperative games and study some solutions concepts closely related to the game theoretical concept of core, but rather than to focus specifically on the core of a transportation game, we introduce and study a new solution concept, a core catcher, which can be motivated by a kind of bounded rationality which can arise in these cooperative contexts.

■ MC-30

Monday, 12:30-14:00 - SOUTH BUILDING UV S312

Neighbourhood search

Stream: Metaheuristics
Chair: *Adolfo Urrutia Zambrana*

1 - A biased-randomized iterative variable neighborhood descent to solve the integrated hybrid flowshop and vehicle routing problem
Leandro Martins, Sara Hatami, Eliana Maria Gonzalez-Neira, Angel A. Juan, Jairo R. Montoya-Torres

Broadly speaking, supply chains are composed of producers, suppliers, and customers that must to be coordinated to reduce waste and lead times. In this context, production and distribution as two essential operational functions play an important role in the supply chain. Improving the management of these systems provides a strong tool to face the twenty-first-century global market challenges and remain them competitive. This paper studies an integrated Hybrid Flowshop and Vehicle Routing Problem (HFSVRP) that consists of two sections: production and transportation. The first section of the HFSVRP is composed by a production factory with hybrid flowshop configuration, where jobs are produced. These jobs have to be delivered to a set of customers in the second section of the problem. Distribution is carried out in batches through a single vehicle with limited capacity. The objective of the HFSVRP is to minimize the service time of the last customer. To solve this integrated problem, a Biased-Randomized Iterative Variable Neighborhood Descent (BRIVND) algorithm is designed. Different test factors such as different initial solutions, solution representations, and loading strategies are considered to study their effects on the proposed algorithm. A complete set of instances was generated and the results were analyzed using a comprehensive ANOVA statistical evaluation.

2 - Consistent neighborhood search for two-dimensional vector packing
Mirsad Buljubasic, Michel Vasquez

We propose a consistent neighbourhood search approach to solving the 2-dimensional vector packing problem. Given a set of items, each having a weight and a volume, the problem consists of finding the minimum number of bins, with a weight and a volume capacity, necessary to pack all the items. The solution is iteratively improved by decreasing the number of bins being used. First, the upper bound, UB, is obtained by First Fit. Next, an attempt is made to find a feasible solution with UB-1 bins, and this process continues until reaching a lower bound or the time limit. In order to find a feasible solution with a given number of bins, m, we build a partial solution with m-2 bins and then transform it into a complete solution with m bins through applying a local search. The partial solution is one that contains a set of items assigned to m-2 bins, without any capacity violation, and a set of non-assigned items. The goal is, by rearranging the items, to obtain a configuration such that non-assigned items can be packed into 2 bins, thus producing a feasible solution with m bins. Moves consist of adding/dropping items to/from the bin. The objective is to minimize the total weight of non-assigned items. An exploration of this search space of partial solutions comprises two parts: a tabu search with limited add/drop move and a descent with a general add/drop move. Algorithm finds optimal solutions for all 400 instances from literature, including those not solved to optimality before.

3 - Large neighborhood search algorithm for buffer allocation problem
Mehmet Ulaş KoyuncuoĞlu, Leyla Demir

The buffer allocation problem (BAP) is a well-known manufacturing system design problem and it aims to find optimum size and location of the buffers to maximize the throughput of a production line. Since the problem known as a nonlinear stochastic knapsack problem the heuristic/meta-heuristic search algorithms are widely used to solve BAP. This paper proposes a large neighborhood search (LNS) algorithm for solving BAP in unreliable serial production lines. To the best of authors' knowledge, this is the first study that proposes LNS algorithm for solving BAP. The performance of the proposed LNS algorithm is demonstrated using existing benchmark problems. The numerical results shows that the proposed LNS algorithm produces remarkably good solutions and the number of iterations required to convergence of the algorithm is less than the other solution methods for all considered benchmark problems.

4 - On the tourist itinerary creation: a variable neighborhood search for solving the generalized orienteering problem
Adolfo Urrutia Zambrana, Gregorio Tirado, Alfonso Mateos

The design of tourist itineraries is one of the many practical applications of the NP-hard problem known as the Generalized Orienteering Problem (GOP). The GOP extends the well-known Orienteering Problem (OP) by dealing with multiple-scored attractions and a nonlinear objective function. As in the original OP, a set of nodes that could potentially be visited is given and the travel time between any pair of nodes is known, together with the time budget. However, the difference with the OP is that in the GOP, each node is associated with several scores, and the objective consists of finding a closed tour maximizing a weighted sum of different score types.

Due to its non-linear objective function, the GOP has been approached using different metaheuristics, including Neural Networks, Genetic Algorithms, and others. In this work, we propose a Variable Neighborhood Search (VNS) to solve it. Our VNS uses a reduced number of local search operators and performs the calculation of the scores in an efficient way. In the literature, a case study of 27 Chinese cities was used as a benchmark by most of the authors approaching the GOP, so we also use it to evaluate the performance of our algorithm. Furthermore, we have also created some more data sets to test the performance of the VNS. In the experiments, the VNS has been able to find better local optima in a shorter computational time in most cases.

■ MC-31
Monday, 12:30-14:00 - SOUTH BUILDING UV S313

Descriptive Studies of Decision Making

Stream: Behavioural OR
Chair: *Konstantinos Katsikopoulos*

1 - The use of round numbers in preference representation
Ewa Roszkowska, Gregory Kersten, Tomasz Wachowicz

Decision-makers use heuristics to process large and different type information and to quickly determine solutions to complex problems. One of the heuristics is the predisposition to use round numbers (5, 10, 15, ...) as opposed to sharp numbers (3, 4, 6, ...). Using an experiment, this tendency was analyzed in the context of preference representation. Experiment participants were given a case which included textual and graphical descriptions of preferences. Based on this case, they were asked to formulate numerical preferences. We observed that they tend to use round numbers more often than sharp numbers. This resulted in spikes in the distribution of the preferences at round numbers. The implication for the design of preferences elicitation tools are discussed. We also studied the relationship between information processing systems used by them and tendency to produce round and sharp numbers. [Acknowledgements. This research was supported by the grant from Polish National Science Centre (2016/21/B/HS4/01583)]

2 - Simple methods of portfolio decision making: what do we lose and what do we gain?
Ian Durbach

We propose and assess some simple strategies for making portfolio decisions, where the goal is to select a preferred subset of projects subject to resource constraints. These strategies construct a portfolio by iteratively adding the project that is currently considered "best", but differ in the information and computational operations they have access to when deciding what is best, leading to more or less "frugal" heuristic strategies. We evaluate these strategies in three ways. We report results from simulation experiments comparing the portfolio selected by these strategies to the optimal portfolio; give theoretical results on potential information savings achievable under each heuristic; and report results from behavioural experiments assessing the extent to which these strategies are employed in unfacilitated decision making.

3 - The attention economy of online search: a natural experiment
Shashwat Pande, Christopher Holland, Konstantinia Papamichail, Peter Kawalek

This paper explores synergies between the Behavioural OR (BOR) research stream and behavioural studies in the Information Systems discipline. Traditional models of the economics of search suggest that as information acquisition costs associated with searching for products and services online are greatly reduced because of the Internet, consumers should search more extensively in online contexts. Recent empirical research strongly contradicts this hypothesis. We provide an alternate explanation by situating the problem of limited search within an economy of attention. Informed by a behavioural decision theoretic approach, we develop an empirical framework for consumer attention based on the size of the consideration set, market concentration of attention and search time. We conduct a natural experiment using a commercial panel of online clickstream data from seven major consumer markets representative of search activity from one-million consumers. Our results show that a parsimonious consumer search process can be explained by accounting for the attentional limitations of online searchers. Consumers face an attention allocation problem characterised by a trade-off between the number of alternatives searched for and the time spent searching for information on individual alternatives. Furthermore, we find that the competitive context of online markets effects both the magnitude and strength of this relationship. We discuss practical and managerial implications of our findings.

4 - One-reason decision making!?
Konstantinos Katsikopoulos, Ozgur Simsek, Jan Malte Lichtenberg, Gregory Wheeler

Even though theoretical decision analysis initially dismissed one-reason decision making (e.g., lexicographic heuristics) as descriptive but flawed, behavioural science research in recent decades is providing empirical evidence that, under some conditions, one-reason decision making is prescriptive. The performance of one-reason decision making varies greatly across problems but it is not well understood why. We leverage ideas from epistemology to develop a novel theory of one-reason-decision-making accuracy. The theory uses two statistical characteristics of decision problems which are known to influence accuracy–predictability and redundancy. The traditional measures of these characteristics are limited because it is not known how they combine to determine accuracy. We analytically show that one-reason-decision-making accuracy can be decomposed in a surprisingly simple way, as the ratio of predictability to redundancy, for two well-motivated measures of these characteristics. The decomposition requires no auxiliary assumptions and applies to multi-attribute choice as well as classification problems. The theory is tested empirically on a hundred natural data sets. We compare the explanatory power of the theory to that of other theories of one-reason-decision-making accuracy, which either employ traditional measures of predictability and redundancy or rely on structural characteristics of decision problems such as simple and cumulative dominance.

■ MC-32

Monday, 12:30-14:00 - SOUTH BUILDING UV S314

Maritime Transportation

Stream: Routing, Logistics, Location and Transportation
Chair: *Anisa Rizvanolli*

1 - The traffic assignment problem (TAP) on lattice and circular network geometries
Sam O'Neill, Ovidiu Bagdasar, Stuart Berry, Nicolae Popovici

The Traffic Assignment Problem (TAP) focuses on modelling a transportation network and the flow on the given system. It is a widely accepted phenomenon that given the selfish nature of drivers' attempts to minimise their own travel time, a system will settle to an equilibrium state were no driver can benefit from switching his/her route. This principle, as defined by Wardrop (1952), is often referred to as User Equilibrium (UE). Wardrop's other main principle, System Optimal (SO), differs in that the average journey time is minimised and this can only happen with social co-operation or central control. Under these circumstances, certain users are worse off when compared with the UE, however it minimises the total travel time. A common measure for how much a network deviates from SO is to compare UE with SO; this is done using the price of anarchy (PoA) (Koutsoupias and Papadimitriou 1999), the ratio UE/SO. Paradoxes can arise where shutting down of roads may lead to improved travel times (Braess 1969).

Using these principles we explore two main network geometries. A lattice structure inspired by the classic example of Sioux Falls (US) and a concentric ring-roads/radial roads structure resembling cities such as London (UK) and Birmingham (UK). These two structures can be considered limit cases whereby, in many instances, a city at a macro level resembles the circular structure, but its centre, at the micro level, resembles the lattice.

2 - Uncertainty in maritime inventory routing problem: comparing approaches
Filipe Rodrigues

Maritime transportation is one of the most common ways to transport goods. However, this kind of transportation is characterized by high levels of uncertainty, since the weather conditions have a great impact in the sailing times. We consider a single product maritime inventory routing problem in which the production and consumption rates are constant over the planning horizon. The problem involves a heterogeneous fleet and multiple production and consumption ports with limited storage capacity. The impact of the uncertainty in the sailing times is analysed according to five different approaches: deterministic model, deterministic model with safety stocks, robust optimization, stochastic programming, and a stochastic model using the conditional value at risk measure. This last approach has never been used to solve this problem. The non-deterministic approaches assume two-stage decisions, where the routing as well as the quantities to load/unload are fixed before the uncertainty is revealed, while the visit time to ports and the inventory levels are adjusted to the scenario. For each approach, a mathematical formulation is proposed. An extensive computational comparison of the proposed approaches, based on several quality parameters, is carried out over a set of 21 instances. The obtained results show that substantial gains can be obtained when the uncertainty is incorporated into the model.

3 - Strategic planning of dry port-based distribution systems
Jenn-Rong Lin, Andrew Andrew, Emrah Demir, Anthony Beresford

The purpose of the study is to formulate and analyze a planning model for dry port-based freight distribution systems with storage capacity considerations. The key planning decisions considered are: the number and locations of dry ports in the system, the creation of rail lines between ports, the selection of transport paths of shipments between origins (sea ports/inland regions) and destinations (inland regions/sea ports), and the storage space capacities to be held at the dry ports. The planning decisions are made while taking into consideration both total cost and service levels (measured both by the availability rate for storage space at the dry port and coverage of the origins/destinations). The optimal planning of this system requires an integrated view of transportation costs of transported demands, the usage costs of storage space and the facility costs of dry ports and rail lines as well as service levels. A hub location inventory model is presented. Numerical examples regrading Scotland dry port projects are created to illustrate and to test the proposed model.

4 - Vessel crew scheduling in ship management: a modelling approach
Anisa Rizvanolli, Ole John

One of the crucial tasks in Ship Management is the long-term crew scheduling where the future crew as well as the contract periods for each seafarer is determined under consideration of compliance requirements and scheduling rules. Depending on the size of the fleet and the number of seafarer, this problem can be hard to solve and it is usually done in a decentralized, short-term planning without modern decision support tools. In this talk we consider both, the Contract Period Construction Problem (CPCP) and the Vessel Crew Scheduling Problem (VCSP) in Ship Management which together solve the long-term Crew Scheduling. We give an introduction to both problems, point out similarities and differences to other, known scheduling problems and put emphasis on some unique characteristics. Due to the special compliance requirement, such as rank, experience time and leave time of the seafarer or the defined deviation between crew changes, we are challenged with two complex scheduling problems. We present and discuss a MIP formulation for each problem and show first computational results. At last, we compare the determined solution with a hand-made operation schedule.

■ MC-33

Monday, 12:30-14:00 - SOUTH BUILDING UV S315

Data Mining and Statistics II

Stream: Data Mining and Statistics
Chair: *Kemal Özkan*

1 - Comparison of machine learning classification algorithms performances in consumer credit-risk scoring
Mervan Aksu

Especially after 2007 financial crisis, the quality of credits given by a bank has started to play a vital role for bank's profitability and for its competition power. When we take a deep look into a bank's credits, we see a worldwide trend that the proportion of consumer credits is increasing year by year. Due to the weight of consumer credits in banks' lending portfolio the quality (lower default rate) consumer credits affect the bank's profitability. So it is really important for banks to classify their customers as part of credit assessment process to decrease the number of consumers who would be unable to pay back their debt. In Banking/Finance literature this process is named as credit scoring. These models use statistical tools to help banks in the approval of consumer credits. With these methods the banks can decide about who will get the credit and how much they could get. After tackling these two issues banks can develop operational strategies which will increase their profitability. We applied several classification algorithms such as k-Nearest Neighborhood, Support Vector Machines, Logistic Regression, Decision Trees, Stochastic Gradient Descent, Random Forest, and Artificial Neural Network to German credit data to classify new a credit applicant. To be sure about algorithms' accuracy we applied k-Fold Cross-Validation (10) and additionally for sake of robustness of each algorithm, we applied Grid-Search to find the optimal parameters for each algorithm.

2 - Data analytics for value determination: an application on data for aircraft spare parts
Clemens Wickboldt, Natalia Kliewer, Natalia Kliewer

Turning data into value is a challenging task for Data Science in times of an exponentially growing amount of data. Maintenance, Repair and Overhaul companies are facing pricing related decision problems on a daily basis. The industry sits on vast amount of data. Due to lack of transparency in the surplus spare part market and missing concepts to efficiently use internal data, existing information is not used exhaustively to improve data-based part utilization decisions. As an intersection of Data Mining, Statistics, Pricing and Machine Learning, the Automated Spare Part Valuation (ASPV) Framework is positioned as a Meta-Model-Management-System. We will present interim results and findings of evaluating the ASPV framework with data from an international Maintenance Repair and Overhaul company. Information from heterogeneous sources is aggregated, transformed and then supports machine learning methods to automatically determine a Fair Market Value for surplus spare parts. Handling incomplete historical data sets as well as validating the calculated Fair Market Value are some of the challenges which become visible.

3 - Dependence-biased conditional permutation importance for variable selection
Gianluca Gazzola, Myong-Kee Jeong

We introduce a new method for variable selection based on a novel data-partitioning technique for the assessment of conditional variable importance with random forests (RFs). This technique relies on a form of clustering in which the criterion is designed to reflect the structure of dependencies existing among input variables. We incorporate this method into a RF-based backward elimination algorithm, aimed at the selection of a minimal subset of input variables characterized by high predictive power and low redundancy. We illustrate our algorithm on both simulated and real-world data sets, and show its competitiveness with respect to a variety of state-of-the-art RF-based variable selection algorithms.

4 - Optimized parameters for bell-shaped error function in recommender system
Kemal Özkan, Seke Erol, Yusuf Kartal, Tolga Ünal, Mahmut Kasap

There exist several approaches like matrix factorization (MF) or adaptive k nearest-neighbor (kNN) for item recommendation systems that use implicit feedbacks such as website clicks and purchases. Recently, a generic optimization criterion for personalized ranking, BPR-Opt, a maximum posterior estimator derived from a Bayesian analysis of the problem, is gaining popularity. However, one important feature, visual appearance of the items being considered (VBPR), is typically ignored by existing personalized recommendation and ranking methods. In order to build a model for user-item relation in these methods, a sigmoid function is used to optimize the Loss function. In this work, it is experimentally shown that a bell-shaped function improves the performance. Close-to-optimal parameters of the bell-shaped error function are determined using a special method. The function with calculated parameters is used within a gradient optimization algorithm. It is applied to a selection of large, real-world datasets obtained from Tradesy.com, a second-hand clothing trading community. Dataset covers the users' purchase histories and preferences that are used together as positive feedback in the algorithm. Note that recommendation in this setting inherently involves cold start prediction due to the 'one-off' trading characteristic of second-hand markets. In the experimental work, we obtained the AUC (Area Under the ROC curve) scores of 0.6508 and 0.7891, respectively.

■ MC-34

Monday, 12:30-14:00 - SOUTH BUILDING UV S113

Numerical and Simulation Methods in Finance I

Stream: Numerical and Simulation Methods in Finance
Chair: *Gordon Dash*

1 - Practical considerations for credit price optimisation
Marius Smuts, Fanie (SE) Terblanche

The competitive nature of the financial industry requires the effective use of prescriptive models to assist with strategic decision-making. For secured retail lending products the challenge is to determine optimal prices (interest rates) that will maximise loan take-up and expected revenue. The computation of prices has to be performed as efficient and accurate as possible in order for financial institutions to be competitive. This involves reducing the solution times of pricing optimisation models so that the turnaround time of proposing an interest rate to the customer is reduced.

In this paper, the proposed price optimisation model relies on a response model which captures the price sensitivity exhibited by the potential customers. In an attempt to reduce computing times, linear interpolation was applied to optimally calculated prices, which were determined based on a predetermined grid of different attributes. Computational tests are based on real-world problem instances.

2 - Forecasting crude oil futures prices using global macroeconomic news sentiment
Paresh Date, Zryan Sadik, Gautam Mitra

We propose a method of incorporating macroeconomic news into a predictive model for forecasting prices of crude oil futures contracts. We utilize the Kalman filtering framework for forecasting arbitrage-free (futures) prices, and assume that the volatility of oil (futures) price is influenced by macroeconomic news. The impact of quantified news sentiment on the price volatility is modelled through a nonlinear functional map. We report results of extensive numerical experiments which use macroeconomic news sentiment in such a fashion and conclude that this significantly improves the predictive ability of the filter-based model.

3 - Hedging home price risks
William Mingyan Cheung, Li Bao, Stephan Unger

Why home owners do not hedge home price risks? We analyze the benefits of hedging downside risk of housing prices to U.S. homeowners using the standardized exchange traded put option on a set of well-developed U.S. home price indexes. We estimate empirically the hedging benefits with standard put options on Case-Shiller Home Price Index (CSI) futures from the Chicago Mercantile Exchange and Barone-Adesi and Whaley (1987) simulations. Our estimated recovery for an average U.S. homeowner who insured her full house value with CSI put options during the 2006-2008 market downturn is about 75% of losses in house value, given the market illiquidity. We find that more liquid put options improve hedging benefits by lowering transaction costs significantly. This benefit is robust to various magnitudes of interest rate or income shocks. The Shapley-Owen variance decomposition suggests that returns of put options explain 20:14% of the variation of the underlying CSI return. We extend this estimation to active home sellers, who would sell their properties for prot. We suggest that the use of exchange traded housing derivatives may benefit U.S. homeowners.

4 - Modeling statewide 2018 tax-induced regime shifts through artificial intelligence and big data analytics
Nina Kajiji, Gordon Dash, Domenic Vonella

In the American economy, the recently enacted 2018 Act is expected to increase demand for municipal debt. Overall, the 2018 tax reforms are intended to simplify the tax reporting system; however, it is likely that the pricing of individual municipal bonds will become more complex, more unpredictable, and increasingly dependent on issuer and state demographics. In fact, it is widely expected that the Act will increase demand for the securities from investors hardest hit by limits on the ability to deduct state and local taxes on their federal returns in high-tax states such as California, New York, and New Jersey. Already faced with a market structure described as illiquid and inefficient, the Municipal Securities Rulemaking Board (MSRB) amended Rule G-15 to require brokerage firms to disclose to retail investors the pricing mark-up (mark-down) on municipal bond trades. This change was accompanied by the release of 30-minute trade records for the industry; a data artifact that is best described as a Big Data analytics problem. Here, we present analytics on more than 36 million municipal bond trades from May 2014 to December 2017, inclusive. Also, this paper is the first to provide comparative algorithmic and predictive state-level yield curve analytics derived a radial basis function artificial neural network and a Support Vector Regression (SVR). Bond portfolio managers will find this research invaluable in valuation applications under evolving municipal market efficiency.

■ MC-48

Monday, 12:30-14:00 - 4D UPV B.3

Practice-Based Research in Humanitarian Logistics

Stream: Humanitarian Operations
Chair: *Harwin De Vries*

1 - Donation management for menu planning at soup kitchens
Marjolein Buisman, René Haijema, Renzo Akkerman, Jacqueline Bloemhof

The food industry is confronted with a pressure to reduce waste and to make agreements on donating surplus food to charitable organizations. Charitable organisations such as soup kitchens can use these donations in preparing meals for their clients. Donation management is strongly influencing menu planning, and conversely, menu planning considerations have a strong impact on donation management decisions. To make the best use of (mostly highly perishable) food donations, we develop an MILP model for integrated donation management and menu planning that proposes a menu plan and suggests which (part of the) donations to accepted. The combination of menu planning and donation management is essential for soup kitchens, but has not been studied before. The model is used to assess the impact of contracts on a strategic or tactical level, and captures operational decision making by integration of donation management and menu planning. To deal with meal variety considerations and to resemble planning practices, the developed model is solved in a rolling horizon. The results show that (i) the use of donations reduces overall costs for the soup kitchen; (ii) despite the short shelf life of donations, most donations can be used efficiently; and (iii) meal variety can be easily ensured and food donations increase this variety. Furthermore, the approach has implications for waste reduction in food supply chains, by structural/contractual donations of surplus food by retailers.

2 - Location planning and inventory management of emergency medical centers for post-disaster
Mehmet Kursat Oksuz, Sule Itir Satoglu

Devastating effects of disasters and global crises on people increasingly improve the importance of humanitarian logistics studies for pre and post-disaster stages. In this study, we aimed to determine the location and number of temporary medical centers in case of a disaster by considering the locations of the existing hospitals and medical supplies warehouses, patient capacities of the medical centers and hospitals. At the same time, we intended to decide the amount of the medical supplies distributed into these medical centers. For this purpose, a two-stage stochastic programming model was developed. In case of a disaster, there is a possibility of damage to the hospitals and roads as well as damage to the residential buildings. For this reason, the probability of damage of hospitals and roads for different scenarios was considered in the stochastic model. Besides, for different scenarios, the number of possible casualties in each disaster area were considered and the casualties were classified according to a triage system. In this study, we conducted a case study for Kartal which is one of the districts expected to be damaged at most in the earthquake expected to occur in Istanbul. The estimated number of injured on the basis of districts are taken from the JICA report (2002) and used as demand data. Moreover, we use the expert support from the Doctors Worldwide which is an INGO to determine the medical supplies and triage system for the injured people.

3 - Design of water supply networks and source selection for slums by using mixed-integer programming
Lea Rausch, John Friesen, Peter Pelz

The UN defined "ensuring access to water and sanitation for all" to be Goal No. 6 of the 17 UN Sustainability Development Goals to transform our world. To address this goal, we present an approach which makes use of remote sensing data to design optimal water supply networks for slums. We focus on slums within large urban areas since currently one quarter of the urban population lives in slums which are characterized by inadequate water supply in many cases. Furthermore, forecasts assume that the number of inhabitants of slums is still to increase in the next few years, especially South Asia and Sub-Saharan Africa. We apply methods of mathematical optimization to choose between different decentral and central approaches combining water supply by motorized vehicles with supply by pipe systems. The problem is modeled as a mixed-integer linear problem (MILP) aiming to find a network describing the optimal supply infrastructure. An extension of the basic model allows to include several water sources and optimizes their utilization. We analyze the impact of this extension by applying the model to a small slum cluster and comparing the results for varying input parameters related to water sources.

4 - Do optimization models for humanitarian operations need a paradigm shift? The case of evidence-based vehicle planning
Harwin De Vries, Luk Van Wassenhove

Optimization approaches for planning and routing of humanitarian field operations have been studied a lot. Yet, their adoption in practice seems absent. Based on interviews, literature, and modeling results, we discuss the applicability and cost-effectiveness of such approaches and identify areas where future research is needed.

■ MC-49

Monday, 12:30-14:00 - 4D UPV B.4

Moments in History of OR

Stream: Moments in History of OR

Chair: *Graham Rand*
Chair: *Gerhard-Wilhelm Weber*

1 - La Nova Scientia: rewriting the history of operational research
Roberto Rossi

The accepted lore is that OR traces its roots back to the First and Second World Wars, when scientific research was used to improve military operations. However, the history of warfare is punctuated by attempts to apply some elements of quantitative analysis to understanding the causes of victory and defeat. An example of new military practices introduced in the sixteenth century are innovations adopted by Maurice of Nassau, Prince of Orange, in the period between 1585–1625, which included systematising loading and firing of matchlock guns into forty-two sequential moves, so that soldiers could fire more rapidly and in unison; another example being the military use of gunpowder in Roberto Valturio’s “De Re Militari” (1486). A natural question then arises: were military practitioners of the sixteenth century simply following common sense, or did some of them follow a principled, scientific approach akin to the one in use today? In this work I argue that Tartaglia’s “La Nova Scientia” (1537) represents an exception and should be, in fact, regarded as one of the seminal works in the field of OR, intended as the systematic application of the methods of science to complex problems faced in military operations.

2 - Design of decision support systems for large infrastructure projects: a review
Carolina Toczycka

The need for intervention in large-scale social choices is articulated by Flyvbjerg (2014) through the iron law of mega projects that are "over budget, over time, under benefits, over and over again". This paper will present a review of mathematical modeling and implementation approaches (optimization, simulation, MCDA, DEA etc.) as well as the approaches for understanding and eliciting values in large infrastructure projects (>’1bn), as part of the complex societal problems field (DeTombe, 2002).

From the UK perspective, the infrastructure pipeline size (’500bn as of 2017), systemic cost overruns, together with the growing requirement for transparency call for an inquiry into prescriptive analytics (Bilal et al., 2016). However, the complexity, ambiguity and the continuous redefinition of objectives of mega projects (delivery of the asset but also social, environmental and political objectives) call for a holistic approach to optimization and attention to the dynamic processes and values in which the model building work is embedded.

This review paper is part of a larger interdisciplinary research ambition between operations research, critical accounting and organization theory aim to address the challenges of designing, building and, implementing the decision structures for megaprojects.

3 - Sixty years of European OR conferences: a UK perspective
Graham Rand

61 years ago the first international OR conference was held in Oxford. That led directly to the first OR Society conference the following year, the creation of IFORS, and later to the creation of EURO, and EURO-k conferences, in the mid-70s. This talk will reflect on the Oxford conference, the OR Society conferences, the 60th of which will be held this year, and EURO conferences.

■ MC-50
Monday, 12:30-14:00 - 4D UPV 1.1

OR for Developing Countries II

Stream: OR for Developing Countries
Chair: *Herman Mawengkang*

1 - An optimization model for planning and scheduling of seafood product with quality traceability in Aceh province of Indonesia
Devy Mathelinea, Herman Mawengkang

The seafood production is part of a semi-continuous process and it is subject to individual characteristics. Seafood is a notably perishable product within the category of food industry. The perishability highly restricts its storage duration and delivery conditions. In order to maintain the quality of seafood beside perishability, it is necessary to have traceability of the quality of the product. This paper presents seafood production planning and scheduling of a seafood manufacture company which produces simultaneously a multi-kind of seafood products, located at Aceh Province, Indonesia. The perishability nature of fish highly restricts its storage duration and delivery conditions. Traceability is a tracking requirement to check whether the quality of the product is satisfied. The production and distribution planning problem aims to meet customer demand subject to traceability of the seafood product and other restrictions. The problem is modeled as a mixed-integer linear program, and then it is solved using a neighborhood search approach.

2 - An integer optimization model for managing industries hazardous waste disposal
Avery Boy Detinty, Herman Mawengkang

It is normal that the advancement of industries and technology could create a negative impact, such as, hazardous waste, particularly at the urban area. It is well understood that such waste has been treated systematically in order to produce minimum waste. Nevertheless, there are still large amounts of hazardous waste needed to be managed in the effort to plan and to develop sustainable areas. The management of hazardous waste consists of collection, transportation, treatment, and disposal. This paper proposes an integer programming model based on a location-routing system. The objective of the model is to minimize cost and risk involved.

3 - A combined approach for solving a scheduling problem in periodic heterogeneous vehicle routing problems
Ellis Mardiana Panggabean, Herman Mawengkang

Vehicle Routing Problem (VRP) is one of the important issues that exist in transportation system. This is a well-known combinatorial optimization problem which consists of a customer population with deterministic demands, and a central depot which acts as the basis of a homogeneous fleet of vehicles. The objective is to design a set of vehicle routes starting and terminating at the central depot, such that the demand of customers is totally satisfied. This paper develops an optimization model for the management of periodic deliveries of a given commodity. The company has different types of vehicles with different capacity to deliver the commodity for customers. The problem is then called Periodic Heterogeneous Vehicle Routing Problem (PHVRP). The goal is to schedule the deliveries according to feasible combinations of delivery days and to determine the scheduling of fleet and driver and routing policies of the vehicles. The objective is to minimize the sum of the costs of all routes over the planning horizon. We propose a combined approach of heuristic algorithm and exact method to solve the problem.

4 - An optimal decision model for hospital capacity management planning problem
Suryati Sitepu, Herman Mawengkang

The most obvious wish for most people in this planet is to have a good health. The legal institution which provides and maintains good health in any country is the hospital. Therefore, it is understandable that nowadays the people’s demand for hospitals is increasing. One of the main causes of this rise lies in the ageing populations who are putting heavy demands for health care. However, due to the rising cost of healthcare services, hospitals need to consider efficiencies in order to overcome the rising demands and cost problems. This paper deals with an integrated strategy of staff capacity management and bed allocation planning to tackle these problems. Mathematically, the strategy can be modeled as an integer linear programming problem. We solve the model using a direct neighborhood search approach, based on the notion of superbasic variables.

■ MC-51

Monday, 12:30-14:00 - 4D UPV 1.2

Circular Supply Chains

Stream: Environmental Sustainability in Supply Chains
Chair: *Gerald Reiner*

1 - Sustainable sourcing with recycled materials: a contribution towards circular economy
Patricia Rogetzer, Lena Silbermayr, Werner Jammernegg

We investigate a sustainable sourcing strategy faced by a manufacturer operating in the electronics sector considering the possibility to include recycled raw materials. Return flows from end-of-life products in that area are not sufficient to satisfy the entire need for (critical) raw material from recycling sources only. Moreover, the recycling efficiency for these materials is still an ongoing research. Therefore we also rely on virgin material. We develop a single period inventory model to derive optimal order quantities from two suppliers with the aim to minimize the expected total costs of the manufacturer. The suppliers are non-identical as one delivers virgin material without supply uncertainty and the other provides recycled material with possible quantity restrictions. By means of a sensitivity analysis on the key input parameters we discuss the impact of demand, yield and price uncertainty and provide managerial insights into the economic and environmental benefits of sustainable sourcing with recycling. We also study the effect of taking correlation between uncertainties into account and conclude that ignoring them could overestimate the cost benefits. Moreover, the manufacturer contributes to the concept of circular economy as the total input of virgin material in the production process is (partly) replaced by recycling material. Consequently, the input of virgin material is reduced which contributes to the objectives of the EU action plan for a circular economy.

2 - Responsible supply chain decision making considering circularity
Boualem Rabta, Gerald Reiner

Recent studies have pointed out that important attributes of supply chain performance can not be verified by the consumer, due to asymmetric information between the company and its consumers.

Public opinion is becoming increasingly aware of environmental issues and customers are becoming more interested in related practices. There is a need for transparency as more and more consumers seek to make positive decisions about what they buy. However, companies operate under high competition and pressure to reduce costs to maintain their profitability.

One of the main challenges in circular economy is the definition and the implementation of effective measurements. In this paper, we discuss the problem of the quantification of the circularity based on the information from the whole supply chain and its use in supply chain decision making. In particular, we explore models for optimal product design and optimal supplier selection under consideration of circularity.

3 - When remanufacturing meets product quality improvement: the impact of production cost
Weihua Zhang, Gendao Li, Marc Reimann

When remanufacturing and quality improving innovations coexist in one company, their interaction is not clear. On the one hand, past research found a positive impact of remanufacturing on product quality. On the other hand, remanufacturing was shown to be negatively affected by an industry's technology trajectory of quality improvements. Using a stylized model of endogenous product quality improvement and remanufacturing we find that the main driver of the contradicting results is the change in manufacturing costs caused by improving product quality. A strong increase in manufacturing costs due to product quality improvement may induce the firm to take up remanufacturing when introducing the new product. Conversely, a small impact of product quality improvement on manufacturing costs reverses this effect and may indeed lead the firm to cease remanufacturing when introducing the new product. We find that the latter outcome is never beneficial from an environmental point of view, while the former always is. With endogeneous product quality improving innovation we then characterize conditions where a remanufacturing manufacturer would take a different product quality improvement decision than a non-remanufacturing manufacturer. We observe that remanufacturing stifles (stimulates) product quality improvement when manufacturing cost of quality improved products are low (high). Neither of the two results is exclusively beneficial or detrimental from an environmental perspective.

4 - Transition to circular supply chains induced by new business models
Gerald Reiner, Stefan Gold, Boualem Rabta, Tanja Olip

The purpose of this research is to show how innovative circular economy business models, and related supply chain (SC) processes and new technologies, require a transformation to circular SCs for technical as well biological nutrients. In order to model these dependencies, a system dynamics model will be developed that analyses how circular SCs facilitate different types of circular economy business model patterns (Lüdeke-Freund et al. 2018). This model will integrate key performance indicators and measures to evaluate the value proposition, delivery and creation by circular SCs on the triple bottom line dimensions. This model will contribute to (cf. Jammernegg et al. 2018) - developing standards for circular SC reports and circular SC labels; - deriving directions for future circular SC regulations, e.g., stronger focus on repair & maintenance, reuse & redistribution and refurbishment & re-manufacture and related business models; - addressing all relevant supply processes and not "only" technical processes, i.e., source, transport, storage, make, deliver, re-valorization and return. Literature: Jammernegg, W., Reiner, G., Wakolbinger T. (2018 in press): Circular Supply Chain: Combining Supply Chain Strategy and Circular Economy, Corsten, H., Gössinger, R., Spengler, T. (Ed.), Handbuch Produktions- und Logistikmanagement in Wertschöpfungsnetzwerken. Lüdeke-Freund, F., Gold, S., Bocken, N. (2018, in press): A Review and Basic Typology of

■ MC-52

Monday, 12:30-14:00 - 4D UPV 1.3

Health Care Modelling (ORAHS) II

Stream: OR for Health and Care I
Chair: *Kursad Bilgili*

1 - Analytics in prioritizing access to hepatitis C treatment in U.S. prisons
Turgay Ayer

HCV prevalence in prison systems is significantly times higher than the community, and hence prison systems offer a unique opportunity to control the HCV epidemic. New HCV treatment drugs are very effective, but providing treatment to all inmates is prohibitively expensive. As such, current practice recommends prioritizing treatment based on clinical and incarceration-related factors, including disease staging, remaining sentence length, and injection drug use status. However, there is controversy about how these factors should be incorporated because of the complicated tradeoffs. In this study, we propose a restless bandit modeling framework to support hepatitis C treatment prioritization decisions in U.S. prisons. We parameterize and validate our model using real-world data from Georgia state prison system and published studies. We test the performance of our proposed policy using a detailed, clinically-realistic simulation model and show that our proposed policy can significantly improve the overall effectiveness of the hepatitis C treatment programs in prisons compared with the current practice and other benchmark policies, including the commonly used Whittle's index policy. Lastly, we have developed a decision support tool for practical use, which is currently being piloted in two state prison systems.

2 - Using simulation modelling for evaluating a national colorectal cancer screening programme in Chile
Richard Guerrero-Ludueña

Colorectal Cancer (CRC) is a major cause of cancer death worldwide. In Chile, CRC was the second cause of cancer death in 2010 and mortality from CRC has doubled over the past 20 years. CRC screening programme reduces mortality through the early detection of malignancies and the identification and removal of adenomatous polyps (asymptomatic benign precursor lesions that may lead to CRC). There are a number of tests currently available for screening, such as faecal occult blood testing (FOBt), flexible sigmoidoscopy, and colonoscopy. Despite this, in Chile, there is not a national programme for early detection of CRC. This paper describes the application of simulation modelling for evaluating the impact of different strategies of a National Colorectal Cancer Screening Programme in Chile. The study focused on the estimation of future demand for cancer diagnostic services, in particular, endoscopy services, in order to support long-term capacity planning.

3 - Foodborne transmission mechanisms for norovirus: a study for the UK's food standards agency
David Lane, Elke Husemann, Darren Holland, Abdul Khaled

The paper concerns modelling work for UK's Food Standards Agency (FSA). Norovirus causes infectious intestinal disease in humans via person-to-person contact (P2P) and foodborne (FB) transmission. The FSA commissioned a study to increase understanding of FB mechanisms, and of where to target its efforts. An existing P2P model with an exogenous parameter for FB transmission was transformed into a System Dynamics model of the FB vectors. Modelling involved expert interviews and a facilitated group modelling session. Vectors included were: bi-valve shellfish; sludge; some fruits and vegetables; other foodstuffs. This new model demonstrated that an account of the underlying causal mechanisms could be given. It also allowed parameters to be categorised in a way that was useful in future research agenda-setting and in identifying policy levers. Data and steady state analysis then made it possible to calibrate a P2P model for the first time. The resulting sensitivity analysis indicated that small changes in human behaviour could explain the observed x10 seasonal variations in Norovirus cases, and gave insight into the relative importance of FB and P2P vectors. The consequences of the study included an increased understanding by the FSA of the different means of trying to control Norovirus, practical actions and ideas for further work.

4 - A simulation based decision support toolkit for informing the management of patients with diabetes
Kursad Bilgili, Eren Demir, Reda Lebcir, Anne Kilvert, Jonathan Rippen, Eileen Richardson

The treatment of diabetes is complex and resource intensive so that these patients require long-term follow-up,resulting in increased pressure on clinical workloads.Due to limited clinic capacity,coupled with the ever increasing demand for diabetes services and funding cuts,service managers are forced to find effective ways of allocating scarce resources.The aim of the research is to develop a Discrete Event Simulation(DES) that informs the decision making process regarding reconfiguration of the services providing care and management of patients with Diabetes.DES was developed in conjunction with clinical experts from the UK of National Health Service(NHS) and DES is calibrated by parameters driven from large national datasets and local ones from the context where the DES is designed.This research,therefore,contributes to the improvement of services provided to Diabetes patients through the combination of DES and Data analysis approaches to improve the performance of service delivery and meet both the demand and expected care quality standards for Diabetes patients.By the help of DES,we explore the impact of a range of changes to diabetes services,namely:What is the impact of increasing the number of patient referrals to community service? Is diabetes service able to continue to provide effective care to their patients in 12 months' time with the existing resources?

■ MC-53
Monday, 12:30-14:00 - 4D UPV 1.4

Demand and Supply Management

Stream: Operations/Marketing Interface
Chair: *Yongbo Xiao*

1 - Push, pull, and supply chain risk averse attitude
Jian Chen

The literature has shown that supply chain performance is affected by the allocation of inventory risk. Traditionally, a pull supply chain generates a higher optimal order quantity and hence higher supply chain profit than a push supply chain when firms are risk neutral. Extended from the classic push and pull newsvendor models, this paper investigates the impact of firms' risk averse attitudes on supply chain performance. Based on firms' Conditional Value-at-Risk (CVaR), our analysis indicates that push can lead to a higher optimal order quantity than pull when the supplier is sufficiently more risk averse than the retailer. Meanwhile, pull contracts cannot always survive push challenge like in risk-neutral supply chains. We demonstrate that three-part tariff revenue sharing contracts can coordinate both the push and the pull supply chains to achieve the Pareto optimality maximizing combined supply chain CVaR. (Joint work with Lei Yang and Gangshu (George) Cai)

2 - Quality information disclosure strategies in a supply chain with duopoly retailers
Xiaosong Ding, Jihong Zhang, Jianbo Xu

This paper investigates product quality information disclosure strategies within a dual channel supply chain, which consists of one manufacturer, two retailers, and consumers. We establish a two-layer disclosure model as a Stackelberg game. After privately observing the product quality, the manufacturer can determine whether to keep silent, or to disclose the product quality information either directly to consumers or indirectly to two retailers, who will in turn decide the retail price and whether to costly forward the product information to consumers. Finally, consumers update the belief of product quality and decide whether to buy the product.

Results show that the quality disclosure thresholds are related to the disclosure cost. Both the manufacturer and two retailers will strategically select their disclosure formats according to the disclosure costs and the ex-post quality level. This leads to some unintended phenomena including that the retail price may decrease simultaneously when the disclosure cost goes up, and sharing more disclosure costs in the disclosure format may help manufacturer to generate a higher ex-post payoff given the product quality is sufficiently low. We also examine the impact of disclosure costs on the supply chain's ex-ante payoff, and find that it may be better off for the manufacturer to afford the entire disclosure costs in the dual channel.

3 - A new framework for naval inventory models
Javier Salmeron, Duncan Ellis

Naval Supply Systems Command, Weapons Systems Support (NAVSUP WSS) sets inventory policy across all echelons of supply, from wholesale sites to retail end-points on globally deployed platforms. To aid these decisions, a robust set of tools and models are required. In 2014, NAVSUP WSS began a partnership with the Naval Postgraduate School to develop "in-house" replacements for the existing commercial suite of inventory level setting models and has, to date, generated three models: - The Wholesale Inventory Optimization Model sets the planned minimum safety stock parameter in the Navy's Enterprise Resource Planning software and is currently in production managing inventory levels on over 45,000 navy items. - The Site Level Inventory Optimization Model generates recommended reorder points and reorder quantities for Navy managed materiel at retail sites, to include Naval Air Stations and Defense Distribution Depots. - The Naval Aviation Readiness Based Sparing Model sets required inventory levels for aviation weapon systems to achieve a given operational availability level. These models introduce novel features while providing the Navy with defendable, auditable, and transparent inventory policy, reducing reliance on contractor developed solutions, and helping to maintain critical skills within the civil service work force.

4 - Dynamic pricing in a trade-in program with replacement and new customers
Yongbo Xiao, Jian Chen

Trade-in programs have been widely adopted by manufacturers, retailers, and service providers in the presence of frequent product rollovers. In this study, we investigate the profit potential of a trade-in program in helping a manufacturer to implement price discrimination across replacement and new segments of customers. We show that the manufacturer fails to optimize his total profit in regular selling because customers have different willingness to pay across segments. When a trade-in program is offered, any replacement customer can return their old product in exchange for a price discount when buying a new product. Starting from the choice behavior of customers, we study the dynamic pricing decisions, which are dependent of the time and on-hand inventory level of returned old items. The effect of a trade-in program on the optimal selling price of the new product is studied, and the structural properties of the optimal pricing policy are established. We show that the trade-in program has great potential in improving the overall profit, and under certain conditions the dynamic pricing policy performs rather close to a semi-dynamic policy in which the new product is priced at a fixed level during the entire selling horizon. We further extend the model to the scenarios with multiple classes of old items and simultaneous trade-in and reselling.

■ MC-54

Monday, 12:30-14:00 - 4D UPV 1.6

Business Models, Policies and Customers

Stream: Energy Economics, Environmental Management and Multicriteria Decision Making
Chair: *Davide Vurchio*

1 - Environmental performance of servicizing and selling business models
Mehmet Ali Kanatlı, Ozgen Karaer

Servicizing is the activity of selling the service provided by the product rather than the product itself. It has been considered as an alternative business model that might be environmentally superior to the conventional selling business model. Servicizing promises pooling of consumer use and products with higher durability. However, it can also inflate demand/consumption and result in a bigger environmental impact overall.

This study compares selling and servicizing business model for a monopolist durable-goods manufacturer. Durability and price decisions of the firm, and usage level decisions of consumers are modeled as endogenous. Under this setting, we compare the profitability and environmental performance of the two business models.

2 - An approach for understanding residential electricity consumption
Gulcan Petricli, Gül Gökay Emel

According to the United States Energy Information Administration, the share of electricity in the delivered energy has been growing in the world, and the residential electricity consumption comprise about one third of it. Based on the World Energy Council data, worldwide average electricity consumption per electrified household has been increasing steadily. Contrarily, the increase for developing countries was much greater than the worldwide average. According to the European Environmental agency, it is expected that the drastic increasing trend in developing countries will continue as their economy keep expanding. On the other hand, non-renewable energy sources deplete day by day. Therefore, reducing household electricity consumption, while maintaining life standards of consumers, becomes important. However, there is no "one size fits all" solution to reduce the consumption as it depends on not only socio-demographic characteristics but also attitudes, intentions and behaviors of consumers.

This work aims to propose a bottom-up approach for understanding main drivers of residential electricity consumption in Turkey. In this approach, a market survey, which is based on the environmental ethics, is proposed to be used in order to determine socio-demographic and abovementioned behavioral factors. Afterwards, outputs of the survey will be integrated into Self-Organizing Maps in order to determine consumption patterns and segments of residential electricity consumers.

3 - A CSR innovation research based on design thinking methodology: insight from material topic identification process
Pin-Rui Hwang

Based on service science concept, this study attempts to integrate cross field domain knowledge with design thinking approach to explore the possible innovation for Corporate Sustainability Responsibility (CSR) and its development. The main concept begins from CSR material topic identification which roots from a pilot qualitative research. A fuzzy group opinion aggregation method is implemented to solve current problems resulting in the stakeholder engagement process. By means of complete and accurate identification of the material topics, companies could invest their limit resources to develop their sustainability strategies accordingly. The second phase focuses on how to apply cross field theories to reinforce the corporate competitive advantages from their sustainability outcomes. The context effect theory is applied to develop a new business model to amplify competitive advantage of companies and to penetrate the global supply chain system. The third phase is utilized the fuzzy cognitive map method to explore the dynamic relationships between material topics and disclosure items in corporate sustainability development. Integrating of expert's knowledge with FCM method, we aim to build a comprehensive CSR model for specific industry. Consequently, this model would build up a framework of the sustainable development goals of Taiwan and upgrade the CSR level of industry in order to respond to the Sustainable Development Goals of the United Nations in the future.

4 - Energy use, productivity and exporting: a firm level analysis for developing countries
Davide Vurchio, Pierluigi Montalbano, Silvia Nenci

This work aims at exploring the relationship between energy use, productivity and international trade for a sample of firms located in Developing Countries. This relationship, although important and relevant to policymaking, has not been studied in depth. Moreover, environmental impact has been extensively analyzed using data at the level of countries, states, and provinces, but relative few firm-level analyses have been performed. There are even fewer firm level analyses of the interaction between energy use and trade. Furthermore, little is known about all this with reference to Developing economies. Thanks to the availability of firm-level data for a large set of Developing countries from the national representative World bank Enterprise Survey (WBES) dataset, we provide a firstcomprehensive empirical analysis of the relationship between energy use on both firms' productivity and their exporting status for the main manufacturing industries, controlling for industry and firm heterogeneity. We also look explicitly at the relationship between energy efficiency and exporting by investigating the correlates between the two variables in the spirit of the new approach to international trade based on firm heterogeneity. Given the difficulty in determining a causal linkage, the empirical validation of whether cross-industries and cross-firms differences in energy efficiency are correlated with differences in productivity is very relevant for policymaking.

■ MC-55

Monday, 12:30-14:00 - 4D UPV 2.1

Fast and Furious: Lightning Talks on Applied OR

Stream: Making an Impact I
Chair: *Ruth Kaufman*

1 - Fast and furious: lightning talks
Ruth Kaufman

At a EURO conference there is an enormous amount of interesting material that any one person can only see a small fraction of. This session will help boost that fraction. Each presenter will have just 5 minutes to present a lightning talk: a maximum of 20 slides at 15 seconds per slide. This will be an opportunity for presenters to get a bigger audience for your key ideas and for the audience to get a wide variety of fast-moving and stimulating talks. Details of presenters within the session will be available in due course.

■ MC-56

Monday, 12:30-14:00 - 4D UPV 2.2

Optimization in Renewable Energy Systems II

Stream: Optimization in Renewable Energy Systems
Chair: *Ida Græsted Jensen*

1 - Use of image analysis methods to determine the chlorine content of refuse derived fuel
Aysun Özkan, Kemal Özkan, Şahin Işık, Zerrin Günkaya, Müfide Banar

Energy recovery from wastes and refuse-derived fuels (RDF) has become of increasing importance for energy-intensive industry branches such as cement manufacturing. The first step should be to use the systems that would continuously and automatically measure the chlorine content of the samples. In this study, a system consisting of a portable near-infrared spectroscopy was designed to determine chlorine content of the RDF samples. For this aim, RDF samples were collected from a plant that produce RDF for a cement kiln next to it. The samples were classified according to their chlorine content as high and low. For image analysis, multiple spectrums of each sample were captured using a portable near-infrared spectroscopy. The spectrum data was acquired using the Line Scan, which was configured for 248 data points across a wavelength range of 900-1700 nm and captured at 1 second total scan time. The feature extraction on the spectroscopy obtained from each wavelength was realized. The obtained features were processed using MATLAB Classification Learner to determine the chlorine content. The spectroscopy analysis results indicated a strong correlation with the classification values (mean r = 0.96). This paper presents initial results of the application of an adapted spectroscopy -based method, and critically assesses how the technique could be improved and developed for environmental applications.

2 - Wind turbine power forecasting by LSTM recurrent neural networks using CNTK platform
Serap Ulusam Seckiner, Muhammet Zara, Yunus Eroglu

Wind turbines are now widely used at interconnected power systems and their power outputs mostly depend on weather conditions. Short term forecasting of wind turbine power output is very important to balance different electric power sources. This study aims to forecast one day power output of a wind turbine at the beginning of the day. A real-world dataset has been used that includes 2 years of samples in the form of 10-minute intervals. Among various deep learning methods, long short term memory (LSTM) recurrent neural networks have been selected, since this network is very efficient at time-series forecasting. Microsoft Cognitive Toolkit (CNTK) has been used as neural network training and testing platform. CNTK can train the neural networks running on graphic processor (GPU), so shortens the training time comparing to running on central processor (CPU). In order to obtain the optimum forecasting results, effects of some parameters have been observed. These are the number of hidden units (memory units) in LSTM cells and using different learning algorithms (Stochastic gradient descent, Adam, AdaDelta). Increasing the number of memory units increases the forecasting accuracy but duration of training also increases. The number of cells can not be increased after a certain point due to overfitting which means to obtain good results with training data while obtaining poor results with validation and test data.

3 - A simplistic method for representing renewable gasses and fuels in an energy systems optimisation model
Ida Græsted Jensen, Frauke Wiese, Rasmus Bramstoft

With an increase in variable renewable energy production in the heat and power system, integration with the gas system is a way to get more flexibility in the overall energy system. Renewable gasses and fuels as, e.g., biogas, can be upgraded by adding hydrogen and thereby serve as a substitute for natural gas and conventional transportation fuels. As continued research within hydrogen conversion and storage technologies shows promising cost reductions and efficiency increases, it seems inevitable to implement these technologies in energy systems models. We present a simplified method to include renewable gasses and fuels and their upgrading, as well as hydrogen production and consumption in the energy systems model, Balmorel. We compare the results from using the simplified method with the results obtained using a more detailed formulation of gas and fuel production in the spatio-temporal network optimisation model, OptiFlow, where the production and upgrading processes are included in the modelling. By comparing the methods, we evaluate the importance of the loss of information in the simplified method compared to the detailed formulation, with respect to correspondence between the two solutions in, e.g., overall cost, investments, and running time.

■ MC-57

Monday, 12:30-14:00 - 4D UPV 2.3

Algorithms for Structure

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Joanna Miskiewicz*

1 - Conflict graphs in pseudoknot modelling
Marta Szachniuk, Tomasz Żok, Kacper Figurski, Mariusz Popenda

Many problems rooted in molecular biology can be modeled using graph approach. This enables their efficient solving via computational methods. Recently, our attention has been caught by pseudoknots which are often found in large RNA structures. These motifs are not well recognized and - to our knowledge - their identification, representation and classification is ambiguous. In our study, a problem of pseudoknot classification and encoding has been recognized as graph-modelable. Here, we present a new conflict graph representation of RNA secondary structure with pseudoknots. Based on that, we propose to untangle pseudoknot classification problem as coloring of a graph with weighted vertices. By finding chromatic number for our graph, we optimize an assignment of pseudoknot classes and we provide a clear procedure of motif encoding for further processing of RNA structure data. We compare the results provided by our new method to those obtained by other algorithms, applied to graphs representing real pseudoknotted RNA molecules. This research was supported by National Science Centre, Poland [2016/23/B/ST6/03931].

2 - Discovery and characterization of cryptochrome destabilizer small molecules enhancing the apoptosis
Seref Gul, Mehmet Tardu, Halil Kavakli, Metin Turkay

Circadian rhythm controls the behavioral, biochemical and physical activities of the organisms from cyanobacteria to human. In mammals, clock mechanism is controlled by two interconnected transcription/translation feedback loops (TTFL) which consist of two activators (BMAL1 and CLOCK) and two repressors (PER and CRY) at the molecular level. This mechanism controls 40% of all genes' expression. Impairment of the organism's clock increases the susceptibility to various diseases, e.g. depression, jetlag, sleep disorders, neurological and cardiovascular diseases, cancer, diabetes and obesity. Furthermore, it has been shown that loss of CRY in cancer prone mice, unexpectedly, caused longer life span than cancer prone mice having the CRY, by initiating the apoptosis. Thus, we proposed that CRY destabilizer or inhibitor molecules may increase the apoptosis in cancer prone cells by enhancing the apoptosis. Hence the stability of the CRY is modulated by the antagonistic action of FBXL3 and FBXL21, we utilized the structure based drug design approach to screen more than 2 million small molecules in silico to identify molecules modulating the overall stability of CRY by targeting the CRY and FBXL21/3 interaction sites. Based on the calculated binding energies (delta G) hit compounds were selected to test their effect on the cells having the circadian output. We could identify and characterize small molecules decreasing the level of CRY and enhancing the apoptosis.

3 - N-way junction modeling and analysis
Jakub Wiedemann, Maciej Miłostan, Marta Szachniuk, Ryszard Adamiak

When comparing a number of records stored in Protein Data Bank and NCBI's RefSeq we can see how large is the gap between the known sequences and structures of biomolecules. Nowadays, this gap is being filled by using various computational approaches. Current methods for prediction of the tertiary structure of biomolecules are far from being perfect. They are successful in handling selected structure elements, but rather unreliable in modeling the others. N-way junction is the example of structure motif that is found hard to predict accurately by computational algorithms. In our work, we found all n-way junctions in RNA structures by analyzing their dot-bracket representations. Based on the obtained set, we created a database to store them, together with their graph models and the information about Euler angles describing the direction of incoming stems. This data can be used in the process of modeling of unknown RNA 3D structures and in the refinement of the existing ones. This work was supported by the National Science Centre, Poland [2016/23/B/ST6/03931].

4 - Computational analysis and visualization of G-quadruplex structures
Joanna Miskiewicz, Mariusz Popenda, Joanna Sarzynska, Maciej Antczak, Tomasz Żok, Marta Szachniuk

G-quadruplexes are non-canonical structural formations that exist in guanosine-rich DNA, RNA and even in nucleic acids analogs. These 4-stranded helical structures, also called G4, are created in vitro by spontaneous foldings. The G-quadruplex form may be built by one, two or four strands and their orientation determine the polarity of the G-quadruplex structure - parallel, antiparallel, and hybrid-type antiparallel. Due to a specific structure of G-quadruplex, it is involved in the various biological processes, such as mRNA processing, regulation, and transcription, which may be influenced by recruiting protein factors. Moreover, G-quadruplex structures are a promising target in many strategies of drug development, including anticancer and neurological disease therapies. In our research, we analyzed G-quadruplex structures in human microRNAs (small non-coding molecules) and we proposed a new manner to visualize their secondary structure. We searched through miRBase database for human miRNA sequences rich in guanosines, and among the chosen ones, we defined possible G-quadruplex motifs. Using structures recognized as the ones containing G-quadruplexes stored in PDB database as templates, we were able to create miRNA models which consist of G-quadruplex formations. This work was supported by the National Science Centre, Poland [2016/23/B/ST6/03931].

■ MC-58

Monday, 12:30-14:00 - 4D UPV 2.4

Teaching OR/MS I

Stream: OR Education
Chair: *Pedro Castellucci*

1 - MODGRAF: a tool to support teaching network problems
Mariusz Kaleta

Although the network problems are a must have position in a typical OR curriculum, there is surprisingly few didactic software in this field. We fill this gap by delivering a tool that can support students in their learning process. The Modgraf software allows students for visual modeling graphs. Students may apply different algorithms for various graph problems, including max flow, min-cost flow, TSP, edge/node coloring, minimum spanning tree, Eulerian cycle. Due to large number of ready-made algorithms, they can more focus on understanding problem modeling issues, especially choosing the right graph model and algorithm, decoding the solution from the graph, without going deeply into algorithmic aspects. For instance, this approach can be suitable for management and business students. Students that are more interested in algorithmic aspect they can follow algorithms in step-by-step mode and observe how the algorithm works in details. Finally, students can deliver their own algorithm implementations in java in a very simple way, without the need of rebuilding the whole system. They can test their algorithm in the environment and compare to other algorithms. In the talk we share our experiences regarding using the tool in teaching OR fundamentals at Warsaw University of Technology.

2 - Sharing experiences of designing and teaching quantitative methods online
Mahmut Sonmez

Online education requires new and fresh approaches to course design and teaching practices. How does a faculty make the transition from a traditional campus teaching to online teaching? In this presentation, the author shares his experiences and answers questions about what it takes to design and teach a fully online quantitative methods course.

3 - Mobile learning as strategy for teaching OR
Laura Plazola Zamora, Sara Marín, Alejandra Gomez Padilla

Mobile learning includes teaching and learning techniques and a variety of mobile applications that can be used as a source of information and as a tool to create material that allows students to actively participate in their learning process. In this work we use mobile learning environments to improve the teaching and learning of key concepts in a class of Operational Research for business and marketing careers at the University of Guadalajara. The use of mobile devices and different pedagogical strategies with applications to present lesson themes and illustrate problem solving, is a way to engage students and help facilitate understanding by improving pedagogy in the classroom and, by extension, the student's learning.

4 - Teaching how to model
Pedro Castellucci, Alysson Costa

In this presentation, we will talk about our experience with a modeling exercise that was used as an assignment in a Masters Level Course on mixed-integer programming at the School of Mathematics and Statistics - University of Melbourne. The problem considered is a (original ?) variant of the traveling salesman problem presenting a number of modeling challenges. Students could decide to make assumptions and simplify the problem (as in real life) but their marks should at least partially reflect the quality of the obtained solutions.

■ MC-59

Monday, 12:30-14:00 - 4D UPV 2.5

Risk and Uncertainty in Agri-Food Systems

Stream: OR Advances in Agribusiness
Chair: *Jorge E. Hernández*
Chair: *Leandro Antonelli*

1 - Modelling agri-food supply chain risks using total interpretive structural modelling and fuzzy MICMAC analysis

Guoqing Zhao, Shaofeng Liu

The perishable characteristics of agri-food products and growing complexity of agri-food supply chain networks cause higher uncertainty compared with other supply chains.In this paper,an attempt has been made to establish and analyse the interconnectedness of agri-food supply chain risks by applying total interpretive structural modelling and fuzzy MICMAC analysis.Total interpretive structural modelling(TISM) is implemented as a methodology for identifying and summarizing relationships among factors that negatively affect agri-food supply chains.The results of TISM are used as an input to process fuzzy MICMAC analysis to precisely analyse the driving power and dependence power of agri-food supply chain risks.15 agri-food supply chain risks identified were machine breakdown,bad working conditions,labour shortage,market price fluctuations,pest and disease risk,bad quality of irrigation water,rising energy cost,food quality risk,food safety risk,waste disposal risk,unstable contract with supply chain partners,customer preference,unstable government policies,unstable weather conditions and rising labour cost.With the help of TISM methodology,these 15 agri-food supply chain risks were constituted 8 levels in the TISM model.The results of fuzzy MICMAC analysis shows that,all the variables considered in this study are necessary as there are no autonomous variables.This study makes a great contribution to understand the interconnectedness of agri-food supply chain risks.

2 - Fuzzy model to increase vegetables quality with a collaboration program under uncertainty

Ana Esteso, Mareva Alemany, Angel Ortiz

Agri-food supply chains (AFSC) profits are dependent on products quality. Consumers require a minimum quality for products and pay a higher price for them than for non-quality products. Problems arise when farmers have difficulties in obtaining products with the quality standards required. Farmers are forced to waste the harvest not meeting the quality standards. This impacts on the quality products sales, and on the profits of the whole AFSC. Collaboration can be used to increase the quantity of quality products harvested. Modern retailers can fund small farmers to improve their knowledge in farming techniques and the technology for the fruits and vegetables production. Unfortunately, the proportion of quality products to be obtained at each harvest and its improvement with each fund are uncertain. If uncertainty is not considered in models, the expected results will not be achieved when implementing a solution to a real AFSC. A fuzzy model based on Wahyudin et al. (2015) to select the funds to be made to maximize the AFSC profits is presented. The main novelties of our approach are: 1) the uncertain modelling of the proportion of quality products and its improvement with each fund, and 2) to include the possibility of rejecting demand and wasting harvested product. A method to select the solution that better balances its feasibility and the decision-maker satisfaction is employed, determining the funds to be finally implemented in the AFSC.

3 - A new 0-1 mixed integer wheat supply network design model proposal that decreases the number of vehicle rounds

Abdullah Oktay Dündar, Mahmut Tekin, Kenan Peker, Mehmet Akif Sahman, Ismail Karaoglan

In the world, bakery products have an important place in nutrition. Turkey is ranked first in the world flour exports. Despite the fact that enough wheat is produced in the country, importing wheat from abroad affects the sector negatively. Farmers deliver wheats by making a large number of rounds with small capacity vehicles in Turkey. This situation increases the costs significantly. The purchased wheat is classified according to quality characteristics in the collection silos. Wheat intake in the silos is limited by the harvest time. On the other hand, wheat shipment from the silos to the flour mill can be made throughout the year. In this study, a new 0-1 mixed-integer wheat supply network design model is proposed for a flour mill to supply sufficient wheat with desired quality and the lowest cost. The model uses different tonnage vehicles and reduces the number of rounds by selecting the appropriate vehicle for the amount of freight. The model also evaluates the railway option in addition to the highway. In this case, the proposed model can be characterized as capacity limited, multi echelon, multi stage, multi transport option, multi product wheat supply network design. The model has been tested with the actual data obtained from Ova Flour Mill which is operating in Konya province. It has been observed that the model provides significant cost advantages in supplying wheat with adequate and desirable quality. Rail transport is recommended in some areas.

4 - Modelling spatially distributed refuge areas and sterile insect releases in a Bt sugarcane agroecosystem

Dirk Human, Linke Potgieter

Genetically engineered crops that produce insecticidal toxins from Bacillus thuringiensis (Bt) are increasingly being developed and used for pest control. Unfortunately, insects develop resistance over time and as a result the toxins' efficacy are reduced, rendering this method of control ineffective as a long-term strategy. One way of delaying pest resistance to Bt crops is the use of refuge areas of non-Bt host plants or crops where susceptible insects reside. In this talk, we present an agent-based simulation approach to modelling resistance development in an Eldana saccharina Walker (Lepidoptera: Pyralidae) population for different spatially distributed or sized refuge areas in a Bt sugarcane scenario. Results from computer simulations indicate that the spatial distribution and size of refuge areas have a direct impact on the long-term success of using Bt sugarcane. The economic viability of differently sized refuge areas are also considered. Apart from using refuge areas, sterile insect releases have been shown as an alternative strategy to delay pest resistance to Bt crops. Sterile insect release has also been indicated as a viable pest control method against Eldana infestation in a sugarcane agroecosystem depending on the spatial distribution of releases. Combining the use of Bt sugarcane, refuge areas and sterile insect releases in a sugarcane agroecosystem as an integrated strategy against Eldana infestation is also considered in this talk.

■ MC-60

Monday, 12:30-14:00 - 4D UPV B.5

EURO Doctoral Dissertation Award I

Stream: EURO Special Sessions
Chair: *Richard Hartl*

1 - Computation of equilibria on integer programming games

Margarida Carvalho

The formulation of optimization problems as mathematical programming models is the standard way for describing and communicating real-world situations unambiguously. Very often, a decision process depends on external parameters controlled by other agents (players). This establishes the connection between mathematical programming and the game theory framework. The goal of this theses was to extend the algorithmic tools for single decision-maker combinatorial problems to games. Namely, we concentrate on non-cooperative games, where each player's set of feasible strategies is characterized through linear inequalities and integer requirements on player's decision variables. These are called integer programming games (IPGs). This work is fleshed out in two parts: we first considered two-round games, called Bilevel Programming problems, and then we focused on games where players select their strategies simultaneously. Although in both types of games each player goal is to maximize his/her utility, the approach to a solution significantly varies. We studied specific games that generalize classical optimization problems with applicability in robust optimization, homeland security, competitive lot-sizing and multi-agent kidney exchange programs. Besides classifying their computational complexity, a strong emphasis was given to algorithmic design which resulted in new methods and frameworks for solution computation. The thesis concludes by analyzing general simultaneous IPGs.

2 - Large-scale network optimization: Steiner tree problems
Martin Luipersbeck

This work studies exact solution methods for the Steiner tree problem in graphs (STP) and other related NP-hard network design problems. The main focus is put on the development of practical computational techniques that are suitable for finding optimal solutions on large-scale problem instances. These efforts are motivated by recent applications of network design models in bioinformatics and pattern recognition. The work's core contributions involve the STP, the prize-collecting STP (PCSTP) and the stochastic STP (SSTP). For the STP, a node-based integer-linear programming (ILP) formulation is introduced which is shown to be particularly effective on notoriously difficult benchmark instances. An algorithmic framework integrating this formulation with other state-of-the-art techniques won the most categories among all participants during the 11th DIMACS Implementation Challenge. For the PCSTP, a branch-and-bound procedure based on dual ascent and reduction tests is designed by which several previously unsolved large-scale instances are solved to optimality. For the SSTP, an ILP formulation is presented which is shown to dominate known formulations and whose convenient structure is exploited in the design of a successful exact algorithm combining dual ascent, Lagrangian relaxation, and Benders decomposition. Additional contributions involve four related network design problems for which ILP-based algorithmic frameworks are introduced and computationally evaluated.

3 - Logistics networks with intermediate stops - designing innovative and green solutions
Maximilian Schiffer

Current challenges and future requirements for logistics networks like tremendous growth in small package shipping and extremely ambitious ecological targets at global and local level call for more flexibility, efficiency, and sustainability in logistics. Herein, logistics networks with intermediate stops constitute a promising concept to realize these goals, as they allow for freight replenishment in-between service stops to use smaller vehicles, for multimodal transportation in city logistics, and for recharging electric commercial vehicles (ECVs) en-route. Against this background, this dissertation focuses on the strategic design and operation of logistics networks with intermediate stops. Regarding its methodological contribution, it introduces a new class of location-routing problems (LRPs), the LRP with intra-route facilities (LRPIF), for the design and operation of such networks. It further presents a generic and competitive algorithmic framework for LRPIFs, but also for 14 different classes of vehicle routing problems with intermediate stops. This algorithmic framework represents a new state of the art in terms of solution quality, computational performance, and usability as it can be applied to a large variety of LRPIFs and VRPISs without additional tailoring. Moreover, these approaches are applied to a real-world case on the deployment of ECVs in mid-haul transportation. Accordingly, this dissertation derives deep managerial insights for fleet operators to foster the adoption of ECVs in logistics networks and thus helps to realize sustainable modes of transportation.

Monday, 14:30-16:00

■ MD-01

Monday, 14:30-16:00 - UPV Nexus

Quantitative models embedded in decision-support tools for healthcare applications

Stream: Keynotes
Chair: *Sibel Salman*

1 - Quantitative models embedded in decision-support tools for healthcare applications
Pinar Keskinocak

We will discuss a few examples from healthcare, where quantitative models embedded in decision-support tools can improve the quality of decision-making (for patients, physicians, or caregivers) and patient outcomes. Examples will come from a variety of applications, including (i) organ transplant decisions for patients and physicians (considering the survival curve estimates of accepting an organ and undergoing transplant, versus remaining on the waiting list hoping to receive a better quality organ in the future), (ii) catch-up scheduling for vaccinations, (iii) prenatal screening for Down Syndrome, (iv) scheduling of patients to receive a combination of services.

■ MD-02

Monday, 14:30-16:00 - SOUTH BUILDING UV S101

Industry 4.0 Production Planning

Stream: Scheduling Practice
Chair: *Maria Mavri*

1 - Qualitative assessment of the influence of manufacturing complexity drivers onto production planning problems in the context of Industrie 4.0
Dennis Horstkemper, Bernd Hellingrath

Within Industrie 4.0, the notion of decentralized planning and control is meant to counter the increasing complexity of production planning tasks, induced through higher customer demands and more flexible production systems. Decentralized planning models are in comparison to centralized ones of considerably less computational complexity and can be solved more efficiently. However, this decentralized approach of production planning can lead to conflicting goals of individual instances and might require additional coordination effort. Thus, a centralized planning approach in production planning is preferable, unless the instance-specific complexity of the planning task leads to inadequate solution times. As of today, there is no set of guidelines available to support a decision maker in framing the choice of a centralized or decentralized production planning approach. Within this work, we try to lay the foundation of such guidance by conducting an examination of the complexity drivers behind production systems in relation to production planning and control tasks. Here, complexity drivers and especially their operationalizations, can be used to measure the current complexity of a production system. The influence of these operationalizations onto the solution times of production planning problems can be shown through simulation studies. Thus, complexity drivers are suitable additional information for decision makes to determine the optimal production planning approach.

2 - Modeling and simulation of a production system with an Industry 4.0 approach, as a new learning environment through the use of virtual tools

Luis Omar Alpala, David Zambrano, Dayana Vallejo, Luis Vallejo

In this research, we propose a new approach enable to design and modeling an industrial plant production system with a Smart Factory by using computer tools included in the BIM (Building Information Modeling) systems. The suggested design integrates software, BIM dimensions and database in a collaborative way to obtain a unique work model in order to reduces time and costs for planners. The virtual plant submits functions as a practical learning which allows to design and model different types of industrial plants in the Manufacturing sector and subsectors keeping similarities in their production system and resources. This type of project is designed so that new projects for the production of goods in the manufacturing sector and its sub-sectors with a Smart Factory approach can be designed, modelled and simulated before they are definitively built, with this learning environment which is based on an experimental laboratory in which it is possible to study the behavior of the main resources that any production plant has in common, it is possible to visualize how production behaves after the use of disruptive technologies. In order to validate the proposal, a group of experts was invited from both the company and the educational sector, using as a main source of visualization the virtual and augmented reality in which participants could verify the hyperrealistic experience of connecting with a virtual and real world at the same time, without the need to be present there.

3 - Future research areas for supply chain management containing blockchain technology
Emine Bozoklar, Ebru Yılmaz

Blockchain is one of the current information technologies associated with Industry 4.0. Blockchain technology plays an important role for supply chain management in terms of some factors such as cost, quality, sustainability and traceability. This study suggests a detailed scrutiny about significance and application areas of blockchain technology for supply chain management in terms of these factors mentioned above. Moreover, some research areas and suggestions are presented for future studies.

4 - Is it cheaper to print a good or to manufacture it using traditional techniques? Cost always makes matter.
Maria Mavri, Evgenia Fronimaki

The Additive Manufacturing (AM) term, also known as 3D printing (3DP), describes the use of a collection of technologies capable of joining materials to manufacture complex products in a single process step. AM technology has the potential to change the future of supply chains and how industries will design, manufacture and repair goods. AM reduces time and costs from the design phase to manufacturing, since there is no investment in designing and fabricating the necessary tooling and fixtures. The cost of manufacturing a product using AM processes exceeds that of traditional methods and may slow the adoption of this technology. Because of the high purchasing and processing costs of AM machines, the planning and scheduling a 3DP network play a crucial role in reducing operational costs, providing services to customers in fewer prices and increasing the profitability of AM industries. Although cost functions have been developed in the literature, 3DP networks have not studied yet. A 3DP network comprises multiple entities and connections among entities. More specifically, a simple 3DP network consists of customers, suppliers, AM manufacturing plants, designers, factory workers, distribution centers, as well as the links among these entities, through which printed goods flow. The goal of this paper is to propose a linear model for cost of manufacturing and goods. The model minimizes investment and operational costs and therefore maximizes profits of an AM industry.

■ MD-03

Monday, 14:30-16:00 - SOUTH BUILDING UV S103

Facility Location in Supply Chains I

Stream: Location Analysis and Optimization
Chair: *Abdullah Dasci*

1 - Locating hydrogen refueling stations with a capacitated flow capturing location model
Kai Zhang, Yu Song

Hydrogen fuel raises widespread concern since it is a sort of environment-friendly and renewable energy sources. Japan is an advanced country in utilizing the hydrogen fuel and pays more attention to developing the fuel cell vehicles (FCVs). In promoting the FCVs, it is necessary to build corresponding hydrogen refueling stations (HRSs) to serve them. Therefore, a problem has arisen that how the HRSs can be located efficiently. In this study, a capacitated flow capturing location model (CFCLM) is proposed to determine the optimal locations of HRSs, which considers the capacity of HRS facilities and allows the FCV flows to have a deviation distance from their shortest paths. Besides, the asymmetry of traffic flow in reality is taken into account, contrary to the assumption of symmetric flows in flow capturing location model (FCLM) proposed by Hodgson. In addition, we conducted numerical experiments of CFCLM with the person trip data of Fukuoka City, Japan. Due to the lack of road network data, a new network is constructed with the covering radius, where the nodes are the zonal centroids and the links depend on nodes' distance compared with the covering radius. The optimal HRSs location problem of Fukuoka City is solved by using mathematical programming solver: Gurobi Optimizer. To shorten the calculating time, a greedy heuristic algorithm is also developed to obtain the approximate optimal solutions, and the effectiveness of the algorithm will be verified with exact solutions.

2 - A warehouse location-transportation model for pharmaceutical distribution planning
Eli Angela Vitor Toso, Aura Jalal

We consider a specific warehouse location-transportation problem in a three-level pharmaceutical logistics network comprised of production plants, warehouses and customers. Unlike typical location problems, ours is characterized by lower warehouse opening costs due to outsourced warehousing and distribution services. Therefore, medium-term transport costs have a higher impact on location decisions and must be evaluated with parsimony. In addition, medicine items are very diverse in sales price, demand behavior and physical characteristics, which also affect transportation mode decisions, e.g., road or air shipments, truckload (TL) or less-than-truckload (LTL) transportation, cargo insurance, and, in some cases, reefer cargo requirements. A multi-product, dynamic and multimodal location-transportation model is thus developed considering practical characteristics of the Brazilian's logistics context, in which the rate of ICMS (value-added tax on sales) varies according to the State (municipality) where warehouses are located. Numerical results based on real-life instances demonstrate the model's effectiveness to support compromised location and transport decisions towards minimizing overall logistics costs plus the total amount of chargeable taxes.

3 - A strategic model for location and route planning for a service parts distribution system
Ajinkya Tanksale, F. Tevhide Altekin, Abdullah Dasci, Hazal Ercan, Guvenc Sahin

In this paper, we deal with the design of a service parts distribution system. We consider a multi-echelon distribution system that consists of one distribution center (DC) and various regional depots, each of which is responsible for a group of authorized service points that deliver repair services directly to customers. We focus primarily on the location of potential depots which is the key strategic decision in such distribution systems. Another policy decision is the frequency of shipments from DC to depot and from depot to service points. We allow a service point to be assigned to more than one depot or to be visited via different routes and/or different trucks. Even though route optimization is beyond our scope, we consider route selection among a set of alternative routes as a decision in the present model. As opposed to simple linear functions, we take into account the transportation costs more realistically by considering a staircase cost structure due to alternate vehicle types of different capacities. In particular, we exploit the utilization of full-truck-load shipments to achieve economies of scale in the considered distribution system. In this way, we presented an extended facility location model that considers detailed transportation decision. We demonstrate the application of the model to the practice through computational experiments.

4 - An iterative BTST method for the multi-Weber problem
Atsuo Suzuki

The multi-Weber problem is a variation of the classical Weber problem where we need to place several facilities to serve the demand points. As the objective function of the multi-Weber problem is nonconvex, it is quite difficult to obtain the exact solution of the multi-Weber problem. We propose an iterative method to obtain a local minimum solution. Starting from an initial layout of the facilities, we move the facilities one by one to a better position until the move of the facilities becomes small. The new location is obtained by solving another variation of the Weber problem. The problem is find the exact solution of the Weber problem where there exist several facilities. Serving for the demand points We apply the BTST method, as the objective function of the problem to find the new location is also nonconvex.

■ MD-04
Monday, 14:30-16:00 - SOUTH BUILDING UV S104

Corporate Finance and Portfolio Management

Stream: New Challenges in Investment Strategies, Risk and Financial Modelling
Chair: *Victor Dragota*

1 - Portfolio selection under cumulative prospect theory with piecewise exponential value functions
Suleyman Ozekici, Nuri Şensoy

In this paper, we formulate and study the single-period portfolio selection problem under Cumulative Prospect Theory (CPT) using the piecewise exponential (PE) value function. The reference point coincides with the risk-free return and the probability weighting functions are ignored. Under the assumption of normally distributed returns of multiple risky assets, we obtain the optimal portfolio explicitly and provide several characterizations. In particular, we investigate the connection of the optimal PE portfolio to those within the mean-variance framework of Markowitz. As a special case, we analyze the single risky asset model and show that the objective function is quasi-concave. Also, we identify the optimal portfolios and analyze the structure of the objective functions in a number of numerical illustrations. Finally, we perform sensitivity analysis on the optimal portfolios with respect to the parameters of the value function.

2 - Optimal financing strategy when considering R&D innovation
Jiang Wang, Changchang Wu, Lihua Chen

In a stylized supply chain where a supplier sells a single product to a manufacturer, this paper studies the manufacturer's optimal financing strategy when considering R&D innovation. The main results are as follows: (1) With demand uncertainty, only when the fixed cost difference between supply chain financing and bank financing exceeds a certain threshold, will the manufacturer apply supply chain financing. If R&D efficiency or demand is higher, or the coefficient of R&D cost is lower, the manufacturer is more willing to apply supply chain financing. (2) With R&D efficiency uncertainty, only when the fixed cost difference between supply chain financing and bank financing exceeds a certain threshold, will the manufacturer apply supply chain financing. If the mean value or variance of R&D efficiency is larger, or the coefficient of R&D cost is lower, the manufacturer is more willing to apply supply chain financing. (3) The R&D level and order quantity under supply chain financing are both higher than under bank financing, which shows that supply chain financing can stimulate the manufacturer's R&D and production.

3 - A hybrid belief rule based decision support system for assessing credit risk for mortgage lending
Swati Sachan, Jian-Bo Yang, Dong-Ling Xu

Mortgage lending institutions assess credit risk to determine the possibility of borrower's failure to pay their loan obligation. A common decision-making approach adopted by lenders consists of following several administratively pre-established rules and transformation of data gathered from credit bureau to a composite score by machine learning models. With accumulation of data over time, rules have become more complex and the consequence of noncompliance is getting more severe. This situation force lender to minimize the stress and unrecognized biases or errors of complex decision making by human interventions. This research proposes a hybrid belief rule-based system to make joint utilization of expert knowledge and heterogeneous source of credit risk data available from external agencies, lending institutions internal data and their pre-existing decline and referral rules. Both expert knowledge and credit risk data are independent and complementary and are used to train the optimal expert belief rule-based and data-driven model, respectively to establish the association between the default feature space and default status space. The proposed methodology can determine the nonlinear relationships between default features and can explicitly represent the underwriter's domain-specific knowledge as well as the judgment from historical data. The result from both the models is fine-tuned by aggregating it by evidence reasoning algorithm.

4 - Dividend policy: estimating the duration of making systematically bad decisions
Victor Dragota, Camelia Delcea

Different papers discuss dividend policy from many perspectives. Some of them propose normative models, providing solutions for making optimal decisions regarding dividend payout. Our paper analyses the case in which the decision-makers make systematically bad decisions regarding dividend payout and its effects. It contributes to the literature approaching dividend payout literature from an agent-based modelling perspective. Our paper analyses the conditions in which making bad decisions can become a systematic phenomenon and proposes a model for the estimation of the duration of making systematically bad decisions in fixing one dividend policy.

■ MD-05
Monday, 14:30-16:00 - SOUTH BUILDING UV S105

Exact Methods for Vehicle Routing Problems I

Stream: Vehicle Routing and Logistics Optimization I
Chair: *Roberto Roberti*

1 - An exact algorithm for the static repositioning problem in bike sharing systems
Jose M. Belenguer, Enrique Benavent, Julio Daza Escorcia

The static bike repositioning problem is defined by a set of stations, a depot, and a homogeneous vehicle fleet. For each station, the current inventory of usable bikes and their target inventory level are known, as well as the number of damaged bikes. The problem consists of designing the routes of the vehicles, and the number of bikes, both usable and damaged, to be moved at each station, in order to minimize the final imbalance of the stations and the number of damaged bikes that have not been taken to the depot. As a secondary objective, the total time of the routes is minimized. We propose an integer linear formulation, reinforced with valid inequalities, that is the basis of a Branch and Cut algorithm for solving the problem. The proposed algorithm was applied to a set of instances based on real data.

2 - An exact method for the multi-trip VRP with time windows
Rosario Paradiso, Roberto Roberti, Demetrio Laganà, Wout Dullaert

The Multi-Trip Vehicle Routing Problem with Time Windows, Limited Duration and Loading Times (MTVRPTWLD) is a variant of the VRPTW, where vehicles can perform multiple trips in the planning horizon. A trip is defined as a sequence of visited customers and a departure time from the depot. Each trip cannot exceed a given maximum time duration. In this work, a new two-phase exact method is proposed to solve the problem. The proposed algorithm is based on a formulation where each variable corresponds to a structure, where a structure is a trip without an associated departure time from the depot. In the first phase, a lower bound is computed by using column generation and all structures having a reduced cost w.r.t. the computed dual solution not greater than the gap between an input upper bound and the achieved lower bound are generated. In the second phase, a branch and cut algorithm based on the set of structures generated in Phase 1 is used to find an optimal solution of the problem. One of the features that differentiates our approach from the others in the literature, is that all our formulations are "structures" based, instead of considering trip or routes (a route is a set of consecutive trips performed by the same vehicle). The computational results achieved by the proposed solution method clearly show its effectiveness.The proposed solution method clearly outperforms the exacts algorithm in the literature, solving all the instances in less than 30 minutes.

3 - Decomposition algorithms for the multi-modal ride-sharing routing problem
David Pisinger, Miriam Enzi, Sophie Parragh, Matthias Prandtstetter

Mobility is changing - people are moving from owning a car towards using mobility services. Sustainability and shared economy are rising topics of concern. In this talk we focus on two different sharing concepts: car-sharing and ride-sharing. In car-sharing a community mutually uses a pool of cars but tours are traveled separately. In ride-sharing individual legs can be shared in order to reduce cost and/or enhance utilization of an integrated fleet.

We introduce the multi-modal ride-sharing routing problem (MMRRP), in which a pool of cars is used to cover a set of ride requests by the employees. Each route must start in a depot and finish in a (possibly different) depot. Since the employees always have the option of using other modes of transportation (e.g. public transportation) the problem can be seen as a prize-collecting Vehicle Routing Problem defined on a acyclic time-space graph. The problem is solved by use of column generation where the master problem makes sure that each person can only participate in one ride for each leg, and the pricing problem generates new promising routes by solving a (time constrained) shortest path problem in a time-space network. The pricing problem also attempts to include ride-sharing whenever possible. Computational experiments are reported showing that the column generation framework outperforms a compact formulation for large-scale problems.

4 - An exact method for the consistent vehicle-routing problem
Roberto Roberti, Dominik Goeke, Michael Schneider

Vehicle-routing problems (VRPs) with consistency considerations are receiving substantial interest because of the practical importance of providing consistent service in many industries. To boost customer satisfaction, customers should be served at roughly the same time (arrival time consistency, ATC) by the same driver (driver consistency, DC) each time they are served. The Consistent VRP (ConVRP) is a multi-day capacitated VRP with ATC and DC constraints.

A few heuristics are available for the ConVRP, but no exact approach has been proposed yet. Most of the state-of-the-art exact methods to solve VRPs are based on column generation applied to formulations where each variable represents a feasible route, and the pricing problem is solved via dynamic programming. However, these methods cannot be directly extended to solve the ConVRP because the linear relaxation of route-based formulations provides weak lower bounds due to the interdependency between the daily routes, which is caused by the required ATC at customers.

In this talk, we propose an exact method based on column generation applied to a formulation in which each variable represents the set of routes assigned to a vehicle over the planning horizon. The exact method initially takes into account DC only, and addresses ATC at a later stage. Computational results show that the proposed exact method is able to solve small and medium sized instances with up to five planning periods and 30 customers.

■ MD-06

Monday, 14:30-16:00 - SOUTH BUILDING UV S106

Retail Distribution Planning I

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Heinrich Kuhn*

1 - Branch-and-cut and heuristic algorithms for an inventory routing problem with perishable products
Aldair Alvarez, Jean-François Cordeau, Raf Jans, Pedro Munari, Reinaldo Morabito

In this talk, we present different mixed-integer programming formulations for an inventory routing problem with perishable products. In the problem, the perishability of the products is modeled by considering a fixed shelf-life, i.e., the product expires a certain number of time periods after it is made available at the supplier. To solve the problem we propose branch-and-cut algorithms and a hybrid heuristic method. We report computational experiments with the algorithms using problem instances from the literature.

2 - Order policies for a perishable product in retail
Karin G.J. Pauls-Worm, Eligius M.T. Hendrix

A challenge of inventory control of perishable products in retail is that in general the age distribution of the items in stock is not known. Only the total numbers of items delivered and sold are recorded, resulting in an estimate of the items in stock. The exact number may be different from the inventory status according to the checkout system due to damaged items and more waste than expected. We investigate order policies for a product with a maximum shelf life of 3 days at delivery. Demand is non-stationary during the week, but stationary over the weeks. Lead time is one day. For planning purposes in the supermarket, we search for order policies with fixed reorder days during the week, so we order at least 3 times a week, and at most every day. It is likely to have items of different ages in stock. Customers can pick the items in front of the shelf (FIFO), as preferred and stimulated by the store, or search for the freshest items (LIFO). The store has a target α-service level to meet demand. A Stochastic Programming (SP) model is presented of the situation in the retailer practice. Several policies to determine the order quantity are studied and compared to a policy from literature. The base is a YS order policy where the reorder days Y are fixed and order-up-to levels S are used, with parameter values generated by an MILP approximation of the SP model. Numerical experiments compare the effectiveness of the policies with respect to costs and reached service levels.

3 - On the issuing rules and agreements in a divergent retail supply network to reduce the waste and increase the freshness of perishable products
Rob Broekmeulen, Karel van Donselaar

Our study investigates control rules at and agreements between different stakeholders in a divergent retail supply network for perishables. The objective is to reduce the time between production at the supplier and delivery to the store to maximize the freshness and minimize the waste. We also study the effects on transportation and handling costs.

The proposed model compares the effect of centralized with decentralized control of the goods flow in such a network. Our results show the benefits of concepts like Supply Chain Synchronization and Vendor Managed Inventory specifically for a perishable divergent network.

4 - Design challenges and performance analysis of the pick-support AGV system
Kaveh Azadeh, Debjit Roy, René de Koster

Recently, an AGV-based pick system (Pick-Support AGV) is developed to minimize the pickers travel time. In such systems, the AGVs (Automated Guided Vehicle) automatically follow the picker closely and transport the roll cages for the picker to put away the retrieved items. Once the roll cage is full, the AGV is automatically swapped with a new AGV carrying an empty roll cage. Therefore, the picker can continue with the picking route without returning to the depot, and the AGV automatically transports the full roll cage to the depot. Due to a parallel movement among the pickers and the AGVs, modeling, analysis, and optimization of such systems is complex. In this research, we attempt to develop queuing network models to capture the realistic movement of the AGVs and the pickers in the system and develop solution methods for performance evaluation. Next, we use an MDP (Markov Decision Process) to find the optimal operational policy when using the AGVs, in case of different demand portfolios.

■ MD-07

Monday, 14:30-16:00 - SOUTH BUILDING UV S107

Analytic Hierarchy Process IV

Stream: Analytic Hierarchy Process / Analytic Network Process
Chair: *Jozsef Temesi*

1 - Preference elicitation from pairwise comparison matrices by evolutionary computing
Ludmil Mikhailov

The paper is concerned with the application of evolutionary computing for deriving priority vectors (scores of alternatives and criteria weights) in the AHP from pairwise comparison matrices.

A new approach to deriving priority vectors from pairwise comparison matrices, which represents the prioritization task as a multiobjective optimization problem was proposed recently by the author. A two-objective prioritisation (TOP) problem is formulated as an optimisation task for minimisation of the Euclidian norm and the number of rank violations, which measure the most important properties of the priority vectors, related to the initial comparison judgements.

The paper investigates the application of evolutionary computing for solving the TOP problem. In order to eliminate the drawbacks of the numerical methods, we propose two evolutionary computing approaches. In the first one, the TOP problem is transformed into a single-objective one, which is then solved by a standard Genetic Algorithm (GA). The second approach applies a multiobjective evolutionary algorithm (MEA) for solving the TOP problem without such transformation.

In order to compare the solution approaches, we have been currently performing Monte-Carlo simulation experiments, by randomly generating a number of pairwise comparison matrices. Our preliminary results show that the MEA outperforms the gradient search and GA solution approaches with respect to accuracy and computational efficiency.

2 - A study on the application of multi-criterion decision making with quantitative data to research and development budget process in Korea
Yoon Been Lee

In many governments, budget process is core part of official decision making in research and development policy and how can we reflect the insight and voice of science communities into the process is always hot issue under tight schedule. Intense discussion is routine because budget process is priority setting for government expenditure or selecting dichotomous choice: yes or no. Moreover, research and development policy covers diverse fields which currently develop very fast. Korean government has made great efforts to build decent process satisfying diverse participants such as scientist, engineers, and budget officials. During the last decade, the analytic hierarchy process is highly regarded among various approaches and tools in the efforts. In this study, we investigated two representative cases related with multi-criterion decision making with the analytic hierarchy process: the one is decision on a single program, and the other is decision on ranking allocation among technology sectors consisting of multiple programs. We found that the analytic hierarchy process could support decision making with structured approach excluding strategic behaviors and promoting discussions among professionals. We confirmed that in the process quantitative data, such as cost-benefit analysis or patent analysis, and sufficient discussion between experts were helpful in narrowing the gap between groups.

3 - An MCDM-integrated maximum coverage approach for positioning of military surveillance systems
Fatma Çarman, Ceren Tuncer Sakar

In this study, we consider a surveillance systems assignment problem within a national security project in Turkey. It is important to monitor critical places in urban areas against possible terrorist and criminal attacks, and these places may have of different significance levels. We propose three set covering approaches to the problem. We implement these approaches in a pilot area of the project. Firstly, we find the minimum-cost solution that covers all points in the area. Then we apply approaches that include budget or number of surveillance systems constraints and generate multiple efficient solutions in two criteria. For the two-criteria cases, we calculate the "criticality" levels of the areas by Analytic Hierarchy Process and maximize weighted coverage.

4 - Correction of the elements of a pairwise comparison matrix: concepts and methods
Jozsef Temesi

Pairwise comparison matrices (PCM) are widely used in multi-attribute decision making for estimating preferences, weights, or scores. Consistency is a crucial property of PCMs. However, in real-world applications inconsistency often occurs. Inconsistent PCMs include ordinally or cardinally intransitive triads. The first part of my presentation describes a typology of the elicitation errors which can lead to any type of intransitivity. In these cases there are two questions to be answered. First, the user has to decide if ordinal intransitivity could be accepted. The second problem is to measure inconsistency and to define an acceptation threshold. Most of the inconsistency indices are able to detect cardinal intransitivity only, and various methods are recommended to decrease the degree of inconsistency stemmed from cardinal intransitivity. Recent papers suggest to deal with both types of intransitivity simultaneously or sequentially. The second part of my presentation focuses on these approaches, suggesting the separation of different types of decision problems in the applications, and applying interactive methods, if it is possible.

■ MD-08

Monday, 14:30-16:00 - SOUTH BUILDING UV S108

Advances in Combinatorial Optimization

Stream: Combinatorial Optimization I
Chair: *Silvano Martello*
Chair: *Paolo Toth*

1 - Longitudinal analysis of heuristic performance
Steven Verwerft, Kenneth Sörensen

Comparing different heuristics for an optimization problem is a difficult task, and several frameworks exist to establish whether one algorithm performs better or worse than another. A related problem is to determine the best settings for the parameters of an optimization algorithm, an activity commonly referred to as "algorithm tuning". Most studies that go beyond an ad-hoc trial-and-error approach to either comparison or tuning, perform some sort of statistical testing such as analysis of variance (ANOVA), or a non-parametric equivalent such as the Friedman test. Most studies, however, fail to incorporate a crucial factor in the analysis: the computation time. Since most heuristics for combinatorial problems are so-called "anytime" algorithms (i.e., produce a valid solution even if stopped before the termination criterion), and have a more or less arbitrary termination criterion, this results in a comparison that is not necessarily representative of the overall performance of the algorithm under study. We propose a longitudinal approach both for comparing different algorithms and for tuning a single algorithm. Our approach allows to reveal significant effects of the algorithms parameters on its performance, and, more importantly, the dependence of these effects on the time of measurement. In this talk, we demonstrate the usefulness of our approach by applying it to a tabu search (TS) algorithm for a single machine job scheduling problem.

2 - Finding shortest pairs of paths with the fewest shared labels
Marta Pascoal, Joao Clímaco

In this paper we address the problem of computing efficient pairs of paths between two nodes of a given network, whose arcs are associated with a cost and a label. The two criteria to minimize are the total cost of the two paths and the number of labels they have in common. An algorithm for finding the efficient pairs of paths is developed. Numerical experiments are presented to illustrate the performance of this algorithm.

3 - A mixed integer linear programming model for rolling stock rebalancing
Federico Farina, Dennis Huisman, Roberto Roberti, Shadi Sharif Azadeh

This work deals with the Rolling Stock Rebalancing Problem (RSRP) with deadhead trips. In the rolling stock circulation problem, given a set of timetables and the rolling stock material available, the various rolling stock units are assigned to each timetable; this plan also defines in which station's inventory the different rolling stock units will be stored when not used. This daily plan is usually repeated each day of the week (with modifications during weekends or holidays). If the plan is repeated cyclically, then at every station the stored units at the end of the day need to match the required units at the beginning of the following day. Because of disruptions in the daily operations, planned maintenance in the network or others reasons, the timetables can deviate from what was originally planned therefore the balancing condition may be violated and there can be a number of off-balanced stations (with a surplus or a deficit of units). To rebalance the rolling stock in the network new deadhead trips, trips that run empty (starting from a surplus station A to a final station B where there is a deficit of those units), have to be scheduled in between the passenger trains by the railway operators. The novel contribution of our work is a new mathematical formulation that allows to route and schedule new deadhead trips in the network in order to solve the off-balanced stations. We will show that it can solve realistic instances on both the Dutch and Danish railway networks.

4 - A robust optimization approach for the cyclic job shop problem
Idir Hamaz, Laurent Houssin, Sonia Cafieri

The present paper addresses the cyclic job shop problem where the task durations are uncertain. We consider the uncertainty set introduced by Bertsimas and Sim (2003,2004) where the activity durations are subject to interval uncertainty and the level of robustness is controlled by a parameter called budget of uncertainty. We propose a two-stage robust optimization formulation to the cyclic job shop problem where the cycle time and the execution order of tasks executed on the same machines have to be decided before the realization of the uncertainty, and the starting times of tasks are delayed and can be adjusted after the uncertain parameters are known. To tackle the robust cyclic job shop problem with cycle time minimization, we propose a Branch-and-Bound algorithm that uses a robust version of Howard's algorithm to derive a lower bound on the optimal cycle time. In order to compute an initial upper bound for the cycle time, we also provide a heuristic method. Finally, we present results on numerical experiments performed on randomly generated instances.

■ MD-09
Monday, 14:30-16:00 - SOUTH BUILDING UV S109

The Role of Mathematical Optimization in Data Science IV

Stream: European Working Group: Data Science Meets Optimization
Chair: *Vanesa Guerrero*

1 - A branch-and-price approach to find optimal decision trees
Murat Firat, Guillaume Crognier, Adriana F. Gabor, Yingqian Zhang

In Artificial Intelligence (AI) field, decision trees have gained certain importance due to their effectiveness in solving classification and regression problems. Recently, in the literature we see finding optimal decision trees are formulated as Mixed Integer Linear Programming (MILP) models. This elegant way enables us to construct optimal decision trees with different error concerns. In our work, we find the optimal decision trees by employing the Column Generation (CG) approach. To do so, we first reformulated the previously proposed MILP model as a master MILP model. This master model is basically a partitioning problem of the rows in the given data set such that every partition, or so-called segment, of the row set is assigned to a leaf of the decision tree. We obtain the integer solutions by applying a Branch-and-Price search. Our approach of constructing decision trees is successfully tested in real-world benchmark datasets.

2 - Predicting review helpfulness: an open problem?
Anne-Sophie Hoffait, Ashwin Ittoo

Online customer reviews represent one of the most popular and accessible source of product/service information. E-commerce platforms enable users to vote for review for their helpfulness, which act as indicator of the review's reliability for other readers. While numerous scientific publications have focused on the topic of predicting review helpfulness, several questions are yet to be addressed. Moreover, the current literature is highly heterogeneous, leading to inconsistent and contradictory results. Our aim with this study is to synthesize and critically assess the state of the art in research on what makes a review helpful and on predicting review helpfulness. Our primary findings reveal the use of highly varying datasets; a huge plethora of distinct features, including some which are counter-intuitive, as the count of n-letters words or of line breaks; the lack of benchmarks for comparing and assessing algorithms' performance in predicting review helpfulness or the application of machine learning techniques overlooking the statistical characteristics of the data resulting in flawed results. We propose several research directions to overcome these gaps and advance the state of the art, such as a standard features set and algorithms to be used as benchmark for assessing future research. We also propose new approaches based on recent innovations in argumentation mining and deep learning as well as more advanced statistic techniques, such as lasso/ridge regression.

3 - Interpretable deep learning models for financial applications
Pavankumar Murali

Statistical learning has been used in the past to build several predictive models for financial applications such as risk estimation, attrition prediction, product recommendation etc. A majority of these models are tailor-built for specific datasets and use-cases. As such, they cannot be used easily across use-cases without heavy-lifting to rebuild models. Secondly, the training methods employed do not allow true isolation of feature effects on the outcome. In popular techniques such as logistic regression, one can only decipher the relative importance of a feature in the presence of other features. In this talk, we present a new approach based on deep-learning to address this drawback of traditional machine learning models, while enhancing the capability to extract individual customer-level rationales behind a predicted outcome. We use a modeling approach called attention models, that is inspired by the flexibility and interpretability of generalized additive models. This modeling framework enables us to isolate the training and contribution of each subset of features. For instance, our approach can be used to identify the importance of customer profile-based features vs. that of daily account transactions to the predicted outcome. We present results based on several publicly available datasets to show how attention models perform better than traditional methods, and can provide superior interpretability.

4 - Optimized re-ranking approaches for a doctor recommender system
Hongxun Jiang

Big data nourishes smarter services while detailed consideration promotes satisfying ones. State-of-the-art literature of physician recommenders has put major efforts on accuracy, which used to overlook an emerging phenomenon. A few "superstar" physicians dominate others in the number of times recommended that brings to a quite long waiting time making users impatience, and causes themselves exhausted as well. Diversity does help but cannot eliminate overworks. A novel metric in this paper called workload caps the times a physician recommended to improve the quality of recommendations, based on which a personalized physician recommender system was developed. The key contributions was an optimized re-ranking approach after supervised learning. The optimization presented as a mix integer programming with subject to the workload constraints for anyone recommended, as well as objective to find the maximum accuracy. It is a large-scale integer programming and has the computation-consuming problem. We supposed a greedy heuristic to find near-optimal solutions that assures the workload standard first and finds alternatives as good as possible. The experimental results proved that the re-ranking approach improved remarkably the quality of recommendations comparing with the benchmark model. In addition, the greedy-based algorithm outperformances the CPLEX-based one in the computational time in all circumstances, while the similar scores in the accuracy of recommendations.

■ MD-10

Monday, 14:30-16:00 - SOUTH BUILDING UV S110

Decision Aiding Methods IV

Stream: Multiple Criteria Decision Aiding
Chair: *Nelson Hein*

1 - Paraconsistent logic in the economic-financial evaluation of Brazilian companies
Adriana Kroenke, Nelson Hein, Luana Sara Bizzato, Eliane Andrade

This research arises from the importance of diagnosing motives and trends of the decrease in the number of companies in the Steel and Metallurgy sector in the Brazilian stock market. The research had as objective to verify the influence of the economic-financial indicators in the performance of the companies of Siderurgia and Metallurgy. Paraconsistent logic, multicriteria analysis techniques and multivariate analysis were combined. The paraconsistent logic evaluated economic and financial data, between the years of 2008 and 2015, steel and metallurgy companies that worked at the BMF & Bovespa, locating their barycenter in the reticulate of the annotations. On each of the positions, the TOPSIS multicriteria technique was applied, which evaluated the performance of companies against favorable and unfavorable scenarios. Finally, the performance obtained through the use of TOPSIS was confronted by a multiple linear regression to the economic-financial indicators. The results indicate that the indicators of dry liquidity, profitability over assets, return on assets, medium-term of stocks positively influence the performance of companies. On the other hand, current liquidity negatively influences performance. It was concluded that the segment needs efficient logistics, as well as a better optimization of operations related to stocks.

2 - Multi-criteria utility models with veto related preference structures - investigation of methods and properties
Andrej Bregar

Utility based multi-criteria decision aiding methods can be extended with the concept of veto to model non-compensation of unsatisfactory preferences. The aim of this research is to analyse approaches to express non-compensation. An overview is provided, with the focus on veto criterion, veto function, and aggregation operators. A new method to derive a criterion-wise veto function from the matrix of discordance relations between alternatives is introduced, and compared to the standard preference lottery based specification. Veto functions are also correlated with criteria weights, as they exhibit common preference structures of decision-makers. The key contribution of this work pertains to the investigation of properties of veto functions and multi-criteria utility models incorporating veto related information. Several evaluation factors are observed, such as the ability to efficiently discriminate alternatives, richness of output data, relevance of judgements, validity of results, and robustness. Particularly, risk aversion of veto functions is studied, and correlated with risk aversion of complementary utility functions. The outcomes of risk averse, risk seeking, and risk neutral veto functions are analysed, and compared to ROC and RS preference specification methods. Different problem solving problematics (ranking and sorting), aggregation models (additive and multiplicative), and types of rank-orders (complete, weak and partial) are considered in simulation experiments.

3 - Assessing energy retrofit strategies for public buildings: an application of the ELECTRE-TRI nC model
Marta Bottero, Giuseppina Ciulla, José Rui Figueira, Salvatore Greco, Grazia Napoli, Federico Dell'Anna

The present study sets out to investigate the usefulness of Multicriteria Decision Analysis for supporting decision problems in the context of energy retrofit investments. Starting from a real case study, the multicriteria ELECTRE TRI-NC method is employed for sorting alternative strategies for the requalification of public buildings in order to support the efficient allocation of economic resources for energy actions. A sample of 36 public buildings located in the Puglia Region (Southern Italy) has been considered for a potential energy retrofit. In particular, 210 specific requalification measures have been evaluated on the basis of four categories of criteria which consider the financial aspects of the operation (i.e., Net Present Value - NPV and investment costs), the timing of the investment (i.e., Payback Period - PBP), the environmental impacts (i.e., CO2 emissions, reduction of primary energy consumption, energy class), and historic value of the buildings. Interviews and focus groups with different experts in the domain of energy systems, public management and restoration were organized in order to validate the structuring of the decision problem, to define the weights of the evaluation criteria and to state the limiting profiles.

4 - Performance of Brazilian companies: an evaluation through moderate pessimism
Nelson Hein, Adriana Kroenke, Vinicius Jacintho

Brazil is a major exporter of iron ore. However, participation in the stock market of steel and metallurgical companies has been falling in the last decade. This research aimed to evaluate the companies listed on the BM & FBovespa (Brazilian stock exchange) in the period 2012-2016, through its economic-financial indicators using the technique known as Moderate Pessimism Decison Making (MPDM). The principle of moderate pessimism combines advantages of the Laplace and Wald rules, assigning a weighting system to the criteria under evaluation and obtained from the so-called non-dominated firms. The exclusion of dominated firms for the formation of consistent weights presupposes the presence of pessimism, but not in its extreme form. Twelve indicators were used, divided into four lots and with them rankings were formed that indicate the accounting position of the companies investigated. The social impact of the research is to allow the investor to elaborate his portfolio and to the governmental strategist to evaluate the performance of the ten remaining companies in the stock exchange, as well as create public policies that mitigate negative consequences, since it is a strategic sector for the nation. The scientific impact lies in the combined use of two techniques discussed and used in the scope of Operational Research, bringing originality to research. Non-triviality is achieved given the volume of data and the extent of the calculations.

■ MD-11

Monday, 14:30-16:00 - SOUTH BUILDING UV S111

DEA Theory III

Stream: DEA: Theory
Chair: *Martina Kuncova*

1 - Perception-based evaluation of online ratings through uncertain decision intervals

Francisco Javier Santos Arteaga, Debora Di Caprio

We formalize the evaluation and choice structure of a decision maker (DM) when the main characteristics defining the alternatives are not directly observed but numerical reports are provided by external raters. The DM observes the overall numerical value assigned by the raters to an alternative and defines an uncertain interval within which the evaluation observed is contained. The width of the interval is determined by the subjective perception and evaluation differences existing between the DM and the raters transmitting the information. We analyze the incentives of the DM to improve upon an evaluation contained within an uncertain interval by retrieving further uncertain information from the raters of other alternatives. Moreover, different scenarios will be developed based on the capacity of the DM to fully assimilate uncertainty and the introduction of a variety of interval widths designed to account for the potential frictions arising from uncertainty.

The above perception-based evaluation scenario is implemented within a data envelopment analysis (DEA) framework in order to study numerically the effects that perception differentials have on the ranking and selection behavior of the DM.

2 - Sensitivity analysis and assurance region of efficiency in data envelopment analysis with integer inputs and outputs

Farhad Hosseinzadeh Lotfi, Mohammad Fallah, Alireza Amirteimoori, Mohsen Vaez-Ghasemi, Bijan Rahmani Parchikolaei, Mohammad Mehdi Hosseinzadeh, Somayeh Razipour-GhalehJough, Hamid Sharafi

Calculation of relative efficiency and determining the benchmark point is done by using the data envelopment analysis technique. For managers, it's important that each unit, which has a specific performance, in what range can it be changed without changing its performance. In fact, the range in which the input and output data of a unit change, but we still make sure that performance remains constant. In other words, the topic of sensitivity analysis is that how much each input and output factor can change, but performance does not change. In this paper, assuming some of the inputs and outputs that apply in the integer condition, a method is presented that adjusts the variation of each input and output so that the performance remains constant. This will be done for efficient units that are on the efficiency frontier as well as for inefficient units. This region, which is obtained separately for each unit, it is calculated through the solution of corresponding optimization for special inputs or outputs. For each unit, the stability radius is calculated to maintain a constant efficiency. Subsequently, this issue and method are used for a set of commercial bank branches and are calculated for each branch with multiple inputs and multiple outputs for the assurance region and stability radius. Indicators of input and output are effective on the performance of bank branches, personnel, costs, trade demands, paid benefits, received profits, fees, facilities, or loans and resources.

3 - Multi-criteria comparison of travel agencies and tour operators in V4 countries

Martina Kuncova, Veronika Hedija

The tourism industry can be classified as a relatively young and dynamically developing sector of the economy in post-communist countries. In the communist era the sector was heavily regulated by the government, and the opportunities for inbound and outbound tourism were greatly reduced. After the Velvet revolution the significant changes in the demand for tourism services, both in terms of inbound and outbound tourism, could be seen. In response to these changes, the number of tour operators and travel agencies has grown rapidly. But the financial crisis in 2008-2009 has changed this trend into decreasing. It can be assumed that only strong companies remained on the market. The aim of this paper is to compare the situation in the Visegrad Four group of countries (it means in the Czech Republic, Slovakia, Poland and Hungary) in the year 2016 from the travel agencies' and tour operators' point of view with respect to their economic efficiency. For the comparison first multiple criteria decision making methods based on 11 selected ratios of financial analysis are used and second the DEA models are used to estimate the efficiency of the travel agencies inside each country and across all countries. The data was taken from the databases Amadeus and Eurostat.

■ MD-12

Monday, 14:30-16:00 - SOUTH BUILDING UV S112

Non-Standard Optimization and Decision-Making Methods I

Stream: Fuzzy Optimization
Chair: *Martin Gavalec*

1 - Condition of order preservation in pairwise comparisons matrix with fuzzy elements

Jaroslav Ramik

In this paper we deal with Condition of Order Preservation (COP) of pairwise comparisons (PC) matrix with fuzzy elements. Fuzzy elements are appropriate whenever the decision maker (DM) is uncertain about the value of his/her evaluation of the relative importance of elements in question, or, when aggregating crisp pairwise comparisons of a group of decision makers in the group DM problem. We formulate the problem in a general setting investigating pairwise comparisons matrices with elements from abelian linearly ordered group (alo-group). Such an approach enables extensions of traditional multiplicative, additive or fuzzy approaches. We review the approaches known from the literature, then we propose our new order preservation concept based on alpha-cuts. We define the concept of consistency of PC matrix with fuzzy elements (PCF matrices). We derive the necessary and sufficient conditions for strict consistency as well as weak and strong COP conditions and relationships. Finally, we deal with some consequences to the problem of ranking the alternatives. Illustrating examples are presented and discussed.

2 - Some fuzzy location and connection models

Karel Zimmermann, Martin Gavalec

Mathematical models using fuzzy set theory are proposed, which are based on combinations of different T-norms to satisfy requirements concerning quality characteristics of location or connection between supply and demand points (e.g. capacity, average speed or time of transport, ecological influence). We consider a finite number of supply points, which serve a finite number of demand points. Each supply point is located on a road connecting two exits to main streets leading directly to the demand points. The requirements are expressed as inequality systems, which must be satisfied by the membership function values to ensure required quality properties of the connections. Existence of solutions of such inequality systems as well as optimization problems with constraints expressed by such systems is studied. Effective solution methods will be proposed.

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3 - On scale normalization in pairwise comparisons
Jiri Mazurek

Perhaps the most known scale for pairwise comparisons is Saaty's fundamental scale from 1 to 9 (with reciprocals), but other scales (S), for example with 3, 5, or 10 items, are also possible. Usually, denotes the degree of importance (preference) between two objects i and j. However, it is demonstrated that the scale itself is also important, though some well known pairwise comparisons frameworks, such as the analytic hierarchy process (AHP), are scale invariant. If, for example, , then its meaning for the scale and the scale is different. In the former case, the preference means medium preference of the object i to the object j, while in the latter case the preference is almost negligible. Therefore, the need of scale normalization arises. The aim of the article is to discuss some suitable transformations of a general scale for pairwise comparisons to interval along with their properties.

4 - Coordination of fuzzy processes working in regular stages
Martin Gavalec, Daniela Ponce, Karel Zimmermann

Mathematical models are proposed, which are based on combinations of different t-norms to satisfy requirements of processes working in regular stages, and on algebraic models of their interactive work. The coordination of the processes is often required in production, transport, economic and social processes, like job-shop scheduling, as well as in some problems of the fuzzy set theory. These lead to systems of (max,+)-linear and (min,+)-linear equations or inequalities. Other similar systems use linear operations (max,T) with a fuzzy t-norm T. The activities in the model may be related to transporting passengers, delivering goods, machine processing of products and others. Each activity is characterized by computing an optimality interval. Finding the solution can be an NP-hard problem. Specific cases in which the problem is polynomially solvable are described.

Support of the Czech Science Foundation GAČR 18-01246S is gratefully acknowledged.

■ MD-13

Monday, 14:30-16:00 - SOUTH BUILDING UV S201

Supply Chain Scheduling

Stream: Supply Chain Management II
Chair: *Lina Simeonova*

1 - Cuckoo search for integrating machine scheduling and vehicle routing
Ting-Jhao Jian, Bailu Fang, Gen-han Wu

In this study, we focus on solving the integrating problem of parallel machine scheduling and vehicle routing with the objective of minimizing the total weighted tardiness time. We coordinate the production sequence in identical parallel machines and delivery routes in identical vehicles simultaneously after accepting the customers' order requests. Both of the cuckoo search and particle swarm optimization algorithm are developed to find the optimal solution. In order to intensify the capability of cuckoo search, cuckoo search and particle swarm optimization algorithm into variable neighborhood search and compare their solving effects. In experimental analysis, two hybrid meta heuristics including cuckoo search hybrid with variable neighborhood searches and particle swarm optimization algorithms embedded with the proposed variable neighborhood searches are implemented to obtain their solving effects in different sizes of problems. The numerical results show that the embedded particle swarm optimization algorithm can obtain better objective values.

2 - Definition of a new flow graph to model the constraints of a VRPPD in the RCPSPR
Marina Vinot, Philippe Lacomme

The RCPSPR (RCPSP with Routing) is an extension of the RCPSP (Resource-Constrained Project Scheduling Problem) where resources must be transported from one activity to another using a vehicle. This problem deals with two interrelated problems, a scheduling problem (RCPSP) and a routing problem (Vehicle Routing Problem with Pickup and Delivery - VRPPD), and belongs to the family of integrated problems. The RCPSPR is solved by Lacomme et al. in 2017 using a resource flow, inspired by Artigues et al. in 2003. The definition of a resource flow permits to identify the transportation operations, and to obtain a solution of the RCPSPR with an evaluation function. In the resource flow proposed by Lacomme et al. in 2017, modelled by a graph flow, the unit-capacity vehicles are not allowed to transport an amount of resource exceeding the demand of the destination activity. A new graph flow is proposed in this paper, in order to extend the routing problem, by allowing the vehicles to transport an amount of resource exceeding the demand of the destination activity with multiple-capacity vehicles. The extra resources transported can either be delivered and stored on the activity or kept in the vehicle to be delivered in another activity. This new model is evaluated with numerical experimentations, based on a mixed integer linear programming solved with CPLEX. The new solutions of the RCPSPR prove that the makespan can be significantly reduced, by avoiding costly transportation operations.

3 - Paint shop scheduling in the automotive supply industry
Felix Winter, Emir Demirović, Nysret Musliu, Christoph Mrkvicka

We formulate and present a production scheduling problem that appears in paint shops of the automotive supply industry. The goal is to find an optimized schedule for the painting of a large number of different synthetic material pieces that will later be used as assembly parts during car manufacturing. During the process of painting, the demanded pieces will be placed on special made carrier devices which automatically move through the paint shop on a system of conveyer belts and pass by multiple cabins that will then apply layers of paint onto the pieces. Finding a good painting schedule therefore includes the determination of an efficient distribution of the demanded pieces onto the carrier devices and deciding on an optimized production sequence. Thereby, the main optimization objective is to minimize the setup costs that are caused by color and carrier changes that appear within the painting sequence. We formulate the problem mathematically and also propose heuristic solution strategies. Furthermore, we provide a collection of instances and evaluate the results produced with the proposed solution methods. Affiliation: Christian Doppler Laboratory for Artificial Intelligence and Optimization for Planning and Scheduling, TU Wien Acknowledgements: The financial support by the Austrian Federal Ministry for Digital and Economic Affairs and the National Foundation for Research, Technology and Development is gratefully acknowledged.

4 - An integrated mixed method approach for decision making in a multi-facility supply chain: a real life case from the UK steel industry
Lina Simeonova, Niaz Wassan, Said Salhi

This research presents an integrated unified approach to Supply Chain Management applied to the case of the largest steel stockholder in the UK. The purpose is to identify the most efficient and effective Supply Chain Route to satisfying customers' orders. In a multi-facility setting, making informed decisions about which facility to supply the raw materials from, where to process the order and where to deliver the order from, is paramount for minimising inefficiencies, multiple material handling and the overall cost of production. We utilise some Lean tools to identify the value added activities in the company's supply chain and then we estimate all costs associated with them using Activity Based Costing. Once all activities and their relevant costs are estimated we determine the optimal route along the internal supply chain for satisfying individual customer orders. We apply our heuristic method with three different objectives, namely minimise cost, minimise time and minimise material handling. Implementing this methodology shows significant savings for the company and it also revealed the true operational cost associated with each order and a clearer representation of the true profit margin. We share some interesting managerial insights and practical implications for an efficient and leaner Supply Chain Management.

■ MD-14

Monday, 14:30-16:00 - SOUTH BUILDING UV S202

Methods for Large-Scale Optimization Problems

Stream: Nonlinear Programming: Methods
Chair: *Zaikun Zhang*

1 - A parallelizable algorithm for orthogonally constrained optimization problems
Xin Liu

To construct a parallel approach for solving orthogonally constrained optimization problems is usually regarded as an extremely difficult mission, due to the low scalability of orthogonalization procedure. In this talk, we propose an infeasible algorithm for solving optimization problems with orthogonality constraints, in which orthogonalization is no longer needed at each iteration, and hence the algorithm can be parallelized. We also establish a global subsequence convergence and a worst-case complexity for our proposed algorithm. Numerical experiments illustrate that the new algorithm attains a good performance and a high scalability in solving discretized Kohn-Sham total energy minimization problems.

2 - A Levenberg-Marquardt method for large nonlinear least-squares problems with dynamic accuracy in functions and gradients
Elisa Riccietti, Stefania Bellavia, Serge Gratton

Nonlinear least squares problems arise in many applications. We consider the case of large scale nonlinear least-squares problems for which function and gradient are evaluated with dynamic accuracy and propose a Levenberg-Marquardt method for solving such problems. More precisely, we consider the case in which the exact function to optimize is not available or its evaluation is computationally demanding, but approximations of it are available at any prescribed accuracy level. The proposed method relies on a control of the accuracy level, and imposes an improvement of function approximations when the accuracy is detected to be too low to proceed with the optimization process. We show numerical results on test problems arising in data assimilation and machine learning.

3 - Accelerated Regularized Newton Methods for minimizing composite convex functions
Geovani Grapiglia, Yurii Nesterov

In this talk, we present accelerated Regularized Newton Methods for minimizing objectives formed as a sum of two functions: one is convex and twice differentiable with Holder-continuous Hessian, and the other is a simple closed convex function. For the case in which the Holder parameter "v" is known we propose methods with iteration complexity of epsilon to the power minus 1/(2+v) to reduce the functional residual below a given precision epsilon. For the general case, in which the parameter "v" is not known, we propose a universal method that ensures the same precision with iteration complexity of epsilon to the power minus 2/3(1+v).

4 - A space transformation framework for nonlinear optimization
Zaikun Zhang, Serge Gratton, Luis Nunes Vicente

We present a space transformation framework for nonlinear optimization. Instead of tackling the problem in the original space, each iteration of this framework seeks for a trial step by modeling and approximately solving the optimization problem in another space. We establish the global convergence and worst case iteration complexity of the framework. We show that the framework can be specialized to a parallel space decomposition framework for nonlinear optimization, which can be regarded as an extension of the domain decomposition method for PDEs. A feature of the decomposition framework is that it incorporates the restricted additive Schwarz methodology into the synchronization phase of the method. It can be applied to design parallel algorithms for optimization problems with or without derivatives.

This is a joint work with Serge Gratton (IRIT-ENSEEIHT, France) and Luis Nunes Vicente (University of Coimbra, Portugal).

■ MD-15

Monday, 14:30-16:00 - SOUTH BUILDING UV S203

Recent Enhancements in Vehicle Routing

Stream: Vehicle Routing and Logistics Optimization II
Chair: *Luís Gouveia*

1 - Determining the best changes in time windows for vehicle routing problems in a city area
Corrinne Luteyn, Pieter Vansteenwegen

In this research, we investigate the possible savings that can be obtained when a delivery company has the ability to discuss possible changes in time windows with their customers. By tuning the time windows of customers, which are closely located to each other, the delivery company can save transportation costs. However, if the company changes some of the time windows, it might loose some goodwill by its customers. Therefore, we present a new variant of the Vehicle Routing Problem with Time Windows (VRPTW), namely the Vehicle Routing Problem with Changing Time Windows (VRPCTW). The objective of this new problem is to determine the best fixed number of time windows changes, such that all customers are served at minimal total transportation cost. In this problem, a difference is made between large changes and small changes. By a large change, the time window of a customer is shifted to another part of the day, while by a small change, the time window is only shifted for a small number of time units. To determine good candidates for a large change in the time window, the customers are clustered. Next, the time windows of the customers within a cluster are tuned to each other. For the case of small changes, a VRPTW with soft time windows is used to determine good candidates. Preliminary results show that by changing only a small number of time windows, the total transportation costs for the vehicles can be decreased by around 3%.

2 - A practical pickup and delivery problem with transfers and time windows
Onur Can Saka, Sibel Salman

The problem we study originates from a complex real-life routing problem faced by a third-party logistics firm, and involves pickup and delivery orders with time windows and cross-docking opportunities causing synchronization requirements. The routes should have specific multi-echelon structures with limited number of stops and length due to practical issues. The vehicle fleet consists of heterogeneous spot-hired vehicles. The objective is to find a minimum cost assignment of orders to feasible route-vehicle pairs while maintaining synchronization. We present an exact mixed-integer linear programming (MILP) model together with a customized route construction algorithm for this problem. A decomposition-based iterative matheuristic algorithm is proposed for solving large instances. We also consider an extended version of the problem, where additionally a limited number of dedicated vehicles are available at lower costs. We propose a two-phase approach for this second problem. The routes obtained in the first phase are re-scheduled in the second phase by replacing the spot vehicles with dedicated ones to maximize savings via an MILP solution. We compare the results of the matheuristic and the MILP model on small instances of the first problem and present the two-phase matheuristic's results on large instances of both problems using the company's data.

3 - The robust vehicle routing problem with time windows: compact model and branch-price-and-cut method
Pedro Munari, Alfredo Moreno, Jonathan De La Vega, Douglas Alem, Jacek Gondzio, Reinaldo Morabito

We address the vehicle routing problem with time windows via robust optimization, considering that customer demands and travel times are uncertain and belong to budgeted uncertainty sets. We propose two different approaches to effectively solve this problem: a compact mixed-integer programming model and a branch-price-and-cut method. The compact model is a robust counterpart obtained by incorporating dynamic programming recursive equations into a standard deterministic formulation. This is a novel strategy that does not require the use of the classical dualization scheme typically applied in robust optimization. The branch-price-and-cut method is based on a set partitioning formulation of the problem and relies on a robust resource constrained elementary shortest path problem to generate routes that are robust regarding both demands and travel times. Computational experiments using Solomons's instances show that the proposed approaches can obtain robust solutions within a reasonable running time, even when for large values of budgets of uncertainty and deviations. The results of an extensive Monte Carlo simulation indicate the relevance of robust routes for a more reliable decision-making process in real-life settings.

4 - A new formulation for the Hamiltonian p-median problem
Luís Gouveia, Tolga Bektas, Daniel Santos

This paper concerns the Hamiltonian p-median problem defined on a directed graph, which consists of finding p mutually disjoint circuits of minimum total cost, such that each node of the graph is included in one of the circuits. Earlier formulations are based on viewing the problem as resulting from the intersection of two subproblems. The first subproblem states that at most p circuits are required, that are usually modelled by using subtour elimination constraints known from the traveling salesman problem. The second subproblem states that at least p circuits are required, for which this paper makes an explicit connection to the so-called path elimination constraints that arise in multi-depot/location-routing problems. A new extended formulation is proposed that builds on this connection, that allows the derivation of a stronger set of subtour elimination constraints for the first subproblem, and implies a stronger set of path elimination constraints for the second subproblem. The paper describes separation routines for the two sets of constraints that are used in a branch-and-cut algorithm to solve asymmetric instances with up to 150 nodes and symmetric instances with up to 100 nodes using the new formulation.

■ MD-16

Monday, 14:30-16:00 - SOUTH BUILDING UV S115

Robust Optimization

Stream: Network Optimization and Social Networks
Chair: *Robert Manger*

1 - Design of water usage and treatment networks: an adaptive discretization approach
Sascha Kuhnke, Arie Koster

In industrial plants, water is extensively used in many different processes. Due to scarcity of suitable industrial water, effective wastewater treatment and water reuse is essential. This motivates the design of water usage and treatment networks. In such networks, water using units have to be supplied with clean water and environmental regulations for wastewater have to be met. To remove contaminants from the water, wastewater treatment units can be installed and operated. The objective is to simultaneously optimize the structure and water allocation of the network at minimum total cost. Due to many bilinear mass balance constraints, this problem is a nonconvex mixed integer nonlinear program (MINLP) where nonlinear solvers have difficulties to find feasible solutions for real world instances.

In this talk, we present a problem specific algorithm to iteratively solve this MINLP. In each iteration, a feasible MINLP solution is computed via an interaction of a mixed integer linear program (MILP) and a quadratically constrained program (QCP). First, we solve an MILP which approximates the original MINLP via discretization to obtain a suitable network structure. Then, by fixing this structure, we obtain a QCP which provides feasible MINLP solutions. To generate more accurate structures, the discretization of the MILP is adapted after each iteration. In many cases where nonlinear solvers fail, our approach leads to feasible solutions of good quality in short running time.

2 - A robust optimization approach to solve the multi-hub express shipment service problem network design problem
Jose Miguel Quesada, Jean-Charles Lange, Jean-Sébastien Tancrez

The premium service of express integrators is the overnight delivery of packages within regions as large as Europe. Designing an efficient network of flights to support such service is a task known as the Express Shipment Service Network Design problem (ESSND). Normally, when the ESSND problem is modeled, the time frame considers one day of operations, using the expected commodity demands for that period as input. Then, the resulting operations plan will be repeated every day for months. However, the literature does not consider demand variabilities, while, in practice, the commodity demands change every day. With certain frequency, some peak commodity demands prevent the express integrators to deliver all the packages on time, which is costly and affects negatively the customers' perception. In this work, we propose a robust model for solving the tactical ESSND problem with demand uncertainty. Based on the Light Robustness approach, we develop a model that maximizes the demand uncertainty that can be absorbed with a specific budget, while ensuring a minimum service level for each commodity. By solving a set of experiments on realistic instances, we evaluate how much our model can reduce the unmet demand caused by the demand variability, compared to a deterministic approach.

3 - Robust operational planning for mobile medical units
Martin Comis, Christina Büsing

Demographic change poses a great challenge to medical care in rural areas: A decreasing number of general practitioners have to care for an aging population with increasing needs. To close this gap in German healthcare provision, associations of statutory health insurance physicians pursue the operation of mobile medical units (MMU).

Mobile medical units provide local, demand-oriented, flexible healthcare in sparsely populated regions characteristic in rural settings. However, this requires a complex operational planning process combining facility location, routing and scheduling problems.

When designing optimization models for this planning process, it is essential to consider the uncertainty inherent to healthcare. We therefore discuss various concepts from robust optimization and show how they can be applied to MMU operational planning.

The resulting robust optimization models are compared with regard to performance and solution quality in a computational study. To assess the quality of solutions, we use an agent-based simulation feeded with data from a model region situated in the northern Eifel.

4 - Algebraic formulation and solution of robust path problems
Robert Manger, Ana Klobučar

Path problems in graphs deal with finding shortest paths, most-reliable paths, paths of maximum capacity, etc. It is well known that various types of such problems can be treated together within a common algebraic framework. Then, each type is characterized by a different "path algebra", i.e. a different instance of the same abstract algebraic structure.

In this work, robust variants of path problems are considered, where arc lengths, reliabilities or capacities are uncertain and expressed through explicitly given scenarios. It is demonstrated that the common algebraic framework, although originally intended for conventional problem variants, can be extended to cover robust variants. Consequently, this work is mainly concerned with constructing new path algebras that correspond to robust path problems. Such algebras are relatively complex, and they incorporate algebras associated with conventional problems as their building blocks.

A benefit of the obtained algebraic formulation is that robust path problems can be solved by well-known general algorithms designed to work over an arbitrary path algebra (e.g. analogues of Gaussian elimination). Indeed, the same algorithms that are used for conventional problems can as well be used for robust problems, although individual algebraic operations within those algorithms are in the robust case more complex. The resulting robust solutions are represented as sets of vectors that are efficient in the Pareto sense.

■ MD-17

Monday, 14:30-16:00 - SOUTH BUILDING UV S205

Stochastic Optimization in Energy and Environmental Management

Stream: Stochastic and Robust Optimization
Chair: *Patrick O'Driscoll*

1 - Meeting corporate renewable power targets
Alessio Trivella, Danial Mohseni-Taheri, Selvaprabu Nadarajah

Large companies have recently started to incorporate renewable energy standards in their corporate sustainability goals. In particular, several companies have committed to procure a specific percentage of their electricity demand from renewable sources, i.e., reach a renewable power target by a future date. Dominant corporate procurement strategies include (i) buying power from the spot market and supplementing it with renewable energy certificates (RECs) and (ii) entering long-term bilateral contracts known as power purchase agreements (PPAs) to buy power directly from a renewable generator. Constructing a multi-period procurement portfolio containing these buying options is complex due to stochastic power demand as well as volatile power and RECs prices. In this work, we study how to set up a power sourcing policy to reach a renewable target and sustain it at minimum expected cost. We provide analytical insights on stylized models containing a few periods. We also formulate a multi-period Markov decision process (MDP) that incorporates a PPA pricing model consistent with practice. This MDP has high-dimensional endogenous and exogenous components in its state and is thus intractable. We overcome this intractability by developing a heuristic policy based on a new dual reoptimization scheme that relies on information relaxations. We find that our dual reoptimization approach outperforms commonly used primal reoptimization methods and simple heuristics on realistic instances.

2 - Multistage stochastic programs in waste management
Dusan Hrabec, Pavel Popela, Radovan Šomplák

This work presents a new modelling approach based on scenario-based multistage stochastic programs for supporting strategic decision-making in the important application area of municipal solid waste management. The key modelling idea is to apply modern principle ideas of so-called circular economy to the complex waste management problem, where the primary goal tends to reduction of waste produced. The generated waste should be preferably recycled as much as possible and the resultant residual waste might be used for energy recovery. Only some waste residues are appropriate for landfilling. The aim is to propose the optimal waste allocation for its suitable processing and also find an optimal waste transportation plan at an operational level. In addition, the key strategical decisions about location of waste treatment facilities must be made within the considered time periods to support waste recycling. Since waste production is very often hard to predict and control, the formulated optimization model considers the waste production as a stochastic quantity. The model, data, and algorithm implementation are presented and discussed. The conclusions show that the presented approach is applicable to the area of waste treatment infrastructure planning and also to operational decision making.

3 - Optimizing environmental water release decisions in river systems
Simranjit Kaur, Avril Horne, Alysson Costa, Rory Nathan, Joanna Szemis

Ecological health of many rivers across the world have declined due to the increase in extraction of water to meet human demands. One strategy to restore river ecosystems is the allocation of a limited volume of water to the environment that can be released from various reservoirs into the river. Environmental water release decisions around volume, location and timing must be planned under the future climate uncertainty. In this talk, we present a mixed integer programming based stochastic model that optimizes the environmental watering decisions for the current month while considering uncertainty in the future climatic conditions over a forecasting period. A dynamic rolling time horizon approach is used that incorporates the updated forecasts at each month of the planning period and the decisions made so far. The Yarra river system in Australia is used as a case study to demonstrate the efficacy of the proposed approach.

4 - A multi-period valuation of a topping oil refinery
Patrick O'Driscoll

Refineries are facing an increasingly difficult economic climate. This paper examines a valuation problem faced by an oil refinery owner, who, over the lifetime of the real asset is constrained by mass balance and resource constraints. By constructing a multi-period linear program with relevant constraints, we develop a numerical procedure which obtains a valuation in a reasonable amount of time despite the colossal state space under complex physical and computational constraints. All refined product commodity price series are captured with stochastic mean reverting equations, and the unique method presented enables a realistic and dynamically consistent optimisation to be solved.

■ MD-18

Monday, 14:30-16:00 - SOUTH BUILDING UV S206

Financial Modeling and Risk Management

Stream: Decision Making Modeling and Risk Assessment in the Financial Sector
Chair: *Markku Kallio*

1 - Mean-risk optimal portfolio in a behavioral framework
Cristinca Fulga

We present an integrated methodological approach for selecting portfolios. The proposed methodology is focused on incorporation of investor's preferences in the Mean-Risk framework. We propose a risk measure calculated with the downside part of the portfolio return distribution which, we argue, captures better the practical behavior of the loss-averse investor. We establish its properties, study the link with stochastic dominance criteria, point out the relations with Conditional Value at Risk and Lower Partial Moment of first order, and give the explicit formula for the case of scenario-based portfolio optimization. The proposed methodology involves two stages: firstly, the investment opportunity set (efficient frontier) is determined, and secondly, one single preferred efficient portfolio is selected, namely the one having the highest Expected Utility value. Three classes of utility functions with loss aversion corresponding to three types of investors are considered. The empirical study is targeted on assessing the differences between the efficient frontier of the proposed model and the classical Mean-Variance, Mean-CVaR and Mean-LPM1 frontiers. We firstly analyze the loss of welfare incurred by using another model instead of the proposed one and measure the corresponding gain/loss of utility. Secondly, we assess how much the portfolios really differ in terms of their compositions using a dissimilarity index based on the l1 norm.

2 - Rational irrationality: how 'predictable' are investors during financial instabilities?
Mohammad Emambocus, Gurjeet Dhesi, Babar Syed

Abstract High market optimism and/or pessimism generate so-called irrational reactions influencing investors' aptitude to deal and process information available in the market. In this paper, we argue that emotional reactions of investors under situations of level of uncertainty in the market create a systemic phenomenon where irrational behaviours start becoming "predictable". Hence, investors confronted with uncertainty will determine their decisions based on the worst-case scenario making them pessimistic. Likewise, situations of low market uncertainty, investors' decision-making abilities is influenced by a sense of optimism leading them to focus highly on good news available to them. Rational irrationality is shown to be determined where investors' main concerns is to produce high return or to limit losses for the company ignoring the consequences of their behaviours on the overall financial market. Appropriate data set case studies are examined to explain the behaviours of financial agents during these windows/periods of high fluctuations where decisions/choices are shown to be more predictable. Therefore, this paper provides predictability measures of the market during financial instability windows in contrast to periods of stability.

3 - Markowitz portfolio optimisation using homogeneous subsets
Elmira Mynbayeva, John Lamb

Markowitz portfolio optimisation tends to produce poorly diversified portfolios that perform poorly in practice. This problem has been called the 'Markowitz optimisation enigma.' We show that Markowitz portfolio optimisation can produce poor portfolios even when asset returns are normally distributed and there are no time-series effects present. This happens in the common case where the assets have large subsets with homogeneous mean returns: that is, where we can find subsets of assets with mean returns that are not significantly different from each other. More surprisingly, we also get poor portfolios when there are large subsets with homogeneous variances. We show, however, that there are cases where Markowitz optimisation performs well. We develop a technique that combines equal-weight allocation with Markowitz optimisation and compare it to pure Markowitz optimisation, equal-weight allocation and Michaud's bootstrapping of Markowitz

4 - Cooperative mitigation of contagion in financial networks
Markku Kallio, Aien Khabazian

Since the beginning of the financial crisis in 2007-2008, several mitigation policies have been considered in order to monitor and stabilize the financial system in the event of a shock. Unlike most commonly in the literature, in this paper we examine the financial network of systemically important banks as a cooperative game. Governments can act as facilitators enforcing incentives for banks to cooperate and prevent the escalation of a financial crisis. To determine the characteristic function of the cooperative game, we develop clearing payment models for alternative coalitions competing in the market and show that the proposed models have unanimously preferred equilibrium solutions satisfying the clearing conditions. As a solution concept, we use nucleolus which implies a possible subsidizing pattern among the banks. For a demonstration, we use major European banks and a scenario which is linked to the adverse economic scenario used in 2016 EU-wide stress testing.

■ MD-19

Monday, 14:30-16:00 - SOUTH BUILDING UV S207

Vector and Set-Valued Optimization IV

Stream: Vector- and Set-Valued Optimization
Chair: *Marcin Studniarski*

1 - Multiobjective approaches based on variable ordering structures for intensity problems in radiotherapy treatment
Thanh Tam Le

Recently, in many papers, intensity-modulated radiotherapy treatment problems are studied as multicriteria optimization problems with respect to a constant ordering cone. In these problems, the goal is to maximize the dose delivered to cancer tumor as well as to reduce side effects. However, from a practical perspective, it is more convenient to consider such problems with respect to a variable ordering structure. In this paper, we introduce an appropriate cone-valued mapping based on the goal of cancer treatment. We consider a mathematical formulation of beam intensity optimization equipped with this ordering structure. In addition, we investigate necessary optimality conditions for solutions of a vector-valued approximation problem with respect to a general ordering cone and the proposed variable ordering structure as well. Finally, we calculate in detail necessary optimality conditions for minimal solutions of the mathematical model of beam intensity optimization in radiotherapy treatment.

2 - Cooperative infrastructure and spectrum sharing in heterogeneous mobile networks
Mauro Passacantando, Lorela Cano, Antonio Capone, Giuliana Carello, Matteo Cesana

To accommodate the ever-growing traffic load and bandwidth demand generated by mobile users, mobile network operators (MNOs) need to frequently invest in high spectral efficiency technologies and increase their hold of spectrum resources; MNOs have then to weigh between building individual networks or entering into network and spectrum sharing agreements. We address here the problem of radio access network and spectrum sharing in 4G mobile networks by focusing on a case when multiple MNOs plan to deploy small cell base stations in a geographical area in order to upgrade their existing network infrastructure.We propose two cooperative game models (with and without transferable utility) to address the proposed problem: for given network (user throughput, MNO market, and spectrum shares) and economic (coalition cost and mobile data pricing model) settings, the proposed models output a cost division policy that guarantees coalition (sharing agreement) stability.

3 - On approximate efficiency for nondifferentiable robust multiobjective optimization problems
Tadeusz Antczak

Robust optimization is an important area of optimization that deals with uncertainty in the data of optimization problems. In our considerations, an uncertain nondifferentiable multiobjective programming problem in the face of data uncertainty in the objective and constraints functions is considered. The robust optimization approach (worst-case approach) for finding approximate efficient solutions of the associated robust vector optimization problem defined for the considered uncertain multiobjective programming problem as a robust (worst-case) counterpart is used. Both necessary and sufficient optimality conditions for a feasible solution to be an approximate efficient solution of the robust vector optimization problem are established. In order to prove this result, a scalarization method is also used. Thus, the equivalence between an approximate efficient solution of the robust vector optimization problem and an approximate solution of its associated scalar optimization problem constructed in the used scalarization method is also established.

4 - Necessary and sufficient conditions for robust Q-minimal solutions in uncertain vector optimization
Marcin Studniarski, Anna Michalak

In many optimization problems one has to deal with some uncertainty of the data. Mathematically, this can be described by an additional set of parameters which influence either the objective function and/or the constraints of the problem. The exact value of this parameter is not known at the moment of decision, but it can be assumed that the parameter values lie in a given uncertainty set. The theory of uncertain optimization (also called robust optimization) for multiobjective problems is a relatively new direction of research. One possible approach to uncertain multiobjective optimization is to interpret an uncertain optimization problem as a special set-valued optimization problem, and then apply the methods of set-valued analysis. We follow this approach and use some kinds of directional derivatives of set-valued mappings to obtain necessary and sufficient optimality conditions for Q-minimal solutions of an uncertain vector optimization problem. Some illustrating examples are included.

■ MD-20

Monday, 14:30-16:00 - SOUTH BUILDING UV S301

Decision Analytical Perspectives on Societal Challenges

Stream: Decision Analysis and Decision Support Systems
Chair: *Juuso Liesiö*

1 - Implications of world mega trends for decision analysis/decision support research
Hannele Wallenius, Jyrki Wallenius

Digital technology is making rapid advances. The implications for people, companies, and societies are pervasive. The envisioned changes will bring about: (1) digital connectivity, independent of time and place, and (2) tools for quickly analyzing vast amounts of digital data. In the recent World Economic Forum's report, the changes are grouped into six "mega-trends".

1 The Internet - world's access to the Internet will continue improving; people's interaction with it will become more ubiquitous 2 Further enhancements in computing power, communications technologies, and data storage 3 The "Internet of Things" 4 Big data and Artificial Intelligence - the ability to access and analyze huge amounts of data; coupled with the 'ability' of computers to make decisions based on this data 5 The sharing (or platform) economy and distributed 6 3D-printing

These trends will greatly impact our lives, businesses, and governments - even universities - all around the world. Our lives are increasingly being driven and enabled by algorithms and software. The envisioned changes will be so profound and rapid that large segments of societies have difficulty in keeping up with the developments as users of technology.

We overview the mega trends transforming the world. We choose several of technical and other trends, which are of interest from the Decision Analysis/Decision Support perspective, for a closer look. We discuss, what role our field could play in this revolution.

2 - Decision analysis and political processes
Nikolaos Argyris, Simon French

Decision analysis has been with us for at least half a century. Over that time it has developed from a theoretical paradigm for individual rational choice to a practical tool for individuals, small groups and 'unitary' organisations, which helps them towards a sound decision-making mindful of the behavioural characteristics of individuals and group dynamics. Decision analysis has also shown its worth in the context of stakeholder engagement and public participation. The time is right for it to be more widely used in making societal decisions. However, to achieve that we need to realise that in many circumstances it will only be one input to the political process that leads to the actual decision. Recognising that suggests that our community of decision analysts needs to deconstruct our paradigm and attend more to communicating the result of the analysis in comparison with other inputs to the societal decision.

3 - Just society: a decision theoretic perspective
Rakesh Sarin

I will explore the structure of a just society from a decision theoretic perspective. I will compare this formulation with the utilitarian approach and Rawl's maximin approach. The main result is that a rational person should choose the structure of a society where a minimum essential level for living a dignified life is met and beyond which everyone maximizes their personal expected utility.

4 - A collaborative expert system for decision support in public policy
Matthias Wildemeersch, Elena Rovenskaya, Leena Ilmola

In the policy arena, there is high pressure to provide right and quick decisions for problems that are often poorly defined. For that reason there is a persistent need to support stakeholders in establishing a shared understanding of policy problems and to assist them in the design of solution paths. Here we propose a methodology based on the construction and analysis of system maps, i.e., graphical representations of the complex interdependencies of all relevant factors that affect the problem under study. Owing to their collaborative design, system maps provide a transparent tool with broad stakeholder acceptance for analysis of ill-defined problems in a formal way. The final target is to assist decision-makers at each step of the decision-making process through the construction and analysis of system maps: i.e., from the understanding of the system behavior, through the listing of objectives and constraints, to the presentation of feasible solutions that are satisfactory over a range of different plausible scenarios. System maps provide us with an effective framework to collect information dispersed over experts, facilitate mediation, and analyze potential pathways, meeting predefined criteria of robustness. We illustrate the methodology by means of a case study on the recent refugee crisis. This case study was developed in collaboration with several Finnish ministries and a government agency responsible for immigration procedures.

■ MD-21

Monday, 14:30-16:00 - SOUTH BUILDING UV S303

Workforce Scheduling and Line Balancing III

Stream: Project Management and Scheduling
Chair: *Evgeny Gurevsky*

1 - Real-time personnel re-scheduling after a minor disruption
Rachid Hassani, Issmail El Hallaoui, Guy Desaulniers

This talk is about a real-time optimization method to adapt a pre-set schedule after a small disruption that can result from delay or absence of employees. The method should propose, in a relatively short time, sequences of decisions leading to solutions close to the current schedule (known as non-dominated policies), while minimizing the costs and the number of modifications to be performed. To find these policies, our method used a probabilistic network.

2 - Bi-objective assembly line rebalancing problem with equipment assignment
Selin Özpeynirci, Elif Simsek

In this study, a bi-objective assembly line rebalancing problem with equipment assignment is considered. We are given assignment of tasks to workstations with required tools and a balanced assembly line. Any disruption in one or more workstations makes the current solution infeasible. The tasks must be reassigned to the remaining workstations with required equipment. We may need to purchase new equipment if the required equipment of some tasks do not exist on the workstations they are assigned to. We consider two objectives while rebalancing the assembly line: minimizing cycle time and minimizing cost of purchasing new equipment. The aim of this study is to generate efficient solutions and determine the most preferred solution. All nondominated objective vectors are generated using two methods: Traditional Epsilon-Constraint Method and Augmented Epsilon-Constraint Method. An algorithm that works interactively with the decision maker is used to find the most preferred solution. Computational experiments are carried out in order to measure the performance of suggested methods and the solutions are reported.

3 - Reconfigurable transfer line balancing problem: exact and heuristic methods
Youssef Lahrichi

We are dealing in this paper with balancing reconfigurable transfer lines. The production lines involved can machine a single part category and could be seen as serial lines of workstations. In this context, reconfigurability is the ability of the transfer line to be rapidly and cost-effectively reconfigured to machine a new part category (1) (addressing shortening product lifecycle times) and to handle changing demand size (2). While (1) is guaranteed by the use of mono-spindle head machines equipped with tool magazines, (2) is guaranteed by the possibility to introduce several machines into workstations. Consequently, setup times between operations should be considered to perform tool change.

The problem consists into allocating the operations necessary to machine a part to the workstations and sequencing the operations into every workstation while respecting the cycle time constraint and minimizing the overall number of machines used.

The problem has been rarely dealt with in the literature and even fewer exact methods have been already suggested. We suggest and evaluate a MIP approach (that extends the one presented in Andr'es et al. (2008)), a novel meta-heuristic and an efficient hybrid approach that approximates the optimal solution. The different approaches are experimentally tested on both benchmark and randomly generated instances.

4 - Set-partition versus set-cover formulations for column generation based solution methodologies for optimal crew scheduling in the airline industry
George Kozanidis, Odysseas Moschopoulos, Christos Kaimakamis

We consider column generation based solution methodologies utilized widely in the context of airline management for crew scheduling optimization. Such methodologies employ a master problem typically formulated as a set-partition model, which optimizes the total cost comprised of the cost of uncovered duties and of the crew-schedules quality cost. We propose alternatively the formulation of the master problem as a set-cover optimization model that purposely ignores the quality cost of the crew-schedules. This helps crew planners discover the optimal flight duty coverage much faster and subject to smaller margin of error, which is of utter importance in the airline industry. We transform the (possibly over-covering) set-cover solution into an equivalent set partition one using an optimization model that suitably removes flight duties from the existing crew-schedules so as to minimize the final quality cost while also retaining the optimal coverage. The fact that removing flight duties from a legal crew schedule does not ruin its legality nor the feasibility for the corresponding crew member justifies the correctness of this approach. We present experimental results from tests performed in realistic environments which demonstrate the comparative performance of the two alternative designs and we report the conditions under which each of them is more suitable.

■ MD-22
Monday, 14:30-16:00 - SOUTH BUILDING UV S304

Multicriteria Optimization for Portfolio and Subset Selection

Stream: Multiobjective Optimization
Chair: *Iryna Yevseyeva*

1 - Mean-variance Pareto front approximations with just a handful of Pareto optimal solutions
Janusz Miroforidis, Przemysław Juszczuk, Ignacy Kaliszewski, Dmitry Podkopaev

The Pareto front to the Markowitz mean-variance portfolio investment problem is the graph of a convex function. The fact that every convex combination of two feasible portfolios is a feasible portfolio can be used in deriving the mean-variance Pareto front approximations. However, the Pareto optimality status of the resulting portfolios is not known. The only Pareto front element known upfront is the portfolio composed in 100% of the asset of the maximal return. Following the rationale of the convex function approximation methods, we assume that a few portfolios of the Pareto front are known and we interpolate the space between them by their pairwise convex combinations which produce lower approximations of the Pareto front. We show that by replacing convex combinations by liner combinations of the Pareto front portfolios, we derive upper approximations of the Pareto front as well. In a sense, our approach is similar to so-called sandwich algorithms. However, our approach to the derivation of upper approximations relieves one from the necessity to make use derivative-type information, as requested in the original developments of sandwich algorithms, or solving series of optimization problems, as requested in extensions of sandwich algorithms for non-smooth functions (the Pareto front is a non-smooth graph). We investigate experimentally the accuracy of lower and upper approximations with mean-variance problems from Beasley OR Library.

2 - Multi-criteria based optimisation model for human resource planning in telecommunication operations
Zirui Feng, Grammatoula Papaioannou, Rupal Rana, Jiyin Liu, Anne Liret

As demonstrated by numerous recent events, telecommunication systems are often affected by extreme weather conditions, for example, floods, blizzards and thunderstorms. These extreme weather conditions can impact the telecommunication business and hence reducing the time of disruption while minimising the cost of recovery becomes crucial in this situation. This study addresses the human resource planning problem arising in the large telecommunication business context. Using demand forecast as an input, the task is to allocate different types of human resources, including doing overtime, borrowing engineers from other areas and utilising contractors over a chosen time horizon. The assignment is a global optimisation among a number of locations, each location has installation demand and a repair demand, where repair demand is dependent on customer care levels and job types. The planning process is affected by numerous constraints including different capacities of different areas and job skills, different time windows for different customer care levels, different productivities of different human resources, and regulations set by government. We present a multiple objective linear programming model that minimises the sum of wages, transportation costs, optional accommodation costs and possible compensation costs while minimising the time of bringing the business back to normal. The results show how human resource allocation process affects the recovery time and total cost.

3 - The R2 Indicator: a study of its expected improvement when used as a selection criterion
Andre Deutz

By a multi-objective optimization problem (MOP) – aka vector optimization problem – we mean the problem of simultaneously optimizing a finite set of real valued functions with a common domain.

The object of interest for multiobjective optimization is the so-called Pareto Front (PF).

The indicator based approach in solving multi-objective optimization problems has become very popular. Indicators are used, among others, to compare the quality of approximation sets to PFs produced by an algorithm or different algorithms.

Among the indicators used the R2 indicator attracted wide spread interest as it is relatively frugal in using computational resources as compared to other indicators.

We will study the expected improvement of this indicator given an approximation set to the PF and given the probability density function of a predictive distribution of objective function vectors. The emphimprovement of this indicator is defined as follows: the R2 indicator is evaluated on the given approximation set of the PF to which a point in the image of the feasible set is added, the R2 indicator is evaluated on the the given approximation set of the PF, subsequently from the former the latter is subtracted; the resulting difference is the R2-improvement of the chosen point with respect to the given approximation set. The emphexpected improvement is the mean of the improvement over the image of the feasible set with respect to the given pdf.

4 - Ranking of instructional videos based on flexible TOPSIS
Blanca Pérez-Gladish, Vicente Liern, Enrique Lopez, Cristina Mendaña

YouTube is the largest Internet video-sharing site in the world. The utility of the performance assessment and ranking of educational videos in this platform goes beyond the simple control of the correctness and precision of the instructional contents. It requires considering other important features as waste of time in the exposition, empathy with the user and the degree of adaptation of the contents to the educational context. In this paper a ranking method for instructional videos will be proposed, taking into account decision criteria of different nature: precise and imprecise and a reference solution. The decision matrix describing the assessment of videos with respect to each criterion will be formed by data of diverse nature: real numbers, intervals on the real line and/or linguistic or sets of categorical variables. Classical normalization procedures do not always take into account situations where the different nature of the data of the decision matrix could make the ranking of the alternatives unstable. A new normalization method will be proposed allowing mitigation of this problem. Through this normalization procedure, the nature of the transformed normalized data will reflect the similarity of each alternative with the reference solution becoming thus, the decision matrix of homogeneous nature.

■ MD-23

Monday, 14:30-16:00 - SOUTH BUILDING UV S305

Event Timetabling

Stream: Timetabling
Chair: *Sanja Petrovic*

1 - Euro conference scheduling: the problem is you!
Thomas Stidsen, Pieter Smet, Greet Vanden Berghe

Scheduling the sessions of the EURO-2018 conference is a complex problem, where more than 400 sessions have to be placed in rooms and timeslots. In this talk we will describe how EURO-2018 was planned, utilizing an approach, based on 5 different MIP models, previously employed at EURO-2015, EURO-2016 and IFORS-2017 but now updated for EURO-2018. The details for the approach for EURO-2016 is documented in our previous article "Scheduling EURO-k conferences", Stidsen et al, EJOR, 2017. In this talk we will present the improvements, which has focused on streamlining the scheduling process, making data-formats more accessible and making special requirements constraints easier to include. Furthermore, the models have been moved from GAMS to Julia. Furthermore, we will describe the problem of missing information: How can we schedule the sessions without specific knowledge about which sessions each conference attendee wants to attend? I.e. YOU are the problem! Getting detailed and reliable information about which talks the attendees are interested in, in time for the scheduling is difficult. Most attendees do not prepare which talks to go to, months ahead of the conference. This missing information is in our view the major problem, in order to get better EURO conference scheduling. Various options will be discussed.

2 - A planning tool for assigning proctors to university exams
Tino Henke, André Scholz, Gerhard Wäscher

During the examination phase at the end of each semester at the Faculty of Economics and Management of the Otto-von-Guericke-University Magdeburg, Germany, all exams are supervised by the scientific assistants working at the faculty. The assignment of proctors to exams is planned centrally in such a way that a sufficient number of personnel is assigned to each exam, preferences of the scientific assistants are respected, and further problem-specific constraints are taken into account. To solve this problem, a planning tool has been developed which is based on a mixed-integer programming model. Compared to the previous manual approach, the application of the developed tool during the last semesters allowed for reducing the planning effort as well as considering additional preferences. In this presentation, the underlying assignment problem and the planning tool will be presented, and experiences obtained from using this tool will be discussed.

3 - Exam scheduling at United States Military Academy West Point
Robin Schuchmann

Each term the United States Military Academy (USMA) West Point needs to schedule its exams. About 4500 cadets taking 5 to 8 exams each, need to be placed in 11 exam periods subject to several soft and hard constraints. Due to the short time frame in which the exams take place, a feasible solution in the sense that no cadet takes more than one exam per period cannot be obtained with a single exam version per course. So called makeups, alternative exams in another period, solve this problem. In order to reduce the extra work for instructors that must prepare those alternative exams, the number of makeups should be minimized. Makeups are also used to improve other objectives which occur at USMA West Point like the number of consecutive exams per cadet or to avoid that cadets take exams in certain periods (e.g. because of sport events they should attend). In this talk a decision support system for scheduling exams at USMA West Point is shown. The system consists of several heuristics and is based on a mathematical programming model. Local search methods are combined with classical integer linear programming approaches in order to find high quality solutions for this multi-objective optimization problem. The result of this work is a system implemented in GAMS which is able to create complete exam schedules in about 20 minutes of computation time to aid the process of creating the schedule for the term end exams.

4 - An integer programming formulation of aposteriori fuzzy MOLP and assessment of efficient solutions via DEA for a case study in course timetabling
Mustafa Mehmet Bayar, Murat Atan, Irmak Uzun-Bayar

This work is a Course Timetabling Problem conducted for the School of Economics and Administrative Sciences at the Gazi University in Turkey. The problem is dealt with aposteriori MODM method approach. The aposteriori MODM (or generation) methods necessitate additional criteria for the DM to be able to identify the "most preferred solution" among the efficient set (the set of all efficient or Pareto optimal solutions).

Here in this study, we propose the additional criterion of "tradeoff performance" between the multiple objectives of the fuzzy-MODM problem at hand. The efficient solutions are treated as the DMU's to be assessed and the multiple objectives are treated as the performance criteria.

A hybrid version of DEA & TOPSIS is presented in this study such that an artificial and ideal DMU added to the efficient set to identify a ranking of the DMU's.

■ MD-24

Monday, 14:30-16:00 - SOUTH BUILDING UV S306

Financial Mathematics and OR IV

Stream: Financial Mathematics and OR
Chair: *Betül Kalaycı*

1 - A neural network enhanced volatility component model
Jia Zhai, Yi Cao

Volatility modeling and forecasting are a central issue in financial econometrics. They also attract increasing attention in the computer science literature as advances in machine learning allow us to construct models that significantly improve the precision of volatility prediction. In this paper, we draw upon both strands of the literature and formulate a novel two-component model for volatility. The realised volatility is decomposed by a nonparametric filter into long- and short-run components with respect to the stationarity of the short term one. The two components, a non-linear smoothed long term trend and a stationary short term process, are then modelled by an artificial neural network and an ARMA process, respectively. We use intraday data on four major currency pairs to perform out-of-sample evaluation of volatility forecasts between our model and well-established alternative models. The empirical evidence shows that our neural network enhanced model outperforms other models across all metrics and over different horizons, substantiating the prowess of our proposed model in providing accurate volatility predictions. It also suggests that the volatility forecasts from our proposed model offer economic value to a mean-variance utility investor in terms of higher portfolio returns and Sharpe ratio.

2 - Time inconsistent stochastic differential game: theory and an example in insurance
Hong Mao

In this paper, a time-inconsistent model was established under stochastic differential game framework. The investment portfolio includes multi-risky assets, whose returns are assumed to be correlated in a time-varying manner and change cyclically. The claim losses of insurance companies and investment are also assumed to be correlated with each other. The Solution to extended HJBI equations results in the portion of retention and an optimal portfolio with equally weighted allocations of risky assets. An optimal control bound is proposed for monitoring and predicting the optimal wealth level. The proposed model is expected to be effective in making decision for investment and reinsurance strategies, controlling and predicting optimal wealth under uncertain environment. Especially, it can be applied easily in the situation of very high dimensional investment portfolio.

3 - Dynamic cash management models with loan opportunities
Zimian Zhang

Classical cash management models concern how an organisation should maintain their (liquid) cash balances in order to meet cash demands over time. In these models the balance can be increased or decreased to offset penalties for not being able to meet a cash demand or the opportunity cost of holding too much cash, respectively. The external source from which this money comes from or is sent to is not explicitly modelled but is assumed to be available at all times. In our work we seek to contribute to this problem by explicitly modelling this external source by the inclusion of a second asset. This asset will generate an income which we allow to be either deposited directly to the cash account or contributes to the asset account's volume. We model this version of the cash management problem, in which credits and debits from/to the cash balance are to/from the asset account and incur transaction costs for these movements, as a Markov decision process. The optimal policy is shown to be of a dynamic threshold type that extends the classical (d, D, U, u) type polices to this setting. The impact of the parameter settings on the optimal policy are studied in a large numerical study. We also extend this model to include the opportunity for the organisation to take out a loan to supplement their cash balance. The decision of whether to take out a loan or not makes the solution of this extended cash management problem computationally expensive. We propose a novel heuristic for the cas

4 - Mutual relevance of investor sentiment and finance by modeling coupled stochastic systems by using MARS
Betül Kalaycı, Ayse Özmen, Azar Karimov, Gerhard-Wilhelm Weber

Stochastic Differential Equations (SDEs) rapidly become a very well-known format to express mathematical models under uncertainty such as financial models, neural systems, behavioral and neural responses, human reactions and behaviors. In a financial system, different kinds of SDEs have been elaborated to model various financial assets. On the other hand, economists have conducted research on empirical phenomena regarding the behaviour of individual investors, e.g., how their emotions and opinions influence their decisions. All those expressions are described as "Sentiment". In finance, stochastic changes might occur according to investors' sentiment levels. We represent the mutual effects between a financial process and investors' sentiment, constructing a coupled system of non-autonomous SDEs. We approximate them by discretization and Multivariate Adaptive Regression Splines (MARS), a Big Data method for regression and classification with interactive variables; time is treated as another variable. We present an application with real-world data, and finish with a research outlook.

■ MD-25

Monday, 14:30-16:00 - SOUTH BUILDING UV S307

Graph Drawing

Stream: Combinatorial Optimization II
Chair: *Rafael Marti*

1 - Resolution of the robust buffer allocation problem using network flows
Pascal Wortel

The fluctuations that affect processing times of workpieces at different stages of a flow line in the manufacturing industry often mean a waste of time, either caused by blocking - the input flow is stopped as a stage is not yet available, or by starvation - a stage is idle as its input flow is interrupted. Buffering is a widely utilized technique to reduce the impact of these bottlenecks yet storage necessarily entails additional costs. A compromise between production rate and low costs is sought. This problem is known as the Buffer Allocation Problem (BAP). Different solution approaches have been derived for the BAP, all of which assume that the processing times of workpieces are known at each stage. However, flow lines are naturally subject to uncertainties. A buffer distribution that is optimal for a given sample may prove to be arbitrarily poor when the actual processing times are slightly different. We propose an algorithm that solves the BAP robustly; the solution guarantees feasibility and good quality for any realization of the processing times within a given uncertainty set. The problem of finding the minimal amount of buffers needed to achieve some required efficiency is formulated as an MIP. It is then broken down into a generative and an evaluative subproblems. We demonstrate how the time-consuming evaluative problem can be reduced to an efficiently solvable network flow problem. We give numerical results showing the efficiency of this approach.

2 - Non-crossings paths with geographic constraints
Rodrigo Silveira, Bettina Speckmann, Kevin Verbeek

A geographic network is a graph where each vertex must lie in a prescribed region in the plane. In this talk we will focus on a fundamental graph drawing problem for geographic networks: Can a given geographic network be drawn without crossings? We focus on the seemingly simple setting where each region is a unit length vertical segment, and one wants to connect pairs of segments with a path that lies inside the convex hull of the two segments. It turns out that answering the question above even in this simple case is NP-complete when paths must be drawn as straight line segments. However, we will see that when paths must be monotone curves, the question can be answered in polynomial time. In the more general case of paths that can have any shape, we show that the problem is polynomial under certain assumptions.

3 - Heuristics for the min-max arc crossing problem in graphs
Arild Hoff, Vicente Campos, Juanjo Peiró, Rafael Marti

We study the problem of reducing the number of arc crossings in a graph. This hard optimization problem has been studied extensively in the last decade, proposing many exact and heuristic methods to minimize the total number of arc crossings. However, despite its practical significance, the min-max variant in which the maximum number of crossings over all edges is minimized, has received very little attention. In fact, we are only aware of one article in which the problem was recently proposed together with an efficient heuristic to obtain high-quality solutions. We propose new heuristic methods based on the strategic oscillation methodology for this NP-hard problem. Our experimentation shows that the new method compares favorably with the existing ones on a set of previously reported instances in both objectives.

4 - Hybrid representations of graphs: complexity results and heuristics
Giuseppe Di Battista

In many applications there is the need to represent graphs that are globally sparse but contain dense subgraphs. As an example, a social network is often composed of communities. The members of the community are closely interlinked, while the different communities are connected by a network of relationships that is much less dense. These graphs can be represented with a hybrid drawing standard, where different conventions are used to represent the dense and the sparse parts of the graph. As an example, the dense parts can be represented by adjacency matrixes or by the intersection of geometric objects, while two adjacent dense parts may be connected by a curve. We survey the recent results in this field showing problems that are solvable in polynomial time and problems that are NP-complete. We also show heuristics that can be used to tackle some of the hard problems.

■ MD-26

Monday, 14:30-16:00 - SOUTH BUILDING UV S308

Railway Rapid Transit Systems Planning and Operation

Stream: Public Transportation I
Chair: *David Canca*
Chair: *Eva Barrena*

1 - Heuristic search for the most compact graph for train unit scheduling optimisation
Pedro Jesús Copado Méndez, Raymond S. K. Kwan

A hybrid approach for train unit scheduling optimization is presented here. An exact core solver has been derived using an integer multi-commodity flow model based on a Directed Acyclic Graph (DAG) and formulated as an integer linear programme. Our hybrid approach called Size Limited Iterative Method (SLIM) proceeds by improving a given reduced DAG with only the essential arcs of a feasible solution, which is called an "essential graph". The essential graph is augmented (resulted in an "augmented graph") by the re-insertion of a limited subset of arcs from the original DAG and then solved using the exact core-solver. The process is iterated heuristically in the generation of the augmented graphs. The essential arcs ensure that no-worse solutions would be yielded in each iteration. The heuristic approach for building augmented graphs supposes that it is possible to identify a meaningful group of arcs that might partake in the optimal solution. Such arc groups are produced in accordance with some selection of inward/outward locations, time intervals and solution flow paths. Then, in each iteration one or more of such groups are used in the augmentation process. Several designs of SLIM corresponding to different levels of randomness and multi-threading will be presented. The experiments on real-life instances show that some designs are competitive with the exact method in some instances, and it significantly outperforms the exact solver in some cases.

2 - Cost evaluation of minimizing energy consumption in railway rapid transit lines timetables
Alejandro Zarzo, David Canca

A methodology to design timetables with minimum energy consumption in Rapid Railway Transit Networks is presented. Using an empirical description of the train energy consumption as a function of running times, the timetable design problem is modelled as a Mixed Integer Non-Linear optimization problem (MINLP) for a complete two-way line. In doing so, all the services in both directions along a certain planning horizon are considered while attending a known passengers' demand. The MINLP formulation, which depends on train loads, is fully linearised supposing train loads are fixed. A sequential Mixed Integer Linear (MILP) solving procedure is then used to solve the timetabling optimization problem with unknown train loads. The proposed methodology emphasizes the need of considering all the services running during the planning horizon when designing energy-efficient timetables, as consequence of the relationship among train speeds, frequency and fleet size of each line. Moreover, the convenience of considering the energy consumption as part of a broad objective function that includes other relevant costs is pointed out. Otherwise, passengers and operators could face up to an increase in the whole cost and a decrease in the quality of service. A real data scenario, based on the C-2 Line of the Madrid Metropolitan Railways, is used to illustrate the proposed methodology.

3 - Static, time dependent and elastic passenger demand in railway timetabling
Eva Barrena, David Canca, Francisco A. Ortega Riejos

We study demand adapted railway timetables focusing on the influence of different passenger demand types in their design and optimization. The objective is to minimize the average passenger waiting time at the stations, which is highly influenced by the passenger demand pattern. Since passenger demand can be of different nature, we analyze the effect of different passenger demand considerations in the resulting train timetables. For that aim, we focus on static, time-dependent and elastic demand. The first considers a constant origin-destination matrix for the planning horizon and assumes that passenger arrive to stations at constant time intervals. The second considers a time dependent origin-destination matrix, whose elements are therefore a function of the time. The third considers that passengers arrive to stations with the intention of boarding a train, and choose an alternative transportation mode if the train delays more than a certain time. We discuss two mathematical programming formulations that generalize the non-periodic train timetabling problem on a single line when different demand patterns are considered. Since exact methods have their limitations to deal with real size instances, we also make use of metaheuristics based on the mathematical properties of the problem. Results show the effect of each of this demand considerations in the resulting timetable and the suitability of each of them according to the network properties.

4 - On solving the integrated network design and line planning problem with elastic demand
David Canca, Alicia De Los Santos Pineda, Gilbert Laporte, Juan A. Mesa

On this work we discuss two approaches for solving the Integrated Network Design and Line Planning Problem with the objective of maximizing the net profit along certain planning horizon in presence of a competing transportation mode. In both cases, due the relationship between the network design and the line operation decisions, for a given demand, a transit assignment has to be done in order to compute the net profit. The first approach uses an Adaptive Large Neighbourhood Search procedure with a local search algorithm to produce 0-1 assignments for a given network structure. The second one combines an Adaptive Large Neighbourhood Search algorithm with an exact Branch and Cut method to obtain real transit assignments at each iteration. The comparison of solutions and the performance of the proposed approaches are illustrated in a real-size scenario.

■ MD-27

Monday, 14:30-16:00 - SOUTH BUILDING UV S309

Facilities Planning and Design

Stream: Production, Service and Supply Chain Management
Chair: *Daniel Ramon Lumbierres*

1 - An algorithm for designing a hybrid layout
Ana Raquel Xambre

Most facilities present a combination of different types of layout systems such as process oriented, product oriented or cellular manufacturing systems, combining them according to their needs, specifically considering the production process, variety and volume of the products that they want to manufacture. The design of such systems is often done in an incremental way, accompanying the growth of the facilities and the increase and change in the demand. In this type of environment, usually there is no specific design of the facility layout, resulting in a production system organized in an inefficient manner. In this work the problem of designing a hybrid layout, specifically for the manufacturing of components, will be analysed. The idea is to develop a system that can accommodate different types of parts, with different processing requirements and different production volumes, identifying the ones that can be incorporated in a family and thus processed in a cell, and the ones that should continue to be processed in non-dedicated equipment. The objective is to improve the system efficiency by reducing transportation distances, reducing setups, increasing the usage rate of equipment, while maintaining some level of flexibility. These objectives and considerations are incorporated in the proposed algorithm.

2 - Optimal component compartmentalisation of process plants for modular construction
Timothy Haughton, Panagiotis Angeloudis, Panos Parpas

Off-site modular construction has been adopted widely in recent years, with most applications relating to residential and governmental buildings. As these initiatives mature and demonstrate their advantages, there has been increased interest in applications to more complex projects, notably process plants and nuclear power stations. Industrial plants have long attracted academic interest, given the complexity of their designs and the importance of developing safe and efficient facilities. Previous studies on the optimisation of process plant design explored methodologies based on the Facility Layout Problem (FLP). However, off-site modular construction fundamentally alters the optimisation problems relevant to process plant design. While optimising the plant layout remains important, it is insufficient, as components must also be grouped into modules to enable off-site construction. These problems are interdependent and must therefore be approached concurrently. In this study, the FLP is treated as a special case of the wider Plant Modularisation Problem (PMP) where a single module encompasses all components. A more general case of the PMP is formulated by introducing more modules, into which components are grouped. This approach makes the model more applicable to real world design decisions. This study develops a mathematical formulation of the PMP, accompanied by an initial solution methodology. The proposed methodology is applied and demonstrated with a case study.

3 - Applying heuristic techniques for the combined design and scheduling of multiple lines multiproduct batch plants
Floor Verbiest, Trijntje Cornelissens, Johan Springael, Tânia Pinto_Varela, Ana Barbosa-Povoa

In multiproduct batch plants, multiple products with similar recipes are produced by sharing available resources. Due to the operational flexibility of such plants, their design is a challenging task. Moreover, to better incorporate the operational use of such type of plants, production scheduling should be included. Hence, this study explores the strategic design and scheduling of chemical batch plants, equipped with parallel production lines. The aim of this work is to minimize capital and operating costs by optimizing several decisions: number of lines to install, their design, i.e. number and size of equipment units at every stage, and a process schedule to achieve the production requirements. The latter means that for every product one has to decide, not only, which proportion of the total demand is produced on every line, but also, what the related number, size, and timings of batches are on each line. A modelling framework often used for the integrated design and scheduling problem is the so called network formulation, which is usually solved exactly. However, due to the complex and different types of decisions, a rapid increase in computational complexity arises and the problem becomes intractable for exact solution approaches. Hence, we present a preliminary version of a decomposition heuristic solution approach developed for the combined design and scheduling problem.

4 - A multistage stochastic programming model for the strategic supply chain design
Daniel Ramon Lumbierres, F.-Javier Heredia

Supply chain management has been widely developed through the evolution of manufacturing, distribution, forecasting and customer behaviour, encouraging the introduction of postponement strategies in its various forms. At these strategies, semi-finished goods are stored in certain operations of the chain, called decoupling points, waiting for the placement of demand orders, which trigger production flows from decoupling points to the remainder operations. Such a design problem facing the speculation/postponement paradigm must intrinsically include elements that "unveil" demand orders when they are placed, that is, the modelling approach should keep demand orders as random variables until their placement, when they are disclosed. This work proposes a multi-stage stochastic programming model that decides the optimal allocation of decoupling points, as well as a process selection among alternative designs for any general supply chain case, where the stochastic parameters, demands by period and product, are represented through a scenario tree, which is in turn generated using the forecasting. Both a risk-neutral model and a risk-aversion approach with stochastic dominance constraints are presented and solved with multi-stage instances of test cases based on real manufacturing problems defined in collaboration with the Accenture consultancy company.

■ MD-28

Monday, 14:30-16:00 - SOUTH BUILDING UV S310

Behavioral Foundations of Service Systems

Stream: Service Operations Management
Chair: *Mirko Kremer*

1 - How observed queue length and service times drive queue behavior in the lab
Zeynep Aksin, Busra Gencer, Evrim Didem Gunes, Ozge Pala

Using laboratory experiments, we study join and renege decisions by subjects from a single server, observable, first come first served queue. We explore the role observed queue length and encountered service time experience plays on these decisions, and show that both the probability of reneging a queue and the survival time in a queue are affected by the queue length as well as experienced service times, for the same total waiting times. While the setting where only average service time information is provided to subjects before joining suffers from a queue length effect on reneging, this effect is partly mitigated when additionally information on total waiting time is provided.

2 - Bounded rationality in clearing service systems
Pelin Canbolat

This work considers a clearing service system where customers arrive according to a Poisson process and decide to join the system or not in a boundedly rational manner. When available, the server serves all the customers in the system at once and instantaneously. Times between consecutive services are independently and identically distributed. Using logistic quantal-response functions to model bounded rationality, we first characterize the total customer utility and the system revenue for fixed price and degree of rationality, then solve the pricing problem of a revenue-maximizing system administrator. The analysis of resulting expressions as functions of the degree of rationality yields the following insights: (i) Being rational maximizes the individual customer utility for fixed price, but when customers have the same degree of rationality and the administrator prices the service by taking this into account, a finite nonzero degree of rationality uniquely maximizes the customer utility, (ii) The administrator revenue becomes arbitrarily large as customers converge to being irrational, (iii) The social utility, defined as the sum of the total customer utility and the system revenue, is maximized when customers are rational, (iv) Independently of the degree of rationality, more than 75% of the social utility goes to the administrator.

3 - Pooling queues in discretionary services
Guillaume Roels, Mor Armony, Hummy Song

Contrary to the classical theory of operations management, recent case studies in retail, call centers, and healthcare indicate that pooling queues may not necessarily result in less expected work in process. In this paper, we propose that this phenomenon may arise when servers choose their own capacity to trade off their capacity costs with the holding costs of customers in service (when the queue is not visible to the servers) or of all customers in the system (when the queue is visible). We show that the difference in operational performance between the two configurations is marginal when the queue is visible, but can be substantial, with a preference for dedicated queues, when the queue is not visible.

4 - Mismanaging the quality-speed tradeoff in congested environments
Mirko Kremer, Francis de Véricourt

The tradeoff between diagnostic accuracy and speed permeates many manufacturing and service settings. We present the results from a set of controlled laboratory experiments designed to test the predictions of a formal sequential testing model that captures this tradeoff in a setting where the gathering of additional information (i.e., diagnostic testing) is likely to improve diagnostic judgments, but may also increase congestion in the system. We find that decision makers are insufficiently sensitive to congestion, with an aversion to stopping a diagnostic process in the face of increasing system congestion. On the other hand, decision makers are overly sensitive to diagnostic signals, with a tendency to stop a diagnostic process immediately after the first test result, even at low congestion levels that render additional testing inexpensive. As a result of these behavioral patterns, besides substantial heterogeneity in how they trade off quality and speed, the majority of decision makers manage their system with both lower-than-optimal diagnostic accuracy and higher-than-optimal congestion cost.

■ MD-29

Monday, 14:30-16:00 - SOUTH BUILDING UV S311

Game Theoretical Models and Applications II

Stream: Game Theory, Solutions and Structures
Chair: *Juan Tejada*

1 - Game-theory approach to selecting the most beneficial inventory management policy: the case of online retailers assortment planning
Zahra Saberi, Morteza Saberi, Omar Khadeer Hussain, Elizabeth Chang

The new paradigm of online retailing has brought a new concept to the whole chain of the retailing industry. One of these changes is the new approach of inventory management, known as drop shipping. Here, the supplier is responsible for keeping the inventory for the retailer, and revenue sharing is used as a mechanism of supply chain coordination by both parties. While drop shipping is the new approach in the field, the older one, batch ordering, can be still viable for E-tailers. Generally speaking, batch ordering leads to economy of scale and cheaper prices and also increases operations reliability. We use game theory to model the interaction of supplier and E-tailer in different power structures. In batch ordering approach, while the supplier determines price per unit and cost for product variation, the E-tailer decide on a product's assortment size. Notably, however, in the drop shipping approach, the revenue sharing contract encourages the supplier to collaborate and then determines assortment size, lot sizing and wholesale price. The E-tailer determines the price for the customers and set up a revenue sharing contract with the supplier. It is clear the batch ordering inventory management is not a flexible approach especially for items that come in a large variety of assortments. Various assortments have different unpredictable demands which finally lead to E-tailer paying a lot for keeping unsold items. The model shows which of the two approaches is profitable.

2 - Some applications of bankruptcy problems to engineering and management problems
Maria Teresa EstaÑ, Natividad Llorca, Joaquin Sánchez-Soriano

In this paper we will comment some applications of bankruptcy problems that are within the framework of game theory, given that the problems that arise in each one of them, they have the common premises that the resources that are available are scarce and that the agents need to reach an agreement for the distribution of said resource. To solve this dilemma, these applications use different models that incorporate the rules of distribution based on bankruptcy problems and extend classic bankruptcy problems. It is observed thus, the potential and applicability of the problems of bankruptcy in concrete, and the theory of games in general, to solve a wide variety of problems in which there is a scarcity of resources and, so, a conflict of interests that is not always easy to solve.

3 - Design of a market mechanism to achieve revenue adequacy for TSOS operating HVDC lines
Andrea Tosatto, Tilman Weckesser, Spyros Chatzivasileiadis

With the progress made in the field of power electronics, High Voltage Direct Current (HVDC) lines are now considered as a valid alternative to AC lines. As a result, future power systems will include a much larger number of HVDC lines connecting AC nodes in large interconnected grids. Currently, the HVDC line losses are not explicitly considered in market operations, resulting in additional costs for the TSOs. The introduction of tariffs to ensure budget balance for TSOs has been a central topic during the early stage of the implementation of the Internal Electricity Market of the EU, but HVDC lines have never been considered. In this paper, we are introducing a methodology to determine a loss factor for HVDC lines to be integrated in the market clearing algorithm, and we study the impact of the introduction of

HVDC grid tariffs on social welfare. First, we focus on the identification of an appropriate loss factor. We propose a comparison between three different models: fixed, linear and piece-wise linear. Second, we investigate the appropriate cost allocation of HVDC losses among the different market participants and the design of an appropriate grid tariff for covering the cost of losses. This is done by formulating the problem as a mathematical program with equilibrium constraints (MPEC), where lower-level problems are the profit maximizations of each market participant and the upper-level problem is the social welfare maximization from a regulator's point of view.

4 - Game theoretical centrality in social networks with multi-valued nodes
Juan Tejada, Javier Castro, Daniel Gomez Gonzalez, Elisenda Molina

Game Theoretical Centrality has been considered by Gomez et al. (2003), for instance, as a way of taking into account, not only de topology of the network but also its functionality or the interests that leads the players to be connected. In their approach, two elements are needed: a network that captures the social relations between the agents, and a cooperative game, that reflects the value that a group of agents -a coalition- can achieve if they act jointly. In general, the games that have been considered were symmetric games in which the value of a coalition depends only of the cardinal of the coalition. In this communication we extend the scope of the applicability of the game theoretical centrality to more general games. To be specific, we consider a general class of games that are based on multiple-weighted or multicriteria-valued nodes which comprise as particular cases the voting system process in the Council of the European Union, or a complex interlocked shareholding structure, among others. We propose a general methodology for aggregating the multiple contribution of the nodes to define the final game on which we calculate the corresponding game theoretic centrality. Alternatively, we study the possibility of aggregate different centralities obtained for each weight or criteria to obtain a unique centrality in the spirit of Scardoni et al. (2009) to identify potential influencer nodes or in biological networks (Meera Gandhia & Muruganantham, 2015).

■ MD-30

Monday, 14:30-16:00 - SOUTH BUILDING UV S312

Game Theory Applications in Operations and Sustainability

Stream: Game Theory and Operations Management
Chair: *Gokce Esenduran*

1 - Converting retail food waste into by-product
Mustafa Hayri Tongarlak

By-product synergy (BPS) is a form of joint production that uses the waste stream from one (primary) process as useful input into another (secondary) process. The synergy is derived from avoiding waste disposal cost in the primary process and virgin raw material cost in the secondary process. BPS increases profit and can have a positive environmental impact by reducing waste. We investigate how BPS can mitigate food waste in a retail grocer setting, and how it interacts with other mechanisms for reducing waste (i.e., waste disposal fee and tax credit for food donation). In the retail setting, waste is generated because of demand uncertainty-the retailer stocks inventory without knowing demand and excess units become waste. We derive the retailer's optimal order policy under BPS and the order policy for a more practical hybrid implementation of BPS and compare these BPS implementations to the benchmark case where the retailer only sells fresh produce. We find that BPS can reduce waste when secondary demand uncertainty and the net tax benefit from donation are low, but can increase waste if increased secondary demand uncertainty drives up safety stock. Our results suggest that under BPS, the threshold net tax benefit required to induce donation increases because BPS competes with donation for excess primary units. We find that the tax credit and disposal fee are substitute mechanisms for inducing food donation.

2 - A parametric analysis of collaborative intermodal transport
Alberto Giudici

Intermodal transport has been known for lower levels of reliability then direct truck transport, especially for the operations related to import and export flows surrounding port areas. Despite its greener environmental impact, improvements of the service level of the intermodal transport chain is hindered by several barriers. From the experience gained from the EU-funded SELIS project, we observe that aiming at improved service level can trigger network operators to cooperate. We consider a cooperative setting where both available transport capacity and orders are shared by seeking an execution at minimum cost. From a cooperative game theory perspective, we perform a parametric analysis of the Shapley value and core. Membership of the Shapley value to the core can give information on the result of the self-interested bargain of cooperating companies and cooperation stability. Basing the cooperative game upon a parametric flow problem, we are able to analyze the impact of service level and network structure on the cooperation stability and Shapley value. Our contribution lays in the mathematical explanation of (in)stability of horizontal and vertical cooperation. Moreover, we numerically test the validity of our insights on complex network structures.

3 - Supplier development in a multi-tier supply chain
Pınar Şimşek Yalçın, Ozgen Karaer, Tim Kraft

In this paper we study when and how a downstream buyer should develop the quality capabilities of his tier-1 and tier-2 suppliers in a multi-tier supply chain setting. We examine how the buyer and the suppliers' decisions are impacted by the market opportunity and the division of the supply chain margin between the three parties. Our findings suggest that if the demand opportunity is such that the buyer should develop only one supplier, then he should invest in the supplier/tier with the higher portion of the supply chain margin. Conversely, if the opportunity is such that he should instead invest in both suppliers, then he should share a larger portion of the cost to improve quality with the supplier/tier with the lower portion of the supply chain margin. To better understand when a buyer should consider using a "full control" strategy such as this, we compare this strategy versus one in which the buyer delegates the development decision of the tier-2 supplier to his tier-1 supplier. We find that a full-control (delegate) strategy should be used when the buyer's tier-2 (tier-1) supplier captures a larger portion of the supply chain margin than his tier-1 (tier-2) supplier.

4 - Incremental solutions to online generalized multi-item multi-unit combinatorial auctions
Anup Kumar Sen, Amitava Bagchi

Online auction schemes have become popular mechanisms in recent years for buying and selling goods and services in business and industry. In online (i.e., continuous) combinatorial auctions, bidders are allowed to join and leave the auction at any time, and in the process, bidders can repetitively bid on packages of items of their choice. In such multi-agent e-business systems, the seller is compelled to provide information feedback to the bidders after every bid on the current state of the auction to help them place more informed bids. This requires provisional winners be computed for every package of items after each bid by solving Winner Determination Problem that maximizes the sales revenue. This paper addresses this issue. In online multi-unit multi-item online combinatorial auctions that sell multiple dissimilar items each having one or more identical units, no bidder can win more than one package under XOR constraints. With OR constraints, a bidder can win any number of packages. This paper considers the generalized version where a bidder is imposed a limit on the number of packages a bidder can win, and presents a dynamic programming approach which can incrementally solve winner determination problem for every package after each new bid. The XOR and OR formulations appear as special cases of this generalized version. This has applications in various domains including spectrum auctions. We present the algorithm and its implementation.

■ MD-31

Monday, 14:30-16:00 - SOUTH BUILDING UV S313

Behavioural OR: General Papers

Stream: Behavioural OR
Chair: *Etienne Rouwette*

1 - Behavioural operational research within two areas of conflict: an extended classification approach

Damian Braschczok

Behavioural Operational Research (BOR) is a young research field in the area of Operational Research (OR). BOR emphasizes the influence of cognitive psychology for the use of quantitative methods as decision support and seeks to embed behavioural findings into OR. This is necessary as the interdisciplinary and real world application driven focus of OR appears to stand in an unbalanced relationship compared to its mathematical-technical research. Among other things, BOR tries to reduce this imbalance. However, it still has the problem of being a rarely well-defined field. Therefore, classification of BOR and its main issues - on a meta-level - is just as important as the embedment of behavioural aspects into OR. This contribution presents BOR as a research field within two areas of conflict, characterized by two dimensions and four theoretical constructs. For simplicity, each dimension concerns real world and model world aspects. Therein, application of OR methods faces the importance of fundamental research concerning these methods, and the postulate of rationality is challenged by behavioural scientists. Out of this new perspective - which will be introduced in detail - central points of BOR are depicted in a different light. This finally leads to an extended classification approach helping BOR to shape its profile and to obtain more acceptance in the scientific community.

2 - Developing ORBIT: the operational research behavioural interventions toolkit

Katharina Burger, Leroy White, Martin Kunc, Jonathan Malpass

The OR field has a long-standing interest in interventions in organisations. However, only recently, has the field focused on the processes related to changes in human behaviour as an intervention progresses. The need for guidance in the application of insights from behavioural sciences in the design, implementation and evaluation of OR interventions is particularly pressing in the context of organisational transformation projects. As a contribution to addressing some of the challenges, we are developing the Operational Research Behavioural Interventions Toolkit (ORBIT), that supports practitioners in understanding the links between different behavioural OR insights, and what and when particular insights are best suited to improve the implementation of a transformation project. Our presentation will focus on the findings thus far. In particular, we will present an outline of the ORBIT toolkit. The focus will be on its design to provide a shared way of thinking about the behavioural interventions during transformation challenges in organisations. The toolkit is intended to serve as a starting point for collaborative empirical research towards an open-source platform for OR interventions, that practitioners can draw on to identify the improvements they need to make to better implement changes arising in their transformation projects.

3 - Integration and application of problem structuring methods: an application in oil exploration

Fahad Mehmood

Several critical elements (such as uncertainty, complexity and lack of structure) limit the use of analytical models and methods in problem solving and decision-aid in practice. In an effort to solve these problems, the initial representation or conceptualization of a problem is so crucial to its subsequent treatment that one is tempted to say that the most important as well as most difficult issue underlying the subject of problem solving is precisely 'how to structure the problem'. The purpose of study is to review concepts related to the problems that require structuring (ill-structured or unstructured problems), the methods that are available in order to deal with these problems (problem structuring methods) and to study the use of these methods in interventions. The research involved creation of a community with the aim of integrating competences on how different methods may be used and integrated to face complex and unstructured decision situations, in order to develop methodological skills that could effectively facilitate the analyst's work. Each member of this community was involved, at the start in relation to a specific old intervention, in an investigation project, in relation to some cases and their modeling processes, which have been developed in real organizations, by means of a specific technical approach or with the support of a multi-methodology with formal tools that propose a limited quantification within a systematic framework.

4 - Physics, foibles and failings: applying the 'behavioural turn' to the breadth of system dynamics practice

Etienne Rouwette, David Lane

Whilst there are some difficulties in defining 'Behavioural OR', the 'behavioural turn' is in full sway across OR. This paper considers its application to System Dynamics (SD). Interest is then on complex dynamic systems, whether what humans do when dealing with such systems departs from normative rationality, and how modelling can contribute. Referencing its Behavioural Decision Theory roots, it rapidly becomes clear that a 'Behavioural SD' approach has promise. Within SD there is, for example, already considerable empirical evidence regarding human inability to understand stock/flow relationships and dynamic behaviour, along with a long-standing interest in deficiencies in mental models and their consequences for system performance. The idea applies to an extensive territory of ideas, from human response to and understanding of actual systems of this type, to the use of maps and models to learn about them, the difficulties in creating such models, how one represent 'behavioural effects' within such models and the problem of getting individuals or groups to learn from such models. Sketching the territory reveals much scope for a behaviouralist view to SD. It provides a conceptual lens that can generate important new insights. With that in mind, a definition is proposed, one which underpins the sketch of the 'Behavioural SD' territory.

■ MD-32

Monday, 14:30-16:00 - SOUTH BUILDING UV S314

Air Transportation

Stream: Routing, Logistics, Location and Transportation
Chair: *Yagmur Simge Gök*

1 - Integrated capacity management for airport runway systems

Stefan Frank, Karl Nachtigall

Ongoing growth of aircraft movements motivates research in the field of airport operations management. The performance of an airport can be measured by its capacity of movements per hour. Therefore, capacity management is used to determine the maximal throughput of an airport, which is limited by several infrastructural and operational factors. In this context, runway system configurations constitute a bottleneck at major international airports. We present two mixed-integer programming formulations for the aircraft scheduling problem at an airport. Within these problem formulations, aircraft movements needs to be assigned to runways and scheduled so as to minimize the overall delay, while separation requirements between all pairs of movements have to be satisfied. The first model formulation focuses on a short-term planning to determine runway allocations and valid sequences for aircraft movements. On the other hand, the second model formulation aggregates flows in a time-discrete network to estimate the capacity of an airport in context of long-term and medium-term planning, where exact sequences of aircraft movements are not of interest. We compare the two approaches and show how to connect them. Doing this, we get (near-)optimal results for the airport scheduling problem and also tight lower bounds, which is a lack of most solution approaches presented in the literature. Therefore, the interaction of the both approaches state promising results in all stages of planning.

2 - Airspace sectorization by graph-and-geometric approach
Yasufumi Saruwatari, Yoichi Izunaga, Takamori Ukai, Kota Kageyama

The traffic safety and efficiency in the airspace are ensured by air traffic controllers in ATM. Every controller is assigned to a subspace of the airspace, called a sector, and has the task to monitor the flights, to avoid conflicts between aircrafts and to exchange information with controllers assigned to adjacent sectors where flights have been planned. The airspace sectorization problem (ASP) is to find the reasonable number of sectors with the set of sectors such that the workload associated with controller's task is balanced, satisfying given geometric conditions. ASP is known to be NP-complete. This paper proposes an algorithm for solving ASP. A variant of ASP is introduced and solved firstly, and the solution is modified so as to satisfy the conditions in the original one. We treat ASP as a graph-theoretic model where the intersection of the existing trajectories and the segment of the corresponding one are regarded as vertices and edges, respectively. Note that a sector is properly determined by a subset of vertices. A partition of the set of vertices is obtained by solving the set-partitioning problem. We construct the method for enumerating trees in the graph efficiently, each of which corresponds to a column of the set-partitioning problem. A heuristics based on computational geometry is proposed for modifying obtained sectors. In order to certify the validity of our algorithm, we apply our algorithm to the Japanese airspace model.

3 - Robust scheduling in airline operations planning: how robust are those schedules?
Aykan Akincilar

In the field of airline operations planning, methodologies that are capable of producing robust schedules are intensely attempted especially after 2000s. As a matter of course, precious works have appeared in this sub-field. However, it is still not very clear to determine how robust the produced schedule is. In this talk, after examining existing literature, two new definitions are defined in order to contribute to fill this gap. It is believed that vagueness about how robust is the robust schedule has been definitely solved via those definitions. In order to demonstrate how this new approach works, a novel methodology, which produces definitely robust routes for aircraft routing sub-problem (ARP), is developed. After usability of this new methodology is tested on real world data, pros and cons of this new approach are discussed.

4 - New efficient heuristics to solve tactical airport check-in allocation problems
Yagmur Simge Gök, Maurizio Tomasella, Daniel Guimarans, Cemalettin Ozturk

We study a tactical airport check-in counter allocation problem (ACCAP) from the viewpoint of the airport operator. We model the ACCAP as a two-dimensional bin-packing problem. Due to NP-completeness, we propose and test the efficiency and effectiveness of new heuristics. Our objective is to minimize the total number of counters needed. We consider: common use check-in counters, adjacency requirements, variable counter profiles (per flight) and different check-in configurations. We used instances from a medium sized airport. Beyond the novelty of the investigated setting and of the proposed heuristics, our model is the first to provide airport operators with additional business insights to negotiate with customer airlines for where to best locate their check-in operations in the available terminals/halls, as well as the minimal number of counters required for them to meet specific service level agreements. This makes it for a more informed decision making and enhanced facilitation of airport/airline service contract stipulation.

■ MD-33
Monday, 14:30-16:00 - SOUTH BUILDING UV S315

Data Mining and Statistics III

Stream: Data Mining and Statistics
Chair: *Ozden Gur Ali*

1 - A data-mining based process to early identify breast cancer from metabolomic data
Víctor Manuel Rivas Santos, Pedro José Sánchez-Rovira, Josè Javier Rosell García, Leticia Díaz-Beltrán, Jose Perez del Palacio, Francisca Vicente Area Head Screening & Validation, Caridad Díaz-Navarro, Daniel Franco, Ana Laura Ortega-Granados, Olga Genilloud, Carmen González-Olmedo, Sergio Granados-Principal, Francisco Javier García-Verdejo

We present the results yielded by our multidisciplinary group in the task of discriminating blood samples coming from breast cancer patients and healthy people. Models used to classify samples have been built using data mining techniques; data have been collected by means of liquid chromatography-mass spectrometry, a technique that detects and quantifies the metabolites present in blood samples.

Different algorithms have been tested under 10-CV and 75/25 scenarios. Our experiments showed that IBk, and J48 and Logistic Model Trees yielded rates greater than 90% only for healthy people. Naive Bayes and Random Forest enhanced the previous results in the 10-CV approach, but they did not yield more than 85% of true positives for patients in the 75/25 one. Finally, bayesian network resulted to be the best algorithm as rates greater than 90% were yielded for both patients and rest of the people.

Many statistics have been computed as well as confusion matrices, showing that the model built by Bayesian network can effectively be used to solve this problem. Currently, the metabolites used to do built the model are being identified by biochemists. This last step will be definitive in order to consider them as a valid biomarker for breast cancer.

2 - Improvement of schools performance with BI implementation
Rose Nelson, Olga Nazarenko

As educational institutions face the challenge of rising costs and limited funding resources, the use of data analytics and business intelligence solutions becomes a necessity to drive an organisation-wide change and performance improvements. We provide specialised business intelligence managed services to the education sector, helping them assess funding needs, develop focused strategies, and demonstrate improvements on all key performance indicators (KPIs). Based on DFE and OFSTED Assessment criteria, our business intelligence services evaluate a school's performance in several different areas, including overall effectiveness, leadership and management, outcome for pupils, personal development, and quality of teaching, learning, and assessment. In addition to this, we leverage on our access to a wealth of information to benchmark schools against each other and against national averages to help them evaluate their performance in comparison to other institutions. It helps schools and MATs to gain an accurate understanding of current situation and making strategies for better performance.

3 - Automatic forecasting of category-store sales considering cross-category effects
Ragip Gurlek, Ozden Gur Ali

A retail chain needs to forecast thousands of category-store-level time-series, making it necessary to use a robust automated method. In addition to seasonality and disturbances, the sales are affected by marketing efforts in the focal category and potentially other categories. We propose an automated method that forecasts multi-period-ahead category-store-level retail sales considering cross-category effects and the SKU level distribution of marketing features. We test the accuracy of the method on a retail dataset supplied by IRI for 3 chains with 154 stores and 31 categories with multiple horizons within the ten years of data. We investigate under which conditions the cross-category effects and distributional features improve the accuracy of the forecasts. In the first stage of the method, we deseasonalize the data. In the second, we regress the sales on marketing features of all categories in the store by using the Elastic Net to deal with high dimensionality. The third stage extrapolates the residuals of the second, with lead time specific models that considers the effect of disturbances in all the categories. Our method outperforms the benchmarks STL, ARIMA, and VAR in forecast accuracy. Disaggregate information improves the forecast, with the longest horizon being the exception. Cross-category marketing and own-disturbance elements contributes to the forecast, but cross-category disturbance does so only for the occasional and convenience categories.

4 - Combining local survey data with meta-analysis of global relative risks - studies to more accurately predict prevalence of diseases
Angi Ghanem, Ozden Gur Ali

In this research, we aim to combine local survey data with results of meta-analysis of global relative risks' studies to more accurately predict disease prevalence. We use a Bayesian framework where the analysis of the local individual level data is guided and fortified by the information obtained from meta-analysis results through the prior distribution on parameters. This is important because even though the individual level data sample size is large, three elements make it difficult to fit a model: large number of factors that can affect the prevalence, relatively low prevalence leading to rare event problem and the nonlinear nature of some of the relationships. We work with health surveys conducted by the Turkish Statistical Institute (TUIK) over the span of 8 years, and meta-analysis global level data from IHME institute to predict Diabetes, Coronary Heart Disease and Depression prevalence in the adult population of Turkey. We use Bayesian models along with flexible nonparametric models (GAM) to model the impact of multiple behavioral, demographic, socioeconomic and geographic factors. The impact of using informative versus non informative priors is assessed for point and uncertainty estimates. Benchmark methods include mixed models and random forests. On the policy level, this model can be used to study the impact of public campaigns and awareness efforts on behaviors such as smoking, second-hand smoking, diet, physical activity level and alcohol consumption.

■ MD-34

Monday, 14:30-16:00 - SOUTH BUILDING UV S113

Numerical and Simulation Methods in Finance II

Stream: Numerical and Simulation Methods in Finance
Chair: *Ana Monteiro*
Chair: *Ayşe Mutlu Derya*

1 - An agent-based model for Korean stock market - KOSPI 200 and interactions among investors
Chansoo Kim, Kyung O Baek, Haneol Cho

We construct an ABM (Agent-based Model) to effectively recreate the fluctuation data of KOSPI 200 (Korea Composite Stock Price Index 200) index market. Our model sets each agents' behavior differently, such as the level of influence of each agents to another and the agents' individual propensity to invest. We fit the simulated result to the actual KOSPI 200 index market (fiscal year 2000-2016) by controlling parameters regarding agents' interaction with each other. The ABM enables us to see the individual agents' earning rates in the market, which leads us to see if the distribution follows the 'Power-Law'; implying that the agents tend to have a herding behavior.

2 - Roster design for complex queue systems in banking
Federico Trigos, Alan Vázquez-Alcocer, Leopoldo Cárdenas-Barrón

The study addresses and solves the problem of finding required number of active server stations and its individual employees to minimize the number of system server hours during a working day while controlling the expected value of the customer waiting time in queue. A simulation model is developed and a heuristic is proposed to solve the problem. Bank data are used to illustrate the methods and to identify key elements for system performance improvement.

3 - Kernel density estimation: local cubic polynomial approach with non-arbitrage constraints
Ana Monteiro, Antonio Santos

Risk-neutral densities (RND) are determinant when dealing with risk management and the pricing of new derivative products. In recent years the amount of information coming from intraday data allows to improve and develop existing and new approaches devoted to estimate risk-neutral densities. Here is proposed a new approach that considers local cubic polynomial estimation, in a kernel smoothing framework, applied to intraday data. Constraints associated with the non-arbitrage hypothesis are directly applied to parameters of the local cubic approximation. Also, by adding a penalty function in the original objective function used in the estimation procedure, we allow RND tails to decay smoothly to zero as it would be expected with a density function. This nonparametric estimator is applied to intraday data associated with European style options from VIX and S&P500 indexes.

■ MD-48

Monday, 14:30-16:00 - 4D UPV B.3

OR Applied to Disaster Relief and Development Operations

Stream: Humanitarian Operations
Chair: *Alfonso Pedraza-Martinez*

1 - Multi-criteria optimization for last mile distribution of disaster relief aid: test cases and applications
Begoña Vitoriano, José María Ferrer, F. Javier Martin-Campo, M. Teresa Ortuno, Alfonso Pedraza-Martinez, Gregorio Tirado

Humanitarian organizations transport large quantities of aid for distribution in the aftermath of disasters. Transportation for last mile distribution includes multiple, and often conflicting, performance criteria that include time (deprivation), cost, coverage, equity and security. We build a compromise programming model for multi-criteria optimization in humanitarian last mile distribution. Regarding security, ours is the first multi-criteria model able to produce an actual vehicle schedule while forcing vehicles to form convoys in humanitarian operations research. We illustrate the multi-criteria optimization using a realistic test case based on the Pakistan floods, 2010. We standardize and share this case as well as cases based on the Niger famine, 2005 and the Haiti earthquake, 2010. Raw data for these test cases will be available at www.mat.ucm.es/humlog. By sharing test cases, we encourage basic scientific tasks such as replicability and model comparison within the humanitarian operations research community.

2 - Multi-vehicle prize collecting arc routing for connectivity problem
Vahid Akbarighadikolaei, Sibel Salman

For effective disaster response, roads should be cleared or repaired to provide accessibility and relief services to the affected people in shortest time. We study an arc routing problem that aims to regain the connectivity of the road network components by clearing a subset of the blocked roads. In this problem, we maximize the total prize gained by reconnecting disconnected network components within a specified time limit. The solution should determine the coordinated routes of each work troop starting at a depot node such that none of the closed roads can be traversed unless their unblocking/clearing procedure is finished. We develop an exact Mixed Integer Program (MIP) and a matheuristic method. The matheuristic solves single vehicle problems sequentially with updated prizes. To obtain an upper bound, we first relax the timing elements in the exact formulation and then solve its relaxed MIP, which decomposes into single vehicle problems, by Lagrangian Relaxation. We show the effectiveness of the proposed methods computationally on both random Euclidean and Istanbul road network data generated with respect to predicted earthquake scenarios.

3 - OR applications to humanitarian logistics in Latin America

Jaime Mora Vargas

This paper presents an analysis of the humanitarian logistcs operations during Mexico 2017 earthquakes. This analysis includes NGO and Government response to fulfill need of water, food and medical equipment, among others. During september earthquakes in Mexico, local and international help was required, leading necessary the governmental, NGO's, private sector companies and militaries intervention. Coordination among stakeholders, is one of the main opportunity area in humanitarian logistics. In order to deliver the humanitarian aid the distribution must be done under a high uncertainty demand and infrastructure damage, where previously considered routes may or not be available after the disaster strikes. This work considers the impact of the coordination between stakeholders and the network availability as two of the trade-offs for the humanitarian logistics decision making process. Based on previous statement, a multi-criteria framework for a reliable aid distribution optimization model is proposed. The methodology for the multi-criteria framework development proposed is centered on a vertical coordination, where the availability of the network, equity, efficiency, coverage and efficacy are prioritized in order to balance and ensure a reliable aid distribution.

4 - OR applied to humanitarian operations

Alfonso Pedraza-Martinez, Maria Besiou, Luk Van Wassenhove

The humanitarian caseload is growing rapidly while funds are declining. The sector clearly will have to do more with less. Optimizing constrained resources is the strength of OR. Our discipline can strongly support humanitarian practitioners provided it works on pressing real problems and translates its research into easily implementable tools whose effectiveness can be verified. This Special Issue gathers a very rich and varied collection of papers along those principles. It clearly shows the value of OR and the many exciting research problems in this important area of humanitarian operations.

■ MD-49

Monday, 14:30-16:00 - 4D UPV B.4

OR in Agriculture I

Stream: OR in Agriculture, Forestry and Fisheries
Chair: *Victor M. Albornoz*

1 - Lagrangian decomposition bounds for a crop rotation problem with adjacency constraints

Geraldo Mauri

The Crop Rotation Problem (CRP) consists of alternating crops in neighbor plots during a period of time in order to find a planting schedule that maximizes the profit of the production ensuring some constraints. Among these constraints, it can be considered the time for soil recovery, the non-consecutive cultivation of crops from the same botanical family, the sowing period of each crop, the non-adjacent planting of crops from the same botanical family, etc. In this paper, a Lagrangian Decomposition (LD) is proposed to find bounds for the CRP. The plots are used to define a conflict graph which is partitioned in clusters of vertices forming sub-problems that can be solved separately by a commercial solver. A dual problem is generated to define an upper bound for the PRC. Computational experiments were performed considering a set of instances based on real-world data and different scenarios were evaluated considering several arrangements for the plots, achieving almost the graph planarity limit. The obtained results demonstrate the potential of the proposed LD which was able to find good bounds within low computational times.

2 - A multi-objective model to optimize the food resource allocation in dairy systems

Gastón Notte, Pablo Chilibroste, Martin Pedemonte, Hector Cancela

One of the problems arising in the dairy industry is the allocation of food resources to a given herd. In a pastoral-based dairy system with supplementation (as the Uruguayan one) this is done by grouping cows and distributing these groups to the different pastures available in the field. Usually the goal of this assignment is to optimize different objectives. In a previous work we formulated a multi-objective mathematical programming model, taking into account the characteristics of the problem. The optimization model follows a multi-period approach, covering a one year schedule, divided into periods of one month. To solve the optimization problem we developed a multi-objective evolutionary algorithm (EA), taking as decision variables a sub-set of input parameters, and using different objective functions. In the present work different computational experiments based on real test data were done to study the quality of the solutions when the objectives are optimized, to compare the obtained solutions using different stocking rates, and to study the diversity of the solutions provided by the EA. The results show that the solutions proposed by the model reached the same values as those obtained by a dairy project that uses optimal solutions (obtained by a single objective exact approach). The results also show that the EA can reach a considerable degree of diversity in its solutions while maintaining a small gap to the optimum.

3 - Mathematical models for improving the process of grape reception at Aveleda

Eliana Costa e Silva, Aldina Correia, Isabel Cristina Lopes

This work attempts to answer an industrial challenge proposed by Aveleda, a Portuguese company in the wine and food sector. The company aims at finding ways to improve its grapes reception process, in order to guarantee wine quality and reduce the suppliers waiting lines. In fact, during the harvest days, the unloading of the grapes trucks may face several hours of delay, and long waiting periods may result in the deterioration of the grapes. At the moment, mathematical models for the grapes reception during the most critical days of harvest are being developed. These models are being tested in different scenarios using data simulated according to the specifications of the company. The mathematical modelling intends to help the company to optimize several of their processes and predict unexpected events, contributing to save time and improving the system efficiency.

4 - Integrated versus hierarchical approach for zone delineation and crop planning under uncertainty

Victor M. Albornoz

This paper considers the problem of zone delineation management and crop planning. The problem consists of selecting which crops to plant in different management zones in order to minimize the total costs subjected to a given demand requirement. From a hierarchical point of view, the process starts by generating a partition of an agricultural field into homogeneous management zones, according to a given soil property. Then, the best crop rotation must be assigned to each management zone, applying agronomic practices in a site-specific manner in each zone. This hierarchical approach establishes two decision making levels of planning. At each level, a two-stage stochastic optimization model is proposed, representing the uncertain behavior of a soil property and crop yields by using a finite set of scenarios. Next, we combined them into a new two-stage stochastic program, solving the problem using an integrated approach by simultaneously determining an optimal partition and allocation. A set of instances used in the application of the proposed methodology and the results obtained are presented.

■ MD-50

Monday, 14:30-16:00 - 4D UPV 1.1

OR for Developing Countries III

Stream: OR for Developing Countries
Chair: *Milagros Baldemor*
Chair: *Leroy White*

1 - Improving underprivileged children's access to education: a multi-methodology intervention in Hungary
Gabriella Csanyi, Valentina Ferretti

This project develops a value-focused Decision Analysis intervention designed and deployed to support the Csányi Foundation (Budapest, Hungary) in selecting underprivileged children to enter the Foundation's Educational program.

The Csányi Foundation is a non-profit organization that has been set up in Hungary to help provide gifted children from disadvantaged backgrounds with the means to help nurture and develop their talent. Currently, the Foundation helps 350 children and young people, 56 of whom are already at university. However, despite the increasing number of applications that the Foundation receives every year, 25% of the children have quitted the program too early due to inadequate selection processes.

This project provided the Foundation with a tool that (i) helped the board members to identify a comprehensive and shared list of objectives, (ii) supported the evaluation of candidates to be included in the Foundation program in April 2017 and (iii) has been embedded in the Foundation selection processes to help them minimize dropout rates. Methodologically, we propose the integration of value focused thinking, Multi Attribute Value Theory and best practices from behavioural decision research. While there exist many applications of OR for personnel selection, this prescriptive intervention represents the first application of a Multi Attribute Decision Analysis approach in the context of underprivileged children selection for educational programs.

2 - Tackling the compositional nature of water, sanitation and hygiene (WASH) data in statistical analysis
Fatine Ezbakhe, Agustí Pérez-Foguet

Monitoring and statistics of drinking water, sanitation and hygiene (WASH) have gained renewed interest and attention with the 2030 development agenda. Data on WASH indicators will continue to be central to monitoring progress against the development goals, and its statistical analysis will be instrumental to achieving the development goals. A key characteristic of these data is that they provide proportions of the population or percentages that always sum to 100, thereby compositions that are intrinsically connected. However, the compositional nature of WASH data is often ignored when analyzed, leading to spurious results when treated with "classical" statistical methods. Our work aims to demonstrate the importance of compositional data analysis for WASH data. We compare some commonly used statistics (e.g., arithmetic mean, standard deviation and correlation coefficients) to WASH access compositions data, and determine the importance of reporting statistics of data has a whole. Data is obtained from UNICEF's Multiple Indicator Cluster Survey (MICS) dataset. First results show, for example, that the coverage for improved drinking water in rural areas of Tunisia, applied to the raw data, amounts to 88.4%, differing from the 95.1% calculated when data are treated as compositions. This reveals the importance of analyzing the individual populations in the WASH datasets as related rather than independent from each other.

3 - Education and environmental awareness in students of civil engineering, César Vallejo University '- Lima East Campus
Cesar Teodoro Arriola Prieto

Introduction: Environmental education develops and strengthens an awareness that stimulates respect and coexistence of people towards their natural and cultural environment, knowing adequately the resources and their capacity for sustainable use, reaching the overall wellbeing of the community, the University adopts a position before environmental problems and acts in different areas of its competence. The objective was to determine the relationship that exists between environmental education and the level of development of environmental awareness in Civil Engineering students. Material and methods: The population was 554 students of Civil Engineering, the census technique was applied; unit of analysis the student of Civil Engineering. The technique used was the survey and the instruments were two questionnaires of own authorship, validated by three expert judges with validity of 80%, reliability by Alfa de Cronbach of 83% and 90%. The research was quantitative, cross-sectional, descriptive correlational and non-experimental design. Ethical aspects considered: respect for the person, privacy, beneficence and informed consent. Results: 30.9% of students have a high level and 34.7% have a low level of knowledge about environmental education. Environmental awareness is low 33.8%, medium 34.3% and high 31.9%. Conclusions: There is a significant relationship between environmental education and the development of environmental awareness, Rho = 0.546 and sig = 0.000 <0.01.

4 - Implementation and evaluation of the targeting performance of the 4Ps program in Northwestern Philippines
Milagros Baldemor

This study evaluated the targeting performance of the 4Ps, an anti-poverty program of the Philippine government and its level of implementation and evaluation in Northwestern Philippines.It further looked into the amount of cash transfers received by the beneficiaries using indicators targeting differential and cost benefit ratio. It was a documentary analysis of the annual poverty indicator survey 2011, a nationwide survey that provides non-income indicators for poverty and the master sample based on the Census of Population and Housing. It was analyzed using the ADePT software developed by the World Bank and the Coady-Grosh-Hoddinott (CGH) index. Findings showed that the program was highly implemented as to: policies, persons involved, monitoring and evaluation, and systems of operations in terms of: beneficiary update system; compliance verification system; grievance and redress system; and supply side assessment, service providers; and stakeholders, while the Millennium Development Goals-well-being; poverty index; education; and gender equality, were highly attained. Out of 198,260 respondents, 78,789 are 4Ps beneficiaries among which 52,654 of them are poor and 81.5% reside in rural areas. The program covered only a small portion of the poor and the leakage is greater than the coverage of the poor. It resulted to a negative targeting differential but still progressive. Poverty gap is reduced by 0.83 for every unit spent on 4Ps.

■ MD-51

Monday, 14:30-16:00 - 4D UPV 1.2

Designing Sustainable Vehicle Operations Management

Stream: Environmental Sustainability in Supply Chains
Chair: *Jutta Geldermann*
Chair: *Christina Scharpenberg*
Chair: *Martin Hrusovsky*

1 - Vehicle routing of mixed fleets with combustion-powered and electric vehicles
Herbert Kopfer, Benedikt Vornhusen, Jan Dethloff

This contribution analyzes the effects of vehicle routing when deploying homogeneous and heterogeneous vehicle fleets consisting of ICE (Internal Combustion Engine) vehicles and/or BEVs (Battery Electric Vehicles). Additionally to different modes of driving (i.e. combustion engine or electric motor, vehicles with different capacities are taken into consideration. Results show that when deploying homogeneous fleets there is no significant potential for reducing energy consumption by replacing the objective of distance or time minimization by the objective of energy minimization. By contrast, when deploying a heterogeneous fleet, a significant reduction of energy consumption in the double-digit percentage order can be achieved. On the other hand the total travel distance as well as total travel time increases. Comprehensive computational experiments show that well-configured heterogeneous fleets are by far superior to any homogeneous ICE- or BEV-fleet.

2 - Sustainable vehicle routing of daily goods from small, regional producers
Christina Scharpenberg, Jutta Geldermann

An increasing demand for regional products can be observed in Germany. Consumers associate inter alia freshness, good quality and environmental friendliness with regional products. Two central facts are that production in the local area strengthens the local economy and because of short distances products can be delivered fresh. To keep transport distances as short as possible and to increase the supply, supermarkets cooperate with small, regional producers. So far, this concept involves an increasing organizational and logistical effort due to a lack of standardization and special requirements of regional producers. Further, the small, regional producers usually separately supply the supermarkets by passenger cars or vans. In terms of environmental protection and overall sustainability, such a system may not be efficient. Our research goal is to develop a vehicle routing algorithm that meets the needs of regional producers and suppliers. Therefore, we follow a bi-objective optimization minimizing transport costs and emissions to find a more sustainable solution for the transport problem above. Further, we consider capacity restrictions, a heterogeneous vehicle fleet and time windows for pickup and delivery.

3 - An integrated simulation-optimization for intermodal transport planning under uncertainty: a combination of offline and online planning
Martin Hrusovsky, Emrah Demir, Werner Jammernegg, Tom van Woensel

The high complexity of transport networks and the growing traffic volumes increase the risk of disruptions with negative influence on operations. Therefore planners look for solutions that enable efficient, reliable and sustainable transport of goods, taking into account economic and environmental factors. In this context, intermodal transport combining different transport modes is often mentioned as an alternative. However, its current share on modal split is very low due to various reasons, including the limited support of transport management systems (TMS) for intermodal transport planning. Whereas some of the TMS can create a deterministic plan under normal conditions, the consideration of stochastic factors (e.g., delays) and implementation of methods for re-planning in case of disruptions is missing. In order to close this gap, we present an integrated simulation-optimization model combining offline (before the start of the transport) and online (real-time) re-planning approaches. Within this model, reliable offline plans for incoming transport orders are created considering the impact of minor disruptions (e.g., congestion). In addition to that, the influence of major disruptions occurring during transport execution is shown and a novel approach for online re-planning of affected orders is presented. The planning model is tested on a real-world case study combining various transport modes and considering multiple planning objectives (i.e., economic and environmental).

4 - The potentials and uncertainties associated with the coordinated charging of electric vehicles
Marcel Dumeier, Jutta Geldermann

A growing number of electric vehicles requires charging. New technical solutions and charging strategies need to be developed and deployed to optimally integrate charging stations into the existing power infrastructure. Consequently, the smart charging of electric vehicles is an interesting topic both from a practical and theoretical perspective. Following a bottom-up approach and through the application of linear programming, the potentials of smart charging are quantified, starting on an individual car level using real-world data of households. The linear programming model at the household level reveals key factors required for smart charging of vehicles and allows to analyze the impact of electricity prices, the arrival and departure times and the required charge of the vehicle. Based on the results for the level of the individual cars, a simulation tool supports a charging station operator to offer suitable charging procedures. The developed model takes into account various types of uncertainty by means of robust optimization. It is designed both for a private and public application.

■ MD-52

Monday, 14:30-16:00 - 4D UPV 1.3

Health Care Modelling (ORAHS) III

Stream: OR for Health and Care I
Chair: *Maria Eugénia Captivo*

1 - A stochastic programming approach for multi-appointment outpatient scheduling in cardiology
Lida Anna Apergi, John Baras, Kenneth Wood, Bruce Golden

This research tackles the problem of multi-appointment scheduling in a healthcare environment with limited resources. Considering elective outpatient procedures in the cardiology department of a large medical center, where patients have to visit the hospital on multiple occasions to go through the required tests and treatments, a model is designed and developed towards optimizing the allocation of the available resources to the patients. The objective is to minimize the weighted combination of the number of visits that the patients have to make to the hospital until the completion of the program they are going through and the time that the outpatients spend in the hospital while waiting in between appointments. Constraints taken into account include the availability of the patients and the required resources, the sequencing of the procedures, and the recovery time that should be provided to patients between procedures. Stochastic programming techniques are applied to optimize the scheduling decisions over time.

2 - Home healthcare staffing and scheduling
Maria I. Restrepo, Louis-Martin Rousseau

We present a two-stage stochastic programming model for employee staffing and scheduling in home healthcare. In this model, first-stage decisions correspond to the staffing and scheduling of caregivers at each geographic district. Second-stage decisions are related to the temporary reallocation of caregivers to neighboring districts, to contact caregivers to work on a day-off, and to allow under-staffing and over-staffing. The proposed model is tested on real-world instances, where we evaluate the impact in costs, caregiver utilization, and service level, by using different scheduling policies and recourse actions. Results show that when compared with a deterministic model, the two-stage stochastic model leads to significant cost savings, as staff dimensioning and staff scheduling decisions are more robust to accommodate changes in demand. Moreover, these results suggest that flexibility in terms of the use of recourse actions is highly valuable, as it helps to further improve costs, service level, and caregiver utilization.

3 - Dynamic appointment scheduling with forecasting for priority queuing systems with access time service levels
Ka Yuk Carrie Lin

This paper analyzed a priority queuing system with access time service level standards for dynamic arrivals. Motivated by the public outpatient appointment systems, several variants of an online appointment system are explored, including real-time scheduling, delayed scheduling and notification, with or without rescheduling. Performances are measured by the proportion of requests that can access the service within the target time specific to their priority class and the access time percentiles. The difficulties of solving this problem include the problem size, time-varying demand and planning horizon considered. A linear goal programming model and a variant of the transportation model are formulated for the service level objective. For instances with moderate or low service level requirements for lower priority class(es), the deterministic problem can be solved by the transportation simplex method. Applying both algorithms with double exponential smoothing forecasting method using tracking signal and adaptable parameters, rolling schedules are developed for the dynamic problem. In the experiments designed based on several high-demand specialist outpatient clinics, scenarios are created to mimic different patterns of demand variations in a one-year arrival horizon. We compare results of the dynamic models with the deterministic model assuming demand uncertainties are known in advance. The annual reported performance statistics also serve as reference in comparison.

4 - Optimizing ambulance dispatching and relocation
Maria Eugénia Captivo, Ana Sofia Carvalho, Inês Marques

Emergency Medical Service (EMS) is one of the most important health care services. Its main goal is to provide basic medical care for any person in an emergency situation. EMS has to manage and mobilize several resources, e.g. high specialized equipment and highly skilled staff. The main challenge is the huge level of uncertainty involved. Exact methods, heuristic algorithms and simulation have been developed to include real life features. In the EMS context, the decision-making process is very important as decisions made are usually closely related, having a direct impact in the service's quality. Three levels of decision can be identified: strategic, tactical and operational. This work focus on the operational level by solving the dispatching and relocation ambulance problems. The decision of which ambulance to send to each emergency is considered in the dispatching problem. The relocation problem includes two decisions focused on maximizing the system's coverage to face future emergencies: i) where to relocate ambulances that have finished the service and ii) whether additional relocations between bases are needed. An effective and efficient EMS response is needed, so it is essential to have an optimized system. In Portugal, practices have been based in handmade tasks. We propose optimization approaches to help managers in the decision-making process at the operational level tasks.

■ MD-53

Monday, 14:30-16:00 - 4D UPV 1.4

Seru Production and Price/Lead-time Competition and Financial Distress

Stream: Operations/Marketing Interface
Chair: *Kathryn E. Stecke*

1 - Newsvendors' equilibrium strategies under price and lead-time competition
Zhengping Wu

Lead-time has been increasingly used as a competitive weapon, in addition to price, to attract customers. This talk considers multiple newsvendors selling substitutable products to the same market where customer demand depends on price and lead-time, and analyzes the newsvendors' equilibrium price, inventory, and lead-time decisions.

2 - Matching uncertain market demand with seru production design
Yong Yin

This presentation introduces a seru production system to cope with shorter product life-cycles,uncertainty in product types and demands. Analytical theorems from this research can be used to explain seru benefit observation. We show that a JIT-OS design problem is NP-hard. A stochastic dynamic JIT-OS algorithm is developed to obtain stable solutions.

3 - Investigating operational factors on the way to financial distress
Nagihan Comez Dolgan

Every year there are many firms around the world that end businesses. In fact, these bankrupt firms face financial distress before they actually end their businesses. Insolvency or declaring bankruptcy for these firms is not a sudden event, but in the opposite it is a gradual process including financial distress. In these terms, it is so valuable to understand an upcoming financial distress so that firms can project their future. In the literature, there are studies which investigate the relation between financial ratios and financial distress. However, there is quite scarce number of work that also account for operational factors in financial distress prediction and analysis. In study, we explore various operational variables in terms of not only considering their single values in time, but also their trends on the way to a financial distress. For this purpose, we use public firm-level panel data and conduct an empirical analysis. Our purpose is to highlight the importance of inclusion of operational metrics, which was ignored in traditional financial distress research, in understanding how some firms enter a financial distress period.

4 - The impact of platform-based product design on product differentiation
Hamed Jalali, Maud Van den Broeke, Inneke Van Nieuwenhuyse

Many companies resort to platforms to develop products targeted at different market segments (e.g., Volvo's scalable platform architecture is used to derive different models, such as the XC90 and V60). A lot of research exist on platforms and product assortment decisions separately; however, only a handful of articles analyze platform and product design decisions together. All of these articles focus on vertically differentiated products, however, we allow for both vertical and horizontal differentiation. Where the former refers to differences in quality (e.g., all customers prefer a better engine), the latter refers to differences in subjective features (e.g., some customers prefer a blue car, while others a grey one). In this paper, we study the impact of using a product platform on the optimal vertical and horizontal differentiation elements. We employ the Hotelling or locational choice model to describe the choice of customers in a market with two quality segments: low-end and high-end (the high-end segment has a higher valuation for the quality). To maximize the firm's profit, we simultaneously optimize the platform quality, product prices, as well as the products' quality and features. Our analysis allows for new findings. For instance, contrary to intuition we find that under certain conditions, the use of platforms can limit differentiation.

■ MD-54

Monday, 14:30-16:00 - 4D UPV 1.6

Multicriteria Assessment

Stream: Energy Economics, Environmental Management and Multicriteria Decision Making
Chair: *Ana Barbosa-Povoa*

1 - Multi-criteria analysis and consequential lifecycle assessment of solid waste management - an integrated approach
João Clímaco, Anna Bernstad Saraiva, Rogério Valle, Cláudio Fernando Mahler

In this communication we aim to show how to improve the decision aiding process in Solid Waste Management (SWM) by combining Consequential Life Cycle Assessment (CLCA) and Multiple Criteria Decision Aiding (MCDA) techniques. The management of food waste from households in the city of Rio de Janeiro will be used as a case study. Combining CLCA and MCDA seems useful for improving aggregation of LCA-results, in order to identify the most preferable alternatives in situations where no alternative is preferable in relation to all investigated impact categories. The aim is also to investigate the influence of different perspectives on the importance of different environmental impacts. VIP-Analysis software was used, because it is an MCDA decision support tool using the additive model coping with incomplete information on the scaling constants, and these characteristics seem very useful to deal with the case study. The results will be presented and discussed from an OR point of view.

Note: Rogério Valle died in 2017

2 - Exploring the use of multi-criteria decision approaches for chemical alternatives analysis
Charles Corbett, Christian Beaudrie, Tom Lewandowski, Timothy Malloy, Xiaoying Zhou

Recent approaches to improving chemical safety focus on prevention, and involve comparing and evaluating a regulated chemical or process and its alternatives across a range of criteria. Alternatives analysis (AA) is a method for conducting such assessments, which are inherently multi-dimensional and based on incomplete and incommensurate information. Decision-makers typically use ad hoc narrative approaches to perform AA. We report on our findings from a workshop in which we conducted a series of AA exercises with 12 participants from businesses and government agencies. The participants conducted the first AA individually prior to the workshop, then during the workshop they performed another AA using (multi-criteria decision analysis), individually or in a small group, and a third AA using structured decision-making (SDM) in a group setting. We surveyed the participants after each of the AA exercises, and found that their confidence in and satisfaction with the decision and method varied widely across settings.

3 - Evidence for overcoming the efficiency gap by fully integrating the decision process
Christian Schützenhofer

An empirical and comparative analysis of the effectiveness of the internalization of efficiency management by ISO mgmt. systems vs. external audits. Literature documents many barriers to energy efficiency but few working methods to overcome these. In the case of firms we argue and provide supportive data for one such working policy. We propose the internalization of the management process of identification and organization of the implementation of efficiency measures via standardized processes. These are so called management systems as documented in ISO14001 (environmental mgmt. system) and ISO50001 (energy mgmt. system). We find supportive data of a cross section of industries in 48 Austrian large firms, realizing 165% more savings, measured by actual energy saved than the control group. Methods: Analytical: comparative analysis of documented energy efficiency barriers vs. prescribed management tools from ISO standards to circumvent them. Quantitative: comparison of firms' resulting savings from enacting measures of the two cases: firms provided with ideas via external energy audits and following their given management processes vs. internal management system audits and implementation via management process as prescribed by ISO14001 or ISO50001. Results: We found a 165% increase of savings compared to the base case of external audits and non-ISO certified energy management processes and abstracted the basic management methods leading to this success.

4 - Environmental impact assessment in supply chain design and planning models: goal and scope definition challenges
Bruna Mota, Ana Carvalho, Maria Isabel Gomes, Ana Barbosa-Povoa

Environmental concerns from stakeholders such as governments, customers and NGOs are increasing the pressure placed on companies. However, environmental impact assessment is not easily applicable in supply chain related decisions. Several environmental impact methodologies have been proposed in the literature and Life Cycle Assessment (LCA) has gained distinction and has been recommended by the European Commission as the most adequate and complete method currently available. This work specifically addresses the challenges in the "Goal and Scope definition" step within LCA in its application to supply chain design and planning models. Of the outmost importance, in this step several decisions are taken related to system boundaries as well as methods selection, which significantly influence the direction and potential outcomes of the study. This impact is assessed and analysed in this work. ToBLoOM (Triple Bottom Line Optimization Modelling), a multi-objective mixed integer linear programming model developed for the design and planning of sustainable supply chains, is applied to the supply chain of a company in the pulp and paper industry, specifically to the supply chain of uncoated wood free (UWF) paper. Different decisions taken at the "Goal and Scope" definition step are studied through different scenarios. Managerial insights on the application of environmental impact assessment methodologies in supply chain design and planning models are derived from this work.

■ MD-55

Monday, 14:30-16:00 - 4D UPV 2.1

Academic-Practitioner Discussion Panel

Stream: Making an Impact I
Chair: *John Hopes*

1 - Academic-practitioner discussion panel: getting the best from each other
Ruth Kaufman

Academics and practitioners have different incentives, and different contractual, personal and professional objectives, but there are considerable areas of overlap and opportunities to learn from each other. This is the third successive EURO conference to bring academics and practitioners together for a question-and-answer panel. Previous panels have considered the obstacles in the way of academic-practitioner collaboration, and ways of overcoming them. This panel will focus particularly on how we can get the best from each other: what would academics like practitioners to know and do, and vice versa. A brief recap of the conclusions from previous panels will be followed by short introductions from experienced academics and practitioners, followed by questions and contributions from the audience.

■ MD-56

Monday, 14:30-16:00 - 4D UPV 2.2

Optimization in Renewable Energy Systems III

Stream: Optimization in Renewable Energy Systems
Chair: *Andreas Bley*

1 - Comparing time aggregation techniques in relation to capacity-expansion modeling
Stefanie Buchholz

A high priority of green energy combined with a hard constraint of demand satisfaction causes system flexibility to be the core building block of a stable energy system. In order to both detect the need for flexibility as well as the optimal flexibility technologies satisfying these needs at minimum cost, the system should be analyzed on an hour-to-hour scale for a long period of time. This often leads to computationally intractable models and one way to regain tractability is to aggregate the time domain. Many different aggregation techniques have been developed all with a common goal of selecting representative time slices to be used instead of the full time scale, causing a model size reduction by the number of variables and/or constraints. The art of aggregation is to balance the model complexity against the solution quality, making validation of the techniques crucial. We come up with a couple of new aggregation techniques, which we validate according to the full size model but also compare to other techniques from the literature. We look into the sensitivity of the performance of the techniques to different data sets and to different model features. With a focus on the complexity of the aggregation techniques, we try to answer the question whether more complex aggregations actually provide better estimates, and experimentally quantify the gains.

2 - European industries' energy efficiency and performance under different productive regimes, revealing the role of heterogeneity, path dependence and energy mix

Eirini Stergiou, Kostas Kounetas

Energy consists an indispensable input in production process and plays a crucial role on countries' growth and human development. Because of the strong and sustained economic growth that exists in the last decades, the demand for energy has been increased massively. In order to achieve environmental sustainable growth, EU has devoted sizable resources towards energy efficient and saving policies through the adoption of social and physical infrastructures to support CO2 mitigation and encourage sustainable development. We model a productive and energy efficient performance of European industries taking into account both desirable and undesirable outputs under a metafrontier framework for 27 European countries and 14 industrial sectors of manufacturing over the 1995-2011 period. This allows for a detailed consideration of the efficiency improvements made possible via technological spillovers within a given class of membership. In a first stage, DEA and DDF approaches were used for the estimation of productive performance, energy efficiency and technology gaps. In a second stage, GMM estimators are employed in order to investigate the endogenous relationship between energy efficiency and productive performance and the role of the implied technology as it is conveyed by the level of each country. Moreover, we investigate the role of energy mix, the existence of path dependence of technology heterogeneity in conjunction with the role of the corresponding group membership.

3 - Uncertainties and impacts of the demand response in the European power system

Héctor Marañón-Ledesma

An optimal planning of the energy transition is crucial to assess the right long-term investments. The so called "winter package" by the European Comission (EC) includes among other measures empowering electricity consumers, allow them to provide and consume flexibility. It is left to see what amounts of energy flexibility consumers will reach in this framework regulation. The question that we want to answer is how the power system develops considering the challenges and uncertainties of DR flexibility. By means of the European Model for Power Investments with Renewable Energy (EMPIRE), the long-term development of the power sector until 2050 is analyzed. The stochastic optimization model EMPIRE uses a multi-horizon approach that consists of decoupling the short-term operation and the long-term strategic dynamics. By changing the limits on potential DR capacities and DR investment costs, three possible development scenarios for DR are created. With a stochastic optimization multi-horizon model we study the impacts of long-term DR uncertainty. The results of the stochastic solution show sensible DR investments before uncertainty is revealed. Due to the large solar capacities expected for 2035 and the support that DR can offer to RES integration, flexible consumers are system-wise efficient even when considering pessimistic scenarios. Flexibility supplied by DR loads partially substitutes battery storage capacity in each scenario and decreases system costs.

4 - A Lagrangian solution approach for multi-sector energy system optimization

Andreas Bley, Frank Fischer, Angela Pape

We consider the problem of optimizing the strategic development of a national energy supply system over multiple incremental planning stages. Our model includes several energy sectors with numerous types of power demands and generation and storage technologies, a high penetration of renewable energies, several cross-sector power transformation options, the underlying transportation networks, and several scenario-depending technical, economical and political parameters. While design and dimensioning decisions are described per planning stage, power productions, consumption and flows are modeled using a time-series per stage. This leads to optimization models that are computationally unsolvable in practice, even for very small test examples. In this talk, we present a Lagrangian solution approach to solve this problem. The approach combines a Lagrangian relaxation, which relaxes several coupling constrains and decomposes the problem into independent unit-commitment-type problems in order to compute globally valid lower bounds, and some problem tailored heuristics that compute near-optimal globally valid solutions based on the relaxation's solution. The proposed approach runs substantially faster than solving the complete model using a state-of-the-art solver and permits the solution of real-world size problems.

■ MD-57

Monday, 14:30-16:00 - 4D UPV 2.3

Data Analytics for Bioinformatics

Stream: Computational Biology, Bioinformatics and Medicine

Chair: *Sofiane Oussedik*

1 - Quality criteria for supply optimization: study case in an oncological healthcare institution

Juan Pablo Zamora Aguas, Oscar Mayorga T., Jair Eduardo Rocha-Gonzalez

This paper presents an optimization model for the decision making of supply operations. Which includes the quality concept for operational cost reduce. The context of the research is about oncological drugs supply chain in a Colombian Healthcare Institution. In this study, the poor quality of the medicines as related to the defects due to failures in the storage and distribution processes (Newton et al., 2011). The quality of the health services are consequence of logistics risk in Healthcare Institutions (Zamora Aguas, Adarme, & Arango Serna, 2013). The lack of controls in the supply chain has been one of the causes of the poor quality of medicines (Hetzel et al., 2014). In Colombia, 8,26% of medicines evaluated between 2006 and 2010, had failures due to expiration, damages in packages and packaging (Pribluda et al., 2012). The quality failures of oncological drugs in supply chain operations were analyzed. The poor quality in operational and administrative logistics was considered. The parameters associated with supply chain operations and quality, were established. A mixed-integer linear programming model was proposed, and an scenario evaluation for to improve the impact on oncological healthcare services was done.

2 - The use of continuous-time Markov models to disentangle differences in patterns of long-term functioning for children with attention-deficit/hyperactivity disorder

Qi Cao, Roel Freriks, Jurjen van der Schans, Annabeth Groenman, Pieter Hoekstra, Maarten Postma, Erik Buskens, Jochen Mierau

Purpose: We aim to validate the use of Markov models to disentangle patterns of long-term functioning for children with Attention-Deficit/Hyperactivity Disorder (ADHD). Methods: Data is retrieved from the Multimodal Treatment Study of ADHD (MTA). Three states of functioning were developed based on a six-point delinquency scale. Differences in patterns of long-term functioning between the ADHD and non-ADHD cohort were estimated with an ordered logit model and illustrated with transition matrices. Subgroups within the ADHD cohort were established based on four treatment modes. Treatment effects within the ADHD cohort were determined with a two-part model. With a continuous-time Markov model patterns of long-term functioning of children within the ADHD cohort were predicted over a ten-year period and validated against the observed data. Results: We found statistically significant differences in level and patterns of functioning between the ADHD and non-ADHD cohort ($P<0.01$). No treatment effects were found within the ADHD cohort ($P>0.10$). Good validation results were depicted with the predicted average probability of not reaching the absorbing state being 0.855, 0.802, 0.813, and 0.876 respectively for the treatment groups we considered. Conclusion(s): This study shows that continuous-time Markov models using delinquency scale as a proxy for disease progression can be used to disentangle and predict the differences in patterns of long-term functioning for children with ADHD.

3 - Integer and constraint programming approaches for long-term care facility location

Mert Paldrak, Gamze Erdem, Gokberk Ozsakalli, Deniz Türsel Eliiyi

Location planning for healthcare facilities and their capacity planning has become a vital issue in many developed and developing countries due to the aging of the population. According to the data gathered by World Health Organization (WHO), 8 percent of the world's population is aged over 65, and this percentage can increase up to 16 percent by 2050. As the number of ill people will increase in parallel, there is a need for making the best planning for locations and capacities of the healthcare facilities. This study focuses on determining the locations of long-term care facilities with the objective of minimizing the maximum patient workload on any facility for a fair assignment. The problem is modelled as both an integer programming model and a constraint programming model. Computational experiments are performed for evaluating the performances of the developed models. The results of the experiments obtained by the two different approaches are compared and contrasted in terms of solution quality and computation time.

4 - Overview of decision optimization for data science experience

Sofiane Oussedik

This presentation will give you an overview of a new offering, IBM Decision Optimization for Data Science Experience, a new private cloud offering that delivers a data science platform with decision optimization, machine learning, and predictive analytics. The new offering allows data scientists to build and evaluate machine learning and optimization models in a unified environment.

Business analysts can configure and evaluate proof-of-concept applications based on the data scientist's models, then application developers can integrate the artifacts created into the operational application required by the line-of-business stakeholders.

■ MD-58

Monday, 14:30-16:00 - 4D UPV 2.4

Teaching OR/MS II

Stream: OR Education
Chair: *Aline Leão*

1 - Methods and tools in operations management - experience from inverted-classroom-teaching

Stefan Treitl

The Specialization Program in Production Management at WU Vienna University of Economics and Business consists of five courses on the undergraduate level. The first two courses are compulsory courses that cover the basics in strategic, tactical and operational production management. The third course covers "Methods and Tools in Operations Management" and is held in a PC-Lab. It is the idea of that particular course to encourage students to immediately apply the knowledge from the basic courses. One big challenge in teaching "Methods and Tools" is to cope with the heterogeneity in the student group (e.g. different previous knowledge on software systems and methods). That is why the concept of "Inverted Classroom Teaching" has been introduced. In this teaching model, the students prepare the content themselves before the class using online learning materials (e.g. lecture notes, videos, etc.). During the actual class, the students work on their own while the instructors serve as individual coaches. The feedback for this new teaching model from students and instructors was quite diverse. In this talk we want to show the experience of teaching inverted-classroom-style in this particular context. First, the rationale for the course design and the syllabus is discussed in detail. Afterwards, the methods and tools that are used are shown before feedback from students and instructors are highlighted. Finally, major insights and takeaways for instructors are summarized.

2 - Legos and board games as resources for designing student-based learning experiences in optimization

Pablo González-Brevis, Cristian Palma

In this paper, we will address our experience in designing student-based activities for teaching and learning Optimization in the Industrial Engineering program at Universidad del Desarrollo, Chile using Legos and modern board games as resources.

We will present different activities varying from mathematical modeling and the simplex method with Legos to networks and algorithms with modern board games. Students have stated that using these resources are a good and fun way to experiment different approaches on a safe environment. Also, some of the activities have proven to help understanding more complex concepts.

3 - Playful labs to support the teaching of linear programming

Jainet Bernal Orozco

The current paper describes the design, validation and operation of two labs in order to support the teaching process of the math formulation of linear programming (LP) problems. Both labs are oriented to motivate and sustain the appropriation of math formulation through the playful learning, what in the hotbed we're called "Playful Labs for the teaching in engineering"

The first make reference to Cutting-stock Problem for which letter-sheet are used from which the participant should identify how many sheets cut and how should be cut to satisfy thedemand of two pieces (the first of 101.5 x 101.5mm and the second one of 127 x 76mm) in orderto minimize the waste production. This playful lab is used as introductory pedagogical device to the course of PL in the Universidad Central, in Bogotá

The second playful lab correspond to a simplify scene of the transfer of patients operation by the ambulances that are operated by the state, for the emergencies attention. This lab support the student formation in the concepts of activation and deactivation of constrains in the LP problems formulation

The results obtained were satisfactory, improving the motivation for this kind of topics and a higher remembrance of the concepts involved in the playful. It's also remarkable the adaptability of both labs tooperate the playful in different spaces, varying the number, the profile and the previous knowledges of the participants

4 - Taking off with mathematics: an activity for introductory OR courses

Aline Leão, Franklina Toledo, Adaiton Moreira de Oliveira Filho

In this talk, we describe an in-class activity that consists of building a model glider using cheap materials. OR/MS and mathematical modelling are used to plan the cut of these materials. By performing proper one-dimensional cutting plans, two model gliders can be built. The activity was primarily designed for undergraduate operational research courses, but it can also be used with secondary students. It encourages the creativity and interest of students in the usage of mathematics in engineering, economic and environmental applications.

■ MD-59

Monday, 14:30-16:00 - 4D UPV 2.5

Supply Chain Modelling and Optimisation

Stream: OR Advances in Agribusiness
Chair: *Jorge E. Hernández*

1 - Determining the space and the percentage of preference of each product category of a department store by using multi criteria decision making methodologies
Gulcin Dinc Yalcin, Zehra Kamisli Ozturk

In a department store, customers can reach to a wide range of product categories which each has its own space in the department store. In literature, it is assumed that the percentage of space of product categories in a department store is known and then the optimal layout is tried to obtain by using several methods. However, a department store manager has to determine his/her department store's space requirement to maximize the profit besides the optimal layout. Therefore, defining the percentage of space of product categories in a systematic way is aimed in this study. Analytical Network Process (ANP) is used to determine these spaces for the perspective of department store manager. By using pairwise comparison with a department store manager in Turkey, weights of the factors and the percentage of space of product categories are determined. On the other side, customers decide to go to the department store for some of these product categories. Analytical Hierarchy Process (AHP) is used to determine the frequency of preference of the product categories in a department store by customers. Criteria for AHP are the product categories and there are no alternatives. Customers are asked to scale the product categories with each other. The percentage of preference of each product category are obtained. The results obtained by department store manager and customers are discussed.

2 - Routes planning for managing inventory at animal husbandry department
Sanjay Choudhari, Saurabh Chandra

The role of animal husbandry department is to improve the genetic qualities and behavior of farm animals by artificial insemination. The semen are collected from healthy animals, processed in the centralized laboratory and filled in straws. These straws are required to be frozen in low temperature for possible distribution to various livestock locations. These straws are transported and stored in small containers at livestock locations in low temperature using liquid Nitrogen. The liquid nitrogen at each livestock location need to be replenished regularly by refiling. The animal husbandry debarment previously prepared various routes based on judgement and experience of logistics planer for Nitrogen distribution.

This research work provides the possibility of redesigning the current routes plan for distributing liquid nitrogen to 177 livestock locations across a district. The objective of the work is to minimize the total cost of logistics in managing the entire distribution planning of liquid nitrogen at various livestock locations. The work uses the vehicle routing planning (VRP) concept and demonstrate the applicability of the model in agriculture industry. The model uses the Clarke and Wright's savings algorithm and develop Excel based spreadsheet model to solve the various scenarios of the above problem. It was found that the considerable saving in the total distance was achieved with significant saving in the annual cost using VRP concept in such industry.

3 - Optimization of cooperative production and distribution schemes in an agro-business model
Jose Velasquez, Camilo Gomez, Liliana Aponte

Efficient and fair agriculture is key to food security, sustainable growth and poverty reduction in developing countries. This research addresses decision processes in a multi-agent agro-industrial problem in the context of the Colombian post-war development. The challenge is to design production and distribution schemes that account for the individual interests of farmers, the shared interest of the farmers' cooperative, and the efficiency of the overall supply chain, considering prices that depend on production levels, which lead to a need for efficient coordination.

We propose an optimization-based methodology, in which Mixed Integer Linear Programming (MILP) models are implemented to: first, satisfy scenarios that pursue individual farmer's interests (i.e., maximizing profits); second, satisfy scenarios that pursue cooperative interests (i.e., collective efficiency); and third, design incentive schemes that exploit efficiency to incentivize farmers to adopt collectively beneficial policies without deterring individual benefits.

We illustrate our methodology with an example regarding the growing of multiple products in the context of a real agro-business model in Arauca (Colombia).

4 - Review on operational research advances in agri-food supply chains and societal challenges
Jorge E. Hernández, Janusz Kacprzyk, Andrew Lyons, Angel Ortiz, Hervé Panetto

Food production and growth has increased since the end of the last 20th century in response to the high increment in population. Therefore, a challenge for setting efficient and optimal Agri-Food Supply Chains is a multi-disciplinary need, where Operational Research has a key role to play to support Agri-Food Supply Chain decision-makers. Several risks and uncertainties (food safety, weather, volatile market conditions and commodity prices), faced by stakeholders, are making the Agri-Food Supply Chain Management a complex task. From the literature, several research questions are identified, such as: an optimised Agri-Food Supply Chain structure will reduce the administrative barriers once facing tariff cuts or changes in administrative regulations?; Can distorted competition risks be minimised by optimising trading policies?; and can the enhancement of food standards optimise Agri-Food Supply Chains performance and sustainability?. Therefore, and based on the on-going work under the H2020 RUC-APS research project network, this research work is oriented to contribute to Agri-Food Supply Chains decision-making field by covering, reviewing and analysing the current trends in Operational Research for supporting Agri-Food Supply Chains decision-makers, in special the multi-disciplinary real industry life challenges. This within the objective to propose an integrated framework based on standardised Operational Research structures to cover the key current key challenges.

■ MD-60

Monday, 14:30-16:00 - 4D UPV B.5

Meet the editors of EJOR

Stream: EURO Special Sessions
Chair: *Roman Slowinski*

1 - Some facts about the European journal of operational research (EJOR)
Roman Slowinski, Emanuele Borgonovo, Robert Dyson, José Fernando Oliveira, Steffen Rebennack, Ruud Teunter

The editors of EJOR will explain their editorial policy, and will give some current characteristics of the journal. They will also describe their approach to evaluation and selection of articles. Finally, they will point out topics of OR which recently raised the highest interest. Two other presentations in the session will be done by authors of representative and highly cited papers published recently in EJOR. Some further research developments and practical implications that followed these publications will be given by these authors. In the last part of the session, the editors will answer some general questions from the audience.

2 - The single-item green lot-sizing problem with fixed carbon emissions
Stéphane Dauzere-Peres, Nabil Absi, Safia Kedad-Sidhoum, Bernard Penz, Christophe Rapine

This presentation is based on our paper in EJOR (Absi et al., 2016), which considers a single-item lot sizing problem with a periodic carbon emission constraint. In each period, the carbon emission constraint defines an upper limit on the average emission per product. Different supply modes are available, each one characterized by its own cost and carbon emission parameters. The problem consists in selecting the modes used in each period such that no carbon emission constraint is violated, and the cost of satisfying all the demands on a given time horizon is minimized. This problem, introduced in Absi et al. (2013), has been shown polynomially solvable when only unit carbon emissions are considered. In this work, we extend the analysis to the realistic case of a fixed carbon emission associated to each mode, in addition to its unit carbon emission. We show that the resulting problem is NP-hard. Several dominant properties are presented, and two dynamic programming algorithms are proposed. We also establish that the problem can be solved in polynomial time for a fixed number of modes when carbon emission parameters are stationary. The presentation will end with a discussion on the extension of the problem to the multi-item case.

3 - The multi-vehicle traveling purchaser problem with pairwise incompatibility constraints and unitary demands: a branch-and-price approach
Daniele Manerba, Michel Gendreau, Renata Mansini

In the Multi-Vehicle Traveling Purchaser Problem (MVTPP), a fleet of homogeneous vehicles with a predefined capacity is available to visit suppliers offering products at different prices and quantities. The MVTPP aims at selecting a subset of suppliers, the relative purchasing plan, and the vehicles' visiting tour so to satisfy products demand at the minimum traveling and purchasing cost. We focus on a variant named MVTPP-PIC in which the products demand is unitary and Pairwise Incompatibility Constraints (PICs) must be considered. PICs prevent loading two incompatible products on the same vehicle. We propose a Column Generation (CG) approach based on a set covering formulation in which each column represents a feasible vehicle route associated with a compatible purchasing plan. To solve the pricing problem, we propose a combined use of a label-setting algorithm (solving a Resource-Constrained Elementary Shortest Path Problem on a duly expanded graph) and of a tailored branch-and-cut. Due to the integrality request on variables, we embed the CG into a branch-and-bound framework exploiting different branching strategies, thus obtaining a branch-and-price (B&P) procedure. Several accelerating strategies are also implemented. Our B&P outperforms, in solution quality and CPU time, an existing branch-and-cut on benchmark instances and optimally solves in a reasonable amount of time instances with up to 50 suppliers, 70 products, and 70% of cross-incompatibilities among products.

Monday, 16:30-17:30

■ ME-01

Monday, 16:30-17:30 - UPV Nexus

The Discrete Charm of Districting

Stream: Plenaries
Chair: *Ruben Ruiz*

1 - The Discrete Charm of Districting
Roger Z. Rios-Mercado

Districting or territory design problems involve essentially partitioning decisions. Given a set of basic geographical areas, the idea is to find a partition of these into clusters or districts in such a way that specific planning requirements are met. These requirements depend naturally on the specific application. Districting problems are motivated by very different applications, such as political districting, sales and service territory design, school districting, the design of territories for waste collection, to name a few. Through the years many ideas for tackling these very difficult discrete optimization problems have been successfully developed.

In this talk, we will go through some of the most representative models and features, highlighting particular properties and successful ideas for efficient algorithmic development. Special emphasis will be given to the computational issues and how particular problem structures and properties can be adequately exploited for efficient algorithmic design. The last part of the talk will include a discussion of current research trends on this fascinating class of discrete optimization problems.

Monday, 17:45-19:00

Tuesday, 8:30-10:00

■ TA-01

Tuesday, 8:30-10:00 - UPV Nexus

Community structure in complex networks

Stream: Keynotes
Chair: *Gerhard-Wilhelm Weber*

1 - Community structure in complex networks
Santo Fortunato

Complex systems typically display a modular structure, as modules are easier to assemble than the individual units of the system, and more resilient to failures. In the network representation of complex systems, modules, or communities, appear as subgraphs whose nodes have an appreciably larger probability to get connected to each other than to other nodes of the network. In this talk I will address three fundamental questions: How is community structure generated? How to detect it? How to test the performance of community detection algorithms? I will show that communities emerge naturally in growing network models favoring triadic closure, a mechanism necessary to implement for the generation of large classes of systems, like e.g. social networks. I will discuss the limits of the most popular class of clustering algorithms, those based on the optimization of a global quality function, like modularity maximization. Testing algorithms is probably the single most important issue of network community detection, as it implicitly involves the concept of community, which is still controversial. I will discuss the importance of using realistic benchmark graphs with built-in community structure.

■ TA-02

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S101

DEA, Banking, Financial Institutions I

Stream: DEA: Applications
Chair: *Julián Benavides*

1 - Evaluating the performance and ranking of Refah bank branches in Iran by using data envelopment analysis
Mohsen Rostamy-Malkhalifeh, Hossein Rahmati, Mohammad Ali Sahmani, Mohsen Ziaee

One of the success factors of advanced countries is paying attention to the efficiency of economic units, especially banks. In this regard, bank managers are required to provide a satisfactory answer to questions about the bank's operations, which is virtually impossible without evaluating the efficiency of the branches under their supervision. One of the methods for calculating efficiency for units with multiple inputs and outputs is the data envelopment analysis method. this method can determine efficient and inefficient branches, rank the inefficient branches and identify a benchmark for them to reach the efficiency frontier. Since all branches of a province are governed by a central unit, if this central unit achieves to the best performance, then all its headed units will be in the highest level of efficiency. Also, the ranking of the central branches can introduce the best benchmark which will improve the banking activities and customer satisfaction. The ranking of units allows constructive competition to reach the highest levels of profitability. In this research, a new model was used to ranking . . . branches of Rafah Bank as well as . . . . central branches of this bank in all provinces of Iran. By Using this method, the efficient and inefficient branches was determined and then the inefficient branches according to the efficiency amount was ranked.

2 - Evaluating efficiencies of financial holding companies in Taiwan: an application of copula-based stochastic frontier methods
Chi-Chuan Lee

Taiwan's financial institutions have has gone through a series of restructuring ever since the implementing of Financial Holding Company Act in 2001. The continuing consolidation policy aims to speed up financial innovations and stimulate market competition and technological progress. Financial services industry is now engaging in a wider array of financial activities. Given that financial holding companies (FHCs) face multiple production functions simultaneously, how to correctly measure and compare efficiency is therefore pivotal and worth a more thorough investigation. This paper applies the copula-based stochastic frontier methods to explore the relative efficiency of 14 financial holding companies for the period 2001-2016. Unlike most previous studies, the current work further accounts for synergistic effects produced by integrating the banking businesses and security businesses. The joint probability density function of the composed errors can be derived in the context of copula methods. The empirical results show that a consolidated financial institution with business diversification is indeed able to improve FHC subsidiaries' efficiency. Compared with the separate estimation, the efficiency gain from using the copula method, arising from the simultaneous estimation procedure, is confirmed. It is worth-mentioning that the choice of methodology has crucial inuences on the estimation results and the implied policy implications.

3 - Introduction to best classification in data envelopment analysis and using it to improve performance of Refah bank branches in Iran
Mohsen Ziaee, Mohammad Ali Sahmani, Hossein Rahmati, Mohsen Rostamy-Malkhalifeh

One of the basic methods for classifying is data envelopment analysis and it allow the classification to be accurate and principled way. The classification of bank branches is so important. For example, a decision is made by a bank lender responsible for lending a client to a customer. Some factors can be very effective in the decision to pay or the amount of the loan.The amount of the loan can be divided into classes with values and the applicant must be in one of these classes. But the important thing here is that with the previous experience for each of the above classes, there is an ideal person who compares with which the applicant is in that class. With these examples, we can say that classification is a data segment and placing data in different parts but according to a predefined benchmark. Classification is an observer-driven learning technique because it collects new data by having an educational data set as a guide. This method is also considered as a predictor method. Now, if this classification is made among the central branches of the banks, then it will create a healthy competitive environment to achieve a higher ranking Which can increase the efficiency of the banking's efficiency. Therefore, the issue of ranking of Branch banks in Iran was the main objective of this research. In this regard, by using classification and data envelopment analysis data, ...branch offices of Iran's Refah Bank were reviewed and a new classification method was applied to them.

4 - Efficiency determinants of Brazilian commercial banks
Julián Benavides, Juan Garrido, Guillermo Buenaventura, Felipe Henao

This research studies the efficiency determinants of 153 Brazilian commercial banks, using a database of quarterly financial statements assembled from the Banco Central de Brazil from 2007 to 2016. To measure efficiency, we apply a DEA model under a hybrid approach, resulting from mixing the intermediation and production approaches, which is closer to the way the banks operate. Our input intermediation variables include funding and equity; while our production variables include interest expenses, non-interest expenses, and income tax expenses. Output variables include intermediation variables such as loans and leases, negative outputs (intermediation) such as loan and lease allowances, loan loss provisions and production variables such as interest income, non-interest income and active rate. Our preliminary results from a Probit analysis yield that the determinants of efficiency include a measure of market concentration (Herfindahl-Hirschman Index), which has a negative impact, while the ratio of equity to assests and the ratio of loans and funding have a positive impact on efficiency. However, efficiency determinants are affected by the bank type: private local, private foreign or state owned.

■ TA-03

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S103

Facility Location in Supply Chains II

Stream: Location Analysis and Optimization
Chair: *Jean-Sébastien Tancrez*

1 - The design of resilient food supply chain networks prone to disruptions
Seyed Mohammad Gholami-Zanjani, Walid Klibi, Mohammad Saeed Jabalameli

Food supply chains are perturbed by an increased supply and demand uncertainty, but nowadays they are also suffering from disruptions. In the specific context of a food supply chain, such disruptions could be linked to natural hazards, industrial accidents or epidemics. The latter context was little studied in the existing literature, although there are numerous cases reported in practice. At the strategic level, this require a novel risk modeling approach and advanced models for the food-supply chain network design problem. Our interest in this research is to propose a robust two-stage scenario-based mathematical model to design a resilient food supply chain under both business-as-usual and epidemic disruptions. To involve uncertainties, epidemics disruptions are modeled as stochastic processes and a Monte-Carlo procedure is derived to generate plausible scenarios. The modeling approach covers special characteristics of food products such as perishability, discount and inventory holding cost based on quality of products. Besides, a number of proactive and reactive resiliency strategies are incorporated into the general model to enhance the resilience level of the designed supply chain network. The developed models are validated based on numerous problem instances, and managerial insights are gained.

2 - Evaluating horizontal cooperation in supply chains
Thomas Hacardiaux, Jean-Sébastien Tancrez

Horizontal cooperation consists in the collaboration of companies that work at the same level of the supply chain. The literature discusses several real-life cases and experimental studies of horizontal cooperation, showing that these partnerships generate cost reductions of various magnitudes. This work analyses the benefits for companies to use a joint supply chain network, and investigates the markets' and partners' characteristics that influence these benefits to understand when horizontal cooperation is particularly profitable. For this, we propose a location-inventory model formulated as a conic quadratic mixed integer program, and we compare the costs of stand-alone companies and horizontal partnerships. The model integrates the main logistical costs such as facility opening, transportation, cycle inventory, ordering and safety stock costs. We perform about 30,000 experiments varying the parameters values (i.e., vehicle capacity, facility opening cost, inventory holding cost, ordering cost and demand variability) and observe a cost reduction ranging from 15% to 30%. The benefits come from the increased delivery frequency, the improved loading rate, the reduced distances, the opening of joint facilities and the reduced lead times. We also discuss the impact of the number of partners, of the ability to open new facilities and of the retailers' locations. Overall, our goal is to offer valuable managerial insights for companies wishing to collaborate.

3 - A methodology for the design of express service lines
Victor Bucarey, Cristian Cortes, Fernando Ordonez, Bruno Stefoni

In this work we address the problem of designing a new express line for a public transit system. This problem is difficult as the integer design decisions are combined with the assignment of passengers from their own travel decisions. Our approach decomposes de problem into an integer optimization problem that aims to design an express line for serving poorly satisfied passengers along with an equilibrium model, the Stochastic Transit Equilibrium (STE), to evaluate how passengers are assigned to a given transit system. The proposed express line is constructed by using the STE model to identify OD pairs that have poor service, identifying the demand that is considered in the integer optimization design problem. We present an example of the use of this decomposition approach to propose efficient express lines for a real transit system of a city of 250.000 habitants.

4 - Flexibility mechanisms for the design of robust supply chains
Jean-Sébastien Tancrez, Matias Schuster

In this work, we propose a stochastic programming model for the design of robust supply chains operating under demand uncertainty. Strategic decisions, i.e., the location and capacity of permanent distribution centres, are taken before uncertain long-term demand changes. Operational decisions, regarding allocation, temporary distribution centres and lost markets, can be adjusted once the demand is observed. Accounting for these various flexibility mechanisms when designing the supply chain allows to deal with long-term changes in demand more effectively, and to obtain a more comprehensive uncertainty mitigation framework. We integrate these decisions in a location-inventory model formulated as a conic quadratic mixed-integer program, which can be efficiently solved using a commercial software. We derive managerial insights from a large set of experiments, analysing the usefulness of integrating various flexibility mechanisms in the design of robust supply chains. In particular, these flexibility mechanisms allow to decrease the overall cost by around 5%. In addition, they reveal interesting trade-offs. For instance, we observe that lost markets and temporary distribution centres appear to be complementary, and that the reallocation of flows allows making a better use of excess capacity.

■ TA-04

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S104

Financial Modelling and Applications

Stream: New Challenges in Investment Strategies, Risk and Financial Modelling
Chair: *Giulia Rotundo*

1 - Evidence regarding external financing in Romanian exporting medium sized enterprises from manufacturing sector
Eduard Gabriel Ceptureanu

In this paper, we test a theory regarding effect of collaborations of medium-sized enterprises (MSEs) on their export intensity and firms' access to external financing. We test our hypotheses on a sample of 143 Romanian manufacturing MSEs using Partial Least Squares and find partial support for the relationships. The implications of these results are discussed.

2 - Debt growth as a leading indicator for stock returns: evidence from an emerging market
Rouhollah Ebrahimabadi, Gurjeet Dhesi

Research investigation into the relation between debt structure of a firm and its expected stock return. This mechanism is still seems to be unresolved. The aim of this paper is to investigate this relationship deeper. Following the capital structure literature, this paper finds no significant evidence of any relation between debt to equity ratio and stock return in an emerging market. However we show that a major change in debt level (either negative or positive), is an indicator of future positive abnormal return. Extreme changes in debt level either positive or negative can have different expiations; however, whichever direction it moves it will be followed by unusual return in future. Immediate drop in debt level can be a signal for large expected incomes that firm feel confidence about, therefore firm diced to pay out their debt. On the other hand, massive increase in debt level might be a signal for highly profitable investment opportunity that firm feels certain about its return, therefore it is able to convince shareholders and market to borrow substantial amount of money. The evidence suggests that there exists a non-linear U-shape relationship between changes in the debt level and expected common stock returns.

3 - Capturing long-term coupling and short-term decoupling crude oil and natural gas prices

Hayette Gatfaoui

This paper scrutinizes the relationship between the U.S. crude oil and natural gas prices. The relationship is unstable over time and exhibits regime changes, in line with current research. Structural break tests determine corresponding regime changes, which depend on technological, economic and geopolitical factors among others. In particular, crude oil and natural gas prices decouple in the short term while they couple in the long term. During decoupling periods, crude oil and natural gas prices exhibit generally a negative correlation. Conversely, they exhibit mostly a positive correlation during coupling periods. Using Kalman filter in linear regressions, we allow for stochastic coefficients (e.g. local linear trend capturing non-stationarity) to appraise the time-varying relationship between crude oil and natural gas prices. Random coefficients illustrate the uncertainty in energy costs and prices, and handle nonlinearity. Incidentally, decoupling price periods exhibit a higher degree of uncertainty. Our findings depict thus changes in the competition between oil price makers and takers, and the impact of technological improvements, including the shale gas revolution. They also open the door to possible short- and/or long-term hedging and arbitrage strategies between crude oil and natural gas prices.

4 - Estimating enterprise values based on linear optimization

Soeren Guntram Harms, Marcel Clermont, Heinz Ahn

While the predominating method for estimating an enterprise's value is based on discounting future cash flows, the validation of the determined values is still a subject for discussion. In most cases, co-called comparable company methods are applied. These methods estimate the value of an enterprise by comparing it to a peer group of reference units. This peer group consists of similar enterprises operating in the same industry. A major advantage of such methods is their ease of application. However, the conventional methods can only consider monetary measures and indicators in the enterprise value de-termination, while aspects like ecological sustainability and social balance are neglected. Being aware of this deficit, we illustrate an alternative approach for estimating and validating enterprise values. Our approach is able to consider any kind of similarities between the enterprise under evaluation and the used reference units, regardless if the measures are monetary or non-monetary. This is achieved through the sequential application of two linear optimization problems, which are inspired by the concept of Data Envelopment Analysis.

■ TA-05

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S105

Exact Methods for Vehicle Routing Problems II

Stream: Vehicle Routing and Logistics Optimization I
Chair: *Hakan Altunay*

1 - A multidirectional dynamic programming algorithm for the shortest path problem with resource constraints

Ilyas Himmich, Issmail El Hallaoui, Francois Soumis

The shortest path problem with resource constraints finds the least cost path between two nodes in a network while respecting constraints on resource consumption. The problem is mainly used as a subproblem inside column generation for crew scheduling and vehicle routing problems. The standard approach for the subproblems is based on dynamic programming. This class of methods is generally effective in practice when there are only a few resources, but it seems to be time-consuming for huge instances with many resources. To handle this problem, we propose a new exact primal algorithm called the multi-directional dynamic programming algorithm (MDDPA). The proposed approach splits the state space into small disjoint subspaces. These subspaces are sequentially explored in several iterations, where each iteration builds on the previous ones, to reduce the dimension of the subspaces to explore and to quickly generate better paths. Computational experiments on vehicle and crew scheduling instances show the excellent performance of our approach compared to the standard dynamic programming method. In particular, MDDPA is able to generate feasible paths with up to 90% of the optimal cost in less than 10% of the time required by standard dynamic programming. This feature is useful in column generation and may greatly reduce the computational effort, because we can stop the MDDPA solution process once columns with sufficiently negative reduced costs are obtained.

2 - Branch and cut solution approach for the capacitated location routing problem

Theocharis Metzidakis, Panagiotis Repoussis, Manolis Kritikos, George Ioannou

This work presents a Branch and Cut solution framework for the Capacitated Location Routing Problem (CLRP). The CLRP is a very challenging combinatorial optimization problem. Given a pool of candidate locations, we need to optimally locate a number of facilities. On the other hand, based on the location solutions, we need to design least cost vehicle routes in order to service a set of geographically scattered customers with known demands using a fixed fleet of homogeneous capacitated vehicles. In this work we propose a Branch-and-Cut solution approach that incorporates various classes of valid inequalities and cuts as well as powerful separation procedures. Based on benchmark datasets taken from the literature, various computational results are reported.

3 - Mathematical models and an exact algorithm for the heterogeneous vehicle routing problem

Federico Perea, Gilbert Laporte, Ruben Ruiz, Luis Fanjul Peyró

In this talk we address the vehicle routing problem with an heterogeneous fleet, in which different vehicles have different capacities and run at different speeds. A review of mathematical programming models for this problem is presented, as well as a new formulation of our own. Based on this new formulation, a decomposition method is presented. This research is tested by means of a computational experience.

4 - A new mathematical model for the close-open vehicle routing problem

Hakan Altunay

In this study, we consider the close-open vehicle routing problem (COVRP). The COVRP is one of the latest variants of the vehicle routing problems. In this variant, unlike the classical vehicle routing problems, whereas owned vehicles must return to depot, hired ones are not required to return to the depot after servicing the last customer. Firstly, we propose a novel mathematical model that improves and extends the previous formulations for the COVRP. Then, the proposed mathematical model is tested with a case study and computational experiments are conducted to assess the performance of the model.

■ TA-06

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S106

Consumer Returns in Retail

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Alexander Hübner*

1 - Selling consumer returns on the secondary market: an OEMs strategy to deal with a non-cooperative retailer
Andrea Borenich, Yanick Dickbauer, Marc Reimann, Gilvan C. Souza

In the electronics industry, consumer returns are typically returned by the retailer to the manufacturer for a full refund of the wholesale price. One example for this would be the practice of Philips. The problem with this practice is that it is difficult to motivate the retailer to reduce the returns. Both in practice and in theory different coordination mechanisms have already been tested and analyzed to achieve that goal, e.g. a limit on the maximum number of products which can be returned, or a rebate on the wholesale price whenever the retailer returns less than a target number of products. While these approaches target the volume of returns, they do not consider the subsequent disposition of the actual returns. As these products are typically lightly used (if at all), their residual value could justify remarketing on a secondary market. In this paper we consider this option by modeling an online store through which the manufacturer can sell the refurbished consumer returns. We study how the potential competition between these refurbished products and the new products affects the retailer's behavior. Our main finding is that the retailer never exerts more effort when faced with the competition through the online store. However, manufacturer profitability is always higher in the presence of the online store. Together these results imply that the effective re-use of the consumer returns and the reduction in the volume of returns are complementary.

2 - Optimal pricing of points in points plus cash reward programs
Ricardo Montoya

Customers in Reward Programs (RPs) typically accumulate points for their purchases that can be redeemed later for rewards. Recently, some RPs offer the option of combining a customer's points with cash to redeem them for products in a Points Plus Cash (PPC) frame. The price of these points need to be determined by the company considering various factors such as the consumers' consumption heterogeneity and willingness to pay for the points, the value of the product, and the cost of that product. The goal of this research is to determine the optimal price in a PPC scheme taking these factors into account. The proposed framework considers differences in consumption rates and product valuations by customers that allow a profit-maximizing firm to determine the optimal dynamic price. Our main result characterizes the optimal price as a function of the time remaining to the end of the selling horizon. We show that the price increases in time and decreases regarding the number of points required to be redeemed for the product. The optimal pricing uncovers three types of customers buying at different times during the selling horizon. We use the developed framework to compare the proposed pricing strategy to other pricing options such as constant pricing and also to explore extensions to our basic model.

3 - Closed-loop supply chain network design under demand, return and quality uncertainty
Sakine Batun, Kadir Biçe

We consider the problem of designing a closed-loop supply chain network under uncertainty in demand quantities, return rates, and quality of the returned products. We formulate the problem as a two-stage stochastic mixed-integer program that maximizes the total expected profit. The first-stage decisions in our model are facility location and capacity decisions, and the second-stage decisions are production quantities and the forward/backward flows on the network. We solve the problem by using the L-shaped method in iterative and branch-and-cut frameworks. We use our numerical results to estimate the value of the stochastic solution and the expected value of perfect information in different problem settings.

4 - The relationship between customer satisfaction and service quality in e-commerce
Evripidis Kechagias, George Chatzistelios, Georgios Papadopoulos, Dimitra Kyriou

The sufficiency of products and services on the global market has radically changed the relationship between suppliers and customers, and quality of services can be strongly associated with customer satisfaction and loyalty. Usually, after a few successful transactions, the customer begins to feel safe with the supplier and gradually becomes loyal. Thus, the competition for businesses, especially those providing electronic services, is shifting and focusing on the quality of customer service. The customer, today, is a cornerstone of the service delivery system. Therefore, for an enterprise to grow in a market with harsh competition, operational and strategic efficiency in delivering quality services is a necessity. It is widely known today that new technology through the Internet, the development of e-commerce and other e-business applications, is revolutionizing commercial businesses. New media become modern weapons for a business, small or big, to meet the demands of the market and the challenges of constant change since information and data are managed more effectively and efficiently. Understanding the customer's value is a guide for improving the quality of service provided as customers are the ones who judge the quality of products and services the company offers. Therefore, e-businesses need to be careful in meeting their customer needs and focus on the quality of the services they provide in order to satisfy those needs and expectations and eventually make them loyal.

■ TA-07

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S107

Analytic Hierarchy Process V

Stream: Analytic Hierarchy Process / Analytic Network Process
Chair: *Massimo Squillante*

1 - A dynamic hybrid modeling approach for global facility location
Hafiz Muhammad Khurram Ali, Khalid Akhtar, Sami Farooq, Mirza Jahanzaib

Global Facility Location (GFL) is a crucial and irreversible decision for top management of the global business firms, searching for potential countries in global markets. It, therefore, requires a broader analysis of a large number of influencing criteria. There are hardly any GFL studies focusing on the real world uncertainties, future dynamics and interaction of GFL stakeholders. This work is about establishing a new platform for dynamic analysis of GFL problems by screening out the most critical influencing parameters and establishing an initial pattern of Agent Based Modeling (ABM). Using a hybrid Fuzzy Analytic Hierarchy Process (F-AHP), the parameters initially explored from literature are prioritized and rankings in terms of objective-functions are calculated for a selected set of countries. The results of F-AHP models in terms of screened out parameters and Country Objective Functions (COF's) are used as inputs to the ABM platform. The investor agent senses the country COF in agent-set of countries and moves for plant installation to one with highest COF value. The results of hybrid ABM-GFL are more flexible and comprehensive than other methodologies as it not only considers the mutli-objective nature of the GFL problem but also takes into account the real world ambiguities in data pools and expert opinions and deals with dynamic priorities and stochastic country ratings which are changing over the time span of simulation.

2 - **The AHP in eco gestation of operations: a reuse of organic waste case**
Astrid Oddershede, Felipe Reitter, Luis Quezada

This article presents a case study for decision making regarding the reuse of organic waste. With a multicriteria approach based on the perspective of the actors of the organization, combining technical parameters and applying the Analytical Hierarchy Process (AHP), a decision model is developed to identify the priority attributes in determining the most appropriate process for treatment of organic waste. Empirical. Data have been compiled from a central supplier located at the Metropolitan Region in Chile. This supplier precincts, contributes as an externality with approximately 50% of the waste of the locality where it is located (CONAMA, 2010) and for the organization approximately 10% of operational costs. An AHP model is developed for the selection of the most favorable alternative for the transformation of organic waste for a center of horticultural trade in accordance with the methodological approach of the study including the experience and perspectives of stakeholders in the organization.

3 - **A multi-phase decision making approach combining the EFA, AHP and Multi-MOORA for the career choice of undergraduates in department of statistics**
Sevgi Abdalla

In the 21st century, career choice has become a complex problem, which includes conflicting criteria that influence undergraduates career plan. Effective decision making requires evaluating of trade-offs and value-based choices. Hence, Multi Criteria Decision Making techniques provide effective solutions for the problems which contain at least two decision alternatives and at least two conflicting criteria. In this study, a multi-phase decision making approach was proposed in order to provide a meaningful knowledge and a practical solution for career choice problem of the undergraduates. Defining the criteria was the crucial phase of problem solving process. To construct the hierarchy model successfully, the main criteria and their sub-criteria were uncovered by utilizing the Exploratory Factor Analysis. Then, Analytical Hierarchy Process was applied to determine the weights of each criterion, because, it enables to; define high-level strategic objectives, measure the relative importance of each criteria, make sensitivity analysis, judge both tangible and intangible criteria and apply to any choice problem. Detecting the best choice among the decision alternatives, Multi Objective Optimization on the basis of Ratio Analysis was carried out. As a result, we have suggested a useful model and given practical insights to researchers and undergraduates to help in their career planning process.

4 - **An experimental approach for comparing inconsistency of multiplicative, additive and fuzzy approaches**
Massimo Squillante, Bice Cavallo, Alessio Ishizaka, Maria Grazia Olivieri

Pairwise comparisons matrices (PCMs) have been long used in psychophysical research to judge and compare sensory intensities; this technique has also gained popularity in decision analysis. In the literature, different types of PCMs are considered, e.g., multiplicative, additive and fuzzy, and several techniques have also been proposed to derive the priorities from a PCM. Unfortunately, a priority makes sense only if the decision maker has a minimum level of coherence. It has never been studied for which type of PCM the decision makers are more coherent when they express their preferences; thus, this paper aims at filling this gap. In particular, we perform an experiment in order to measure the coherence of the participants when they express their subjective preferences by means of additive, multiplicative and fuzzy PCMs. Although multiplicative, additive and fuzzy PCMs share the same algebraic structure (i.e., Abelian linearly ordered group), the experiment shows that when expressing "preference ratios" (i.e., multiplicative preferences) or "preference degrees" (i.e., fuzzy preferences), the participants are more coherent than when they express "preference differences" (i.e., additive preferences). This research shows that Behavioral Operations Research is an interesting field when human behavior needs to be examined and taken into consideration.

■ TA-08

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S108

Combinatorial Optimization on Graphs I

Stream: Combinatorial Optimization I
Chair: *Francesco Carrabs*

1 - **The discrete P-dispersion problem for the close enough traveling salesman problem**
Carmine Cerrone, Francesco Carrabs, Raffaele Cerulli, Bruce Golden

The close-enough traveling salesman problem (CETSP) is a variant of the Euclidean traveling salesman problem in which the traveler visits a node if it passes through the neighborhood set of that node. In this work, we compute a lower bound of the optimal solution by discretizing the neighborhoods. In order to improve the lower bound, we use a Carousel Greedy approach to decrease the size of the input solving a discrete p-dispersion problem. Starting from the lower bound, using iteratively a second-order cone programming model a feasible solution is found. We perform several computational experiments on benchmark instances, the results show that our approach often overcomes the other approached proposed in the literature in terms of both computational time and quality of the bounds.

2 - **A three-stage p-median based exact method for the optimal diversity management problem**
Adriano Masone, Antonio Sforza, Claudio Sterle, Igor Vasilyev, Anton Ushakov

The p-median problem (PMP) is the well known network optimization problem of discrete location theory. In many real applications PMP is defined on large scale networks, for which ad-hoc exact and/or heuristic methods have to be developed. A very interesting industrial application is constituted by the optimal diversity management problem (ODMP) which arises when a company producing a good and/or a service (which can be customized with options) needs to satisfy many client demands with various subset of options, but only a limited number of option configurations can be produced. Exploiting a suitable network representation, ODMP can be formulated as a PMP on a large-scale disconnected network. In this paper we revise and improve a decomposition approach where a lot of smaller PMPs related to the network components can be solved instead of the initial large-scale problem. Proposed approach drastically reduces number and dimension of these subproblems, solving them to optimality by a MIP solver, and combining their solutions to find the optimal solution of the original problem, formulated as a multiple choice knapsack problem. The computational tests show that our approach is able to find optimal solutions of known and new test instances, considerably outperforming state-of-the-art approaches to the large-scale PMP on disconnected networks.

3 - **On a network function virtualization chaining problem with simple path routing: properties and formulations**
Giuliana Carello, Bernardetta Addis, Meihui Gao

The diffusion of applications, both on computers and mobile devices has yielded to an increasing demand for network services. So far, the network services were provided by expensive hardware appliances, which could not keep up with the ever increasing demand nor allow new services to be embedded at a reasonable cost. Thus, Network Functions Virtualization, according to which hardware appliances are replaced with Virtual Network Functions (VNF) running on generic servers, has been recently proposed to overcome such drawback and allow to flexibly, dynamically and cost-effectively operate network services. A key problem to implement the Network Functions Virtualization paradigm is the so called VNF chaining problem: VNFs location must be selected among the network nodes and the routing of the demands must be decided so as to guarantee that each demand can pass through the functions it requires. In this work we consider a particular case of VNF chaining problem where each demand requires a single service and must be routed on a simple path. Link and service capacity are considered. The goal is to minimize the number of VNF instances installed. We investigate the problem properties and we compare two formulations inspired by the two main modelling strategies proposed in the literature.

4 - A metaheuristic algorithm for the all-colors shortest path problem
Francesco Carrabs, Raffaele Cerulli, Andrea Raiconi

Given an undirected edge-weighted graph with a label (color) assigned to each vertex, the all-colors shortest path problem seeks a minimum-weight, non-necessarily simple, path crossing at least a vertex for each different color. The source of the path is not defined a priori. The problem is NP-Hard and finds applications in the distribution network planning scenarios. We propose an effective heuristic approach based on some properties of the problem. The computational results show that our heuristic outperforms the other approaches, proposed in the literature, in terms of both computational time and quality of the solutions.

■ TA-09

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S109

The Role of Mathematical Optimization in Data Science V

Stream: European Working Group: Data Science Meets Optimization
Chair: *Adam Elmachtoub*

1 - Small-data, large-scale linear optimziation
Vishal Gupta, Paat Rusmevichientong

Optimization applications often depend upon a huge number of uncertain parameters with imprecise estimates. We term this setting - where the number of uncertainties is large, but all estimates have fixed and low precision - the "small-data, large-scale regime." For linear programs with uncertain objective coefficients, we prove that traditional methods like sample average approximation, data-driven robust optimization, regularization, and “estimate-then-optimize" policies can perform poorly in the small-data, large-scale regime. We propose a novel framework that, given a policy class, identifies an asymptotically best-in-class policy, where the asymptotics hold as the number of uncertain parameters grows large, but the amount of data per uncertainty (and hence the estimate’s precision) remains fixed. We apply our approach to two policy classes for this problem: an empirical Bayes class inspired by statistics and a regularization class inspired by optimization and machine learning. In both cases, the sub-optimality gap between our proposed method and the best-in-class policy decays exponentially fast in the number of uncertain parameters, even for a fixed amount of data. We also show that in the usual large-sample regime our policies are comparable to sample average approximation. Thus, our policies retain the strong large-sample performance of traditional methods, but also enjoy provably strong performance in the small-data, large-scale regime.

2 - Condition number analysis of logistic regression and its implications for standard first-order solution methods
Paul Grigas, Robert M. Freund, Rahul Mazumder

The elementary probabilistic model underlying logistic regression implies that it is most natural to consider logistic regression when the data is not (linearly) separable. Building on this basic intuition, we introduce a pair of condition numbers that measure the degree of non-separability or separability of a given dataset in the setting of binary classification. When the sample data is not separable, we show that the degree of non-separability naturally enters the analysis and informs the properties and convergence guarantees of two standard first-order methods, namely steepest descent (for any given norm) and stochastic gradient descent. When the sample data is separable – in which case many properties of logistic regression essentially break down – the degree of separability can be used to show rather surprisingly that these two standard first order methods deliver approximate-maximum-margin solutions with associated computational guarantees as well. Last of all, in order to further enhance our understanding of the computational properties of several methods, we exploit recent new results on self-concordant-like properties of logistic regression due to Bach.

3 - Discovering optimal policies: a machine learning approach to model analysis
Fernanda Bravo, Yaron Shaposhnik

We study a novel application of machine learning methods for discovering structural properties of optimal policies in numerically obtained solutions to optimization problems. Our proposed framework provides a systematic approach, which complements numerical experimentation and theoretical analysis, to characterize optimal policies for optimization problems that commonly arise in the context of operations management. As a proof of concept, we apply our framework to core optimization problems, such as inventory replenishment, admission control in queueing systems, and multi-armed bandit (MAB) problems. We demonstrate how to apply standard statistical learning methods to characterize optimal threshold-based policies for the inventory replenishment and admission control problems. For the MAB problem, we derive a new class of policies that generalizes index policies, and develop a new efficient algorithm for computing an optimal index policy. The main contribution of our work is methodological, in proposing and demonstrating the effectiveness of a new machine learning-based method for analyzing optimization problems. Applying our method leads to new insights about optimal solutions to MAB problems.

4 - Smart predict, then optimize
Adam Elmachtoub, Paul Grigas

We consider a class of optimization problems where the objective function is not explicitly provided, but contextual information can be used to predict the objective based on historical data. A traditional approach would be to simply predict the objective based on minimizing prediction error, and then solve the corresponding optimization problem. Instead, we propose a prediction framework that leverages the structure of the optimization problem that will be solved given the prediction. We provide theoretical, algorithmic, and computational results to show the validity and practicality of our framework.

■ TA-10

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S110

Decision Aiding Methods V

Stream: Multiple Criteria Decision Aiding
Chair: *Nguyen Anh Vu Doan*

1 - Better together: improved predictive accuracy of preference disaggregation by discovering structural similarities in preference models
Mohammad Ghaderi, Nuria Agell, Milosz Kadzinski

Preference disaggregation paradigm aims at inferring preference models, in form of value function, from decision examples. This paper focuses on the predictive performance of this class of techniques and introduces an analytical framework to simultaneously estimate preferences of a number of consumers by i) exploiting the consumer’s preference structures at the individual level, and ii) accounting for the structural similarities in the set of estimated preference models at the group level. Results from an extensive simulation study demonstrate that accounting for structural similarities remarkably improves predictive accuracy of the individual’s preference models, and this gain remains considerable across a wide variety of decision problem settings.

2 - GAIA-SMAA-PROMETHEE for a hierarchy of interacting criteria
Sally Giuseppe Arcidiacono, Salvatore Greco, Salvatore Corrente

In this paper we propose an extension of the PROMETHEE methods. Despite PROMETHEE are among the most applied methods in Multiple Criteria Decision Aiding (MCDA), some drawbacks can be underlined with respect to their applicability since they do not take into account few characteristics of multicriteria decision problems that are very relevant in real world applications: (i) robustness regarding the plurality of compatible preference parameters; (ii) interaction between criteria; (iii) hierarchies of criteria. Even if different extensions of the PROMETHEE methods have taken into account all these aspects singularly, we propose to deal with all of them simultaneously presenting a new version which incorporates Robust Ordinal Regression (ROR), Stochastic Multicriteria Acceptability Analysis (SMAA), bipolar Choquet integral and Multiple Criteria Hierarchy Process (MCHP). ROR and SMAA permit to consider all the instances of the considered preference model compatible with the preference information provided by the DM; the bipolar Choquet integral is able to represent the possible positive and negative interactions between criteria as well as the antagonistic effect between some of them; finally, the MCHP permits to decompose the problem in small parts so that each of them can be analyzed more in detail with respect to the problem at hand. Moreover, we also introduce an extension of the GAIA technique to handle visualization in MCDA problems presenting interactions and antagonistic

3 - PROMETHEE R: from ranking to rating
Bertrand Mareschal

PROMETHEE belongs to the family of multicriteria outranking methods. As such it relies on the pairwise comparison of actions and provides the decision maker with rankings based on outranking flows. In particular the net flow is used to produce a complete ranking of the actions. The net flow values can be either positive or negative and cannot be used directly as a rating of the actions. This has led some practitioners to rescale the net flow to a positive "rating" scale using more or less simple usually linear transformations. We show that this can be misleading and we propose an alternative solution: the PROMETHEE R method uses implicit reference actions to compute a modified net flow that can be rescaled to a rating. Several properties of the approach are demonstrated. Potential applications include classification of actions and budget allocation.

4 - An alternative weight stability analysis for PROMETHEE II rankings based on inverse optimization
Nguyen Anh Vu Doan, Yves De Smet

Strategic decision problems often require to simultaneously optimize several conflicting criteria. Among the methods developed to address this matter, PROMETHEE II (P-II) has earned some attention during the past decades. Given some parameters provided by a decision maker (DM) such as the criteria weights, P-II returns a complete ranking from a set of alternatives. In order to assess the stability of the ranking, weight stability intervals (WSI) have been developed. However, the WSI only considers one criterion at once (changes are assumed to be applied uniformly to the other criteria to keep the normalization). In this work, we propose to allow any modifications on any weight, by applying an inverse optimization (IO) based on mixed integer linear programming. The problem can be formulated as follows: what would be the minimum modification on the weights such that a given alternative of rank n > 1 becomes first? Applied to two case studies, this methodology, when compared to the WSI, shows that it is always possible to find narrower intervals while the simultaneous modification of all the weights is never required. Additionally, when using the WSI, it is observed that only few alternatives can be ranked first. However, by taking the IO point of view, all (non-dominated) alternatives can still be placed at the first position (though at the price of large deviations). It is therefore also possible to apply this methodology for a consensus search when different DMs are involved.

■ TA-11

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S111

Uplift Modelling

Stream: Business Analytics
Chair: *Sebastian Maldonado*

1 - Profit-driven decision tree approaches for uplift modeling
Floris Devriendt, George Petrides, Stefan Lessmann, Wouter Verbeke

Uplift modeling is a type of predictive modeling that estimates the incremental effect of performing some action on customer behavior. This allows for a high degree of customization and improved targeting selection in marketing campaigns with the aim to maximize the effect of the campaign and the returns on marketing investment. In previous work, we have extended the maximum profit measure towards uplift modeling for identifying the use in terms of profitability of an uplift model.

In this paper, we take it one step further and consider the profit maximization objective during the model construction phase. We focus on adapting existing uplift decision trees, which in turn are direct generalizations of standard decision trees such as CART and C4.5. Inspired by the literature on cost-sensitive learning techniques, we develop and evaluate an array of approaches to replace the impurity measure in the splitting criterion of decision trees by including components of the maximum profit measure. We present the results of an experimental study, comparing the performance of the various proposed implementations with existing approaches such as uplift random forests on two real-world datasets. To evaluate, we adopt both profit and qini-based model performance assessment approaches.

2 - Sampling techniques for uplift modeling for improved stability and performance
Dimitri Robert, Floris Devriendt, George Petrides, Wouter Verbeke

In this study, we investigate the impact of data sampling on the stability of uplift models. The aim of uplift modelling is to predict people's reaction to a campaign offering incentives towards taking a particular action, such as buying a product or not churning from a service. In the literature, it has been reported that uplift models can be unstable performance-wise (in terms of the Qini measure for example) and may consequently be deemed unreliable. We investigate whether model stability can be improved by modifying the class ratio using data sampling techniques, without worsening the performance in the process. Specifically, we use both under- and oversampling, as well as the methods smote and rose. Whereas the first two remove or duplicate records, the latter two artificially generate new records taking account of their neighbourhood while potentially also removing records. The uplift models are built considering uplift random forests, and the methods of Lo and Generalized Lai. In our experimental design, we take account of different class ratios and we use a number of direct marketing datasets. Furthermore, we check whether these new models show an increased performance, studying whether there exists a trade-off between stability and performance. In some cases, we observe that sampling methods have a positive impact on both the stability and performance of uplift models, but this depends on the method and dataset used.

3 - A survey & experimental evaluation of multiple treatment uplift modeling
Diego Andres Olaya Lasso, Wouter Verbeke

Predictive response modeling has proved to be useful in the identification of customers whose likelihood to respond to a direct marketing campaign is the highest. Unlike traditional response models, which objective function is to predict the probability of a customer reacting to a treatment, uplift modeling focuses on estimating its net impact. Uplift models have not only the potential of supporting organizations to identify likely responders to their campaigns, but also to determine the optimal treatment for each subgroup of customers. In this study, we extend uplift models to the context where marketers have in hand more than one action to undertake. Our interest lies not only in detecting the group of customers (or prospects) whose response's decision can be positively influenced by a particular treatment, but also in finding the most effective marketing campaign. For this purpose, we review the literature on uplift modeling for the multiple treatment case. Despite the little attention given by researchers, it is found that the majority of proposed methodologies are (1) building separate classifiers, (2) including interaction terms and dummy predictors, and (3) direct prediction through tree-based and k-nearest neighbor algorithms. In addition, we experimentally evaluate the most prominent approaches, and contrast their performance by means of the Qini-metric, complemented with visual instruments such as Qini-plots and Uplift Decile charts.

4 - Profit-based credit scoring based on robust optimization and support vector machines
Sebastian Maldonado, Julio López

In machine learning, robustness refers to how effective a model is when is being tested on new data. The performance of a robust model should not deteriorate much when it is trained and tested on data with slightly different distributions, i.e. it generalizes well without overfitting. The choice of the best classification approach is usually made using traditional, statistically grounded techniques. However, a new research line proposes using business-oriented measures for model selection and validation. This is particularly important in credit scoring since the decision whether to accept an applicant or not is made based on financial criteria. In this work, we introduce a novel Support Vector Machine method for profit-based classification. The idea is to balance the profit of granting credit with the variable acquisition costs to construct the most profitable classifier. Inspired in the robust optimization theory, our strategy proposes a chance-constrained formulation, which is further cast into a Second-Order Cone Programming formulation. A case-study of a Chilean bank is presented. Credits are granted to microentrepreneurs based on information from five different data sources. Our proposal concludes that best solutions in terms of profit are achieved using one or two cheap data sources, without the need of expensive interviews. Additionally, important managerial insights are gained into the application thanks to the identification of the relevant variables.

■ TA-12

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S112

Non-Standard Optimization and Decision-Making Methods II

Stream: Fuzzy Optimization
Chair: *Jaroslav Ramik*

1 - Interval linear programming: checking weak optimality of a given solution is NP-hard
Miroslav Rada, Milan Hladik, Elif Garajová

Interval linear programming (ILP) is one of quite modern approaches to grasping uncertainty of input data in linear programming. Generally, it deals with a family of classical linear programs (scenarios) with coefficients independently varying across given intervals. It allows to give robust answers to questions such as "does a property hold for some/all scenarios", where "some/all" are referred to as "weak" and "strong" problems andthe "property" can be any property that could be considered in classical linear programming, such as e.g. feasibility, optimality, boundedness. This talk is devoted to the following problem: given a solution of an interval linear program, decide whether there is a scenario such that the solution is optimal. This problem was recently wrongly stated to be polynomially solvable. We show that it is actually NP-hard and propose an algorithm for the problem, based on disjunctive programming and orthant decomposition. Furthermore, we show that for some classes of ILP the problem can be solved polynomially.

2 - Determinants of technological innovation capability in high technology and manufacturing firms - using Fuzzy-DEMATEL method
Chi-Hui Wu, Po-Wei Su, Ching-Torng Lin, Thi Phuong Thao Tran

The paper explores determinants of technological innovation capability in high technology and manufacturing firms. The technology innovation capabilities (TICs) can be conceptualized as multi-criteria complex problems that involve the simultaneous consideration of multiple quantitative and qualitative requirements. This study analyzes TICs interrelationships by applying the Fuzzy Decision Making Trial and Evaluation Laboratory (Fuzzy-DEMATEL) method. Fuzzy-DEMATEL is applied to analyze the causal relationships among the criteria and sub-criteria. Based on the literature reviews, six main criteria and twenty sub-criteria were extracted and then validated by seventeen experts. A questionnaire was constructed and evaluated by twenty-five experts. Then the Fuzzy-DEMATEL method was applied to analyze the importance of criteria and the casual relations among the criteria were constructed. The result showed that the innovation management capability was the most important criterion in criteria level and influenced the other criteria; in sub-criteria level, the sub-criterion absorptive capability was the most important and influenced the other sub-criterion.

3 - Using multi criteria decision making to select the most appropriate organization of maintenance section in Iran airline
Ahmad Makui

Aviation companies aim to save time in their various operations in order to increase the value of their customers' satisfaction. This article tries to investigate and compare the different structures of maintenance sections used by different airlines. In this study, human resources allocation in maintenance sections in worldwide airlines is classified into four categories. Type A: In this type, the allocation of staff is contingent and depends to the level of inspection and timing and commercial priority for every plane. Type B: In this method, staff is divided into groups based on the required specialties (four groups). The work is divided between them with minimum flexibility. Type C: In this method, staff is divided equally between available aircrafts. Type D: In this method, Airlines divides their technical staff into three expert groups and delegates the cabin section of the aircraft to non-specialized staff. By experts opinion's, evaluation criteria for evaluating the abovementioned four types are listed as follows: 1) Cost, 2) Time, 3) Operational flexibility, 4) Reliability, 5) Systematic complexity, 6) Ability to adapt to development. We use then fuzzy VIKOR to rank the four types mentioned categories based on the six above mentioned criteria. All the criteria are assumed to be fuzzy triangle numbers. The results show that the type D is the most suitable model for organizing the maintenance section in Iran airline.

4 - Computing interval eigenvectors of interval fuzzy and max-plus matrices
Ján Plavka, Martin Gavalec

Fuzzy matrices can be used in a range of practical problems related to fuzzy optimization using eigenproblem and max-plus algebra plays a key role in the study of discrete event systems in connection with optimization problems such as scheduling or project management in which the objective function depends on the operations maximum and plus. The steady states of such systems correspond to the eigenvectors of fuzzy and max-plus matrices, therefore the investigation of the properties of these eigenvectors is important for applications. Matrices and vectors with interval coefficients in fuzzy and max-plus algebras are studied and polynomial algorithms are presented for the recognition problem with several types of interval eigenvectors.

Support of the Czech Science Foundation GAČR 18-01246S is gratefully acknowledged.

■ TA-13

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S201

Continuous Optimization and Industrial Applications

Stream: Applications Related to Continuous Optimization
Chair: *Sureyya Ozogur-Akyuz*

1 - A unified optimization framework for electrochemical wastewater treatment with continuous energy consumption monitoring
Emine Esra Gerek, Ali Savaş Koparal, Omer Nezih Gerek

Treatment of wastewater is a critical environmental issue and electrochemical methods remain to be among the popular methods for reduction of the contaminant. Among various hazardous contaminants (which require treatment at all costs), a wide class of cases require simple reduction of chemical oxygen demand (COD). In batch processes, a certain electrical current density is applied to the electrodes of a reactor (typically submerged in the wastewater) and, while the active contaminant combines/coagulates, its chemical oxygen demand normally reduces by time. We denote this decreasing function as COD(t). On the other hand, the consumed electricity causes an increasing oxygen demand due to possible fuel burning on the generation plant. The amount of energy production oxygen demand is proportional to time and the share of fossil fuels in the generation profile of the country. We denote this time function as P(t), which is a monotonously increasing function. Environmental engineers typically provide a final power consumption or its financial cost at the end of the treatment, but consideration of the total oxygen demand; COD(t)+P(t) provides a continuous optimization methodology for the termination instant of treatment. Since the combined function contains decreasing and increasing components, it produces a minimal point. Real treatment cases with vinegar and tannery wastewater samples are performed and illustrated under AU-BAP 1601F026 and TUBITAK 115Y841project funds.

2 - Optimal cross-border electricity trading
Maria Flora

We show that electricity flows between interconnected locations have a direct and indirect effect on electricity prices in the different locations. The direct effect refers to how prices between two locations are affected when power is flowing between these two locations only. The indirect effect refers to how the flows between two locations also affect the price of power in other locations. Based on this result we propose a model of the joint dynamics of electricity prices where flows of electricity affect, directly and indirectly, prices in all locations, and model a common co-integration factor of prices. We solve the optimal control problem of an agent who uses the interconnector to take positions in all locations and solve the resulting dynamic programming equation up to a system of Riccati equations, which we solve numerically to evaluate the performance of the strategy. We show that including cross-border effects in the trading strategy specification significantly improves the performance of the strategy. For example, considering contracts with delivery at 1 p.m., using our optimal trading strategy over a time interval of 1 year leads to a profit gain of almost 250,000 EUR more with respect to a strategy purely based on the price spread.

3 - Monitoring the multivariate coefficient of variation via optimised control charts
Vicent Giner-Bosch, Philippe Castagliola, J. Carlos García-Díaz, Andrés Carrión

The development of new control charts for the multivariate coefficient of variation (MCV) is recently gaining attention as a way to monitor the relative variability of a multivariate process along time. In this contribution, we review the existing methods proposed in the statistical process monitoring (SPM) literature dealing with the MCV. We also present our recent work regarding the optimisation of control charts aimed at monitoring the MCV. More precisely, results for an exponentially weighted moving average (EWMA) chart for the MCV are reported. The optimal determination of the chart parameters involves the use of derivative-free techniques such as the Nelder-Mead method. Our proposal is shown to outperform the existing methods in terms of the efficiency in detecting unwanted shifts of the process. Preliminary developments of a cumulative sum (CUSUM) control chart for the MCV will be also shown, and further research paths on this topic will be outlined.

■ TA-14

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S202

Proximal Gradient-Type Algorithms

Stream: Nonlinear Programming: Methods
Chair: *Junfeng Yang*

1 - Some theoretical and numerical analysis for nonsmooth convex regression with cardinality penalty
Wei Bian

In this paper, we focus on the constrained sparse regression problem, where the loss function is convex but nonsmooth, and the penalty term is defined by the cardinality function. First, we give a continuous relaxation model of it, and prove that the suggested continuous relaxation model not only preserve its all global minimizers, but also corresponds to its local minimizers. Most importantly, some undesired local minimizers of the original problem can be abandoned by solving the lifted stationary points of the relaxation model. Then, solving the original regression problem with cardinality penalty is equivalent, in a sense, to solving the continuous relaxation problem, which not only enjoys stronger optimal capability, but also owns some better functional properties on the objective function, such as the continuity and piecewise linear penalty. Second, we propose an algorithm, called the smoothing proximal gradient (SPG) algorithm, for solving the lifted stationary points of the continuous relaxation model, which is an effective method for finding a better local minimizer of the studied regression model with cardinality penalty. Our algorithm is a novel combination of the classical proximal gradient algorithm and the smoothing method. Due to the special decomposition method for the objective function in each iteration and the skilled design for the smoothing parameter, the proposed SPG algorithm achieves the only known global convergence for this kind of problem.

2 - Iteratively dynamically reweighted methods for nonconvex regularized problems
Hao Wang

We propose a general formulation of nonconvex regularization problems with convex set constraint, which can take into account most existing types of nonconvex regularization problems, bringing strong practicability to a wide range of applications. We design an algorithmic framework of iteratively reweighted algorithms for solving the proposed nonconvex regularization problems, which solves a sequence of weighted convex subproblems with iteratively updated weights. A novel dynamic updating strategy is also constructed to automatically update the weights. We also provide global convergence under loose assumptions, as well as the analysis for the local behavior. This makes our algorithm a tool for a family of various reweighting algorithms. The effectiveness and efficiency of our proposed formulation and the algorithms are demonstrated in numerical experiments for various regularization problems.

3 - Proximal algorithms with extrapolation for structured nonconvex nonsmooth problems
Bo Wen

In this talk, we mainly consider proximal algorithms with extrapolation for solving two classes of structured nonconvex nonsmooth optimization problems. We first consider the proximal gradient algorithm with extrapolation for minimizing the sum of a Lipschitz differentiable function and a proper closed convex function. Under one error bound condition, we establish the linear convergence rate of both the objective sequence and the iterate sequence generated by the algorithm, Then, we propose a proximal difference-of-convex(DC) algorithm with extrapolation for solving a class of DC problems. We show that any accumulation point of the sequence generated by our algorithm is a stationary point of the DC optimization problem for a general choice of extrapolation parameters. Moreover, using the Kurdyka-Lojasiewicz inequality, we establish global convergence of the sequence generated by our algorithm and analyze its convergence rate. From the results in our numerical experiments on two difference-of-convex regularized least squares models, proximal difference-of-convex algorithm with extrapolation usually outperforms the proximal DC algorithm and the general iterative shrinkage and thresholding algorithm.

4 - On progressive hedging algorithm for multistage stochastic programming and stochastic variational inequalities

Junfeng Yang

Progressive hedging algorithm (PHA) was originally proposed by Rockafellar and Wets in 1991 for stochastic convex optimization. Recently, it was extended to solving stochastic variational inequality problems by Rockafellar and Sun. It is known that PHA is an application of the proximal point algorithm. In this talk,we establish its connections with the alternating direction method of multipliers and Douglas-Rachford operator splitting method. These results sharpen our understanding to PHA and enable us to consider some extensions.

This is a joint work with Xiaojun Chen and Defeng Sun.

■ TA-15

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S203

Vehicle Routing with Time Windows

Stream: Vehicle Routing and Logistics Optimization II
Chair: *Said Dabia*

1 - Logic-based benders decomposition for the heterogeneous fixed fleet vehicle routing problem with time windows

Vinícius Armentano, Ramon Fachini

We propose an exact logic-based Benders' decomposition to solve the heterogeneous vehicle routing problem with time windows and a limited availability of vehicles. This approach is based on a mathematical formulation that suggests an exact or heuristic two-phase method called cluster-first and route-second, which was suggested by Fisher and Jaikumar (1981). The Benders master problem is a generalized assignment problem with binary variables that indicate the designation of each client to a type of vehicle. When such variables are fixed, the Benders sub-problem decomposes into independent traveling salesman problems with time windows. At each iteration, optimality cuts and/or feasibility cuts are generated from the solutions of these problems and incorporated into the master problem which is solved for the aforementioned binary variables. Enhancements to solve the master problem and the subproblem are included and computational results are reported.

2 - The stochastic and robust time window assignment vehicle routing problem

Maaike Hoogeboom, Patrick Jaillet, Yossiri Adulyasak, Wout Dullaert

In the vehicle routing problem with time windows, service time windows are typically an input, imposed by the customers. In practice, however, there are several settings in which logistics service providers determine the service time windows, as in parcel delivery, retail and repair services. The logistics companies are faced with uncertain travel times (and/or service times) that have to be taken into account when determining the time windows and routes prior to departure. The objective of this time window assignment vehicle routing problem is to find routes and time window assignments such that the routing cost and the risk of violating the time windows are minimized. We model two different problem settings: first, the stochastic problem in which the probability distribution of the travel times is assumed to be known. Second, the robust problem in which only some characteristics of the travel time probability distributions are known. In this setting a measure is used to capture the risk of violating the time windows. Both models are solved by a branch-and-cut approach. Experiments address the performance of the proposed solution approach and examine the trade-off between average travel time duration and risk of violating the time windows.

3 - A comparative study of branch-and-price algorithms for vehicle routing with time windows and waiting time costs

Stefano Michelini, Yasemin Arda, Hande Kucukaydin

Branch-and-price is a leading methodology for solving routing problems. Several studies have investigated labeling algorithms to solve the related pricing problem, which is usually a variant of the elementary shortest path problem with resource constraints. Solving this problem efficiently is crucial, since it is a performance bottleneck for the branch-and-price procedure. Such algorithms include methods like decremental state space relaxation, ng-route relaxation, and hybrids of these two. These focus on how to treat efficiently the elementarity constraints, since they tend to make label domination difficult, which translates to more computational resources used. In this study, we investigate the performance of these methods in a branch-and-price framework. The problem under consideration is a variant of the vehicle routing problem with time windows in which waiting times have a linear cost.

We first parametrize several algorithmic components. Then, we search for good parameter configurations for each algorithm with irace, a tool for automated parameter tuning that generates and runs a very high number of configurations on a set of tuning instances and uses statistical tests to determine the best performing configuration. Finally, we run all final configurations on the Solomon benchmark instances and analyze the results with statistical tests. Our results show that a class of hybrid algorithms with certain features based on ng-route relaxation outperforms all the others.

4 - Cover inequalities for a vehicle routing problem with time windows and shifts

Said Dabia, Stefan Ropke, Tom van Woensel

This paper introduces the Vehicle Routing Problem with Time Windows and Shifts (VRPTWS). At the depot, several shifts with non-overlapping operating periods are available to load the planned trucks. Each shift has a limited loading capacity. We solve the VRPTWS exactly by a branch-and-cut-and-price algorithm. The master problem is a set partitioning with an additional constraint for every shift. Each constraint requires the total quantity loaded in a shift to be less than its loading capacity. For every shift, a pricing sub-problem is solved by a label setting algorithm. Shift capacity constraints define knapsack inequalities, hence we use valid inequalities inspired from knapsack inequalities to strengthen the LP-relaxation of the master problem when solved by column generation. In particular, we use a family of tailored robust cover inequalities and a family of new non-robust cover inequalities. Numerical results show that non-robust cover inequalities significantly improve the algorithm.

■ TA-16

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S115

Urban Logistics

Stream: Green Logistics
Chair: *Jan Fabian Ehmke*

1 - Investing in facilities today to reduce routing emissions tomorrow

Fabien Tricoire, Sophie Parragh

We investigate the trade-off between strategic investment in logistics facilities and the long-term environmental impact of daily logistics operations. For that purpose, we consider a bi-objective location-routing problem with the objectives of minimising the cost of strategic investments such as locating facilities and acquiring different types of vehicles, and minimising pollution by using CO2 emissions as an indicator. A set of representative days of operations are used to estimate the long-term environmental impact. This results in a problem combining facility location, fleet-size-and-mix and vehicle routing features. We model that problem as a mixed-integer program, however the model cannot be solved explicitly due to input size. We also develop a decomposition approach that constructs routes, then uses them in a separate set covering model to generate complete solutions. This set covering model is embedded in bi-objective optimisation algorithms. The suitability of our approach is investigated on benchmark test instances as well as on a case study in the city of Vienna. Experiments show that our approach is a valuable tool in aiding such long-term decisions.

2 - A two-echelon vehicle routing problem with unmanned ground vehicles for city logistics

Jakob Puchinger, Shaohua Yu

We introduce a two-echelon vehicle routing problem with unmanned second level vehicles. This problem can be seen as typical for delivering parcels or other small commodities to pedestrianised areas such as a campus or residential areas. The larger vehicles (LV) carry small fully automated ground vehicles for last-mile delivery (SAV) on the first-level route. The LV are not serving customers directly but they stop at parking nodes for dropping off and/or picking up the SAVs which are responsible for delivering to customers on the second-level route. SAVs are always dropped off and picked up by the same LV, but not necessarily at the same parking location. We consider LV and SAV capacity constraints, a maximum travel distance for the SAV as well as time windows on the arrival or departure time at the depot and at customer nodes. We introduce a mixed integer programming model, for the proposed vehicle routing problem including constraints on the spatial and temporal synchronization of the first and second level routes. We will present first computational results based on the MIP model solved via CPLEX and some perspectives for solving larger instances using a metaheuristic approach.

3 - Optimizing routes with sustainability criteria in transportation management

Lorena Reyes-Rubiano, Laura Calvet, Javier Faulin, Angel A. Juan

Recently, the urban freight transport has been developed more frequently and in greater amounts, therefore it has been considered as a vital element for the economic growth of cities. However, transport sector has generated negative impacts on the environment and citizens welfare, encouraging the development of smart systems for supporting decision making in urban distribution. In this context, we tackled a capacitated vehicle routing problem considering on sustainability dimensions as the decision criteria. This abstract tries to manage the preferences of stakeholders in order to provide smart decisions that ensure a balance among sustainability dimensions. Thus, optimization techniques are implemented to design the distribution routes with a minimal economic, environmental and social negative impact. A series of computational experiments illustrate how the preferences of decision-makers' bias on the performance of routes distribution considering costs related to accident rates, fuel consumption, and carbon emissions. Finally, we present and discuss the computational results thus obtained.

4 - Can tolling schemes really reduce emissions of freight transportation in urban area?

Jan Fabian Ehmke, Shu Zhang, Ann Campbell

As urbanization increases, municipalities have become aware of the negative impacts of road-based transportation. As a result, several cities have introduced tolling schemes to discourage vehicles from entering the inner city to reduce congestion and pollution, especially during peak hours. However, little research has been done to examine the impact of tolling schemes on commercial fleets, especially on resulting costs and emissions. In this study, we investigate how different tolling schemes may impact the total costs, the distance traveled by the vehicles, the travel time, the total working time of the drivers, and the emissions in and outside the congestion zone. We consider different congestion charge types as well as different geographies, i.e., different city and congestion zone sizes. We compare the impacts of the same tolling scheme on different geographies. From the computational experiments, we find that the congestion pricing schemes can shift behaviors of commercial fleets. That is, the introduction of congestion tolls can help to reduce the number of vehicles entering the congestion charge zone, the distances that vehicles travel within the zone, and the time vehicles spend in the zone. However, higher congestion charges may not necessarily lead to less emissions, and some congestion pricing scheme may actually increase total emissions, because vehicles may drive farther distances to avoid the zone in the city center.

■ TA-17

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S205

Stochastic Programming in Tactical and Capacity Expansion Planning

Stream: Stochastic and Robust Optimization
Chair: *Laureano Fernando Escudero*

1 - Risk management for rapid transit network capacity expansion planning

Ángel Marín, Luis Cadarso, Laureano Fernando Escudero

The Rapid Transit Network Design planning problem along a multi-period time horizon of up to decades is treated by considering uncertainty in passenger demand, strategic costs and network disruption. The problem has strategic decisions about the timing to construct stations and edges, and operational decisions on the available network at the periods. Disruptions will arise and affect the network on the operations. The strategic uncertainty is represented in a multistage scenario tree, and the operational uncertainty is represented in a two-stage scenario tree rooted at each strategic node. This construction seems appropriate under the assumption that the operational uncertainty and passengers service of the available rapid transit network is independent from one period to the next one in the same stage. The aim of the model consists of maximizing the expected passenger demand, minimizing the expected service interruption and minimizing the expected total design and operational cost over the scenarios along the time horizon. Additionally, two stochastic dominance (SD)- based risk reduction measures are considered on the negative impact of the solutions on non-wanted scenarios , being this impact on the cost excess and a transport demand shortage. The measures are the Time SD for the cost excess and the Expected Conditional SD for the demand shortage. Several matheuristics are developed and computational results are presented for a large-sized pure 0-1 stochastic model.

2 - Scenario reduction by conditional scenarios

Cesar Beltran-Royo

In this talk we consider the Two-stage Stochastic Mixed Integer Linear Programming (SMILP) problem with continuous random parameters. A common way to approximate the SMILP problem, generally intractable, is to discretize the random parameters into scenarios. Another common approximation only considers the expectation of the parameters, that is, the expected scenario. A new approximation corresponds to conditional scenarios which represent a midpoint between the scenario and the expected scenario concepts. In this talk we compare the conditional scenario approach with other scenario reduction approaches.

3 - A tactical planning model with uncertain demand using a two-stage stochastic programming model for a fruit supply chain
LluisM Pla, Wladimir Soto-Silva, Marcela C. Gonzalez-Araya, Jordi Mateo, Francesc Solsona

Optimization models under uncertainty are generating more interest for being used in the primary sector of the economy. In this paper, we formulate a two-stage stochastic programming model for optimal purchase, cold storage selection and the corresponding transportation towards a processing plant. The proposed model relies on the formulation of a deterministic model representing a dehydrated fruit agroindustry. The main aim of this industry is to minimize overall costs and meet annual demand for dried apple overcoming the random uctuations in the quality of the raw material over the season. Scenarios represent the uncertainty on future conversion rate. The model assesses the importance of the quality of the raw material and mitigates the eect of variations in the conversion into dried apples within a fruit supply chain context. The results obtained show a cost reduction of 6.4% with our proposed stochastic approach (VSS). Furthermore, the model was executed and solved in a reasonable time (less than one hour) using a plain Gurobi commercial solver with a small GAP of 0.21%. Thus, these results ensure the applicability of this novel stochastic model in practice.

4 - On strategic and operational uncertainties for capacity expansion planning risk management
Laureano Fernando Escudero, Antonio Alonso-Ayuso

A new scheme for dealing with the uncertainty in the scenario tress is considered in the presence of strategic and operational stochastic parameters for dynamic mixed 0-1 optimization. For the capacity expansion planning (CEP) problem in a given system, e.g., supply chain, production, rapid transit network, energy generation and transmission network, forest fire management, etc. The strategic scenario tree is usually a multistage one, and the replicas of the strategic nodes root a structure in the form of either a special scenario graph or a two-stage scenario tree, depending on the type of operational activity in the system. This work presents the modeling framework for some of the risk neutral and risk averse measures to consider for the CEP problem solving. The risk averse measures are (a) the time stochastic dominance (SD) functional on a given set of functions up to the strategic nodes (including their operational scenarios) in selected stages along the time horizon, and (b) the strategic node-based time-consistent expected conditional SD functional for the set of operational scenarios in the strategic nodes at selected stages. A matheuristic algorithm is presented that takes benefit from the continuous and 0-1 step variables as the only state strategic ones that link the submodels supported by the subtrees rooted with the strategic nodes that belong to the first periods of two consecutive stages.

■ TA-18

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S206

Risk Measurement and Modeling

Stream: Decision Making Modeling and Risk Assessment in the Financial Sector
Chair: *Fabio Bellini*

1 - An ordinal information based estimator of risky asset returns
Eranda Cela, Stephan Hafner, Roland Mestel, Ulrich Pferschy

In this paper we introduce an approach to generate robust estimators for the returns of risky assets exclusively taking as input a partial order relation on the expected returns of the involved assets. The approach we propose generalizes the Black-Litterman model and is based on the Bayes method while fully taking into account the covariance structure of the assets. We apply an algorithm based on importance sampling to efficiently compute the return estimators.

The estimators generated by our algorithm are compared to the estimators obtained by applying other ordinal information based approaches already proposed in the literature. The comparison is made in terms of measures of forecast quality, including the hitrate and the Mahalanobis distance, for the single assets, and also in the portfolio context. The quality measures used in the portfolio context include among others the Sharpe ratio, the certainty equivalent, the Jensen's alpha or the return-loss indicator. The numerical results for our in-sample tests based on shares from three international stock indices show that the return estimators generated by our new approach perform consistently better than previously known methods.

2 - Elicitability and identifiability of measures of systemic risk
Jana Hlavinová, Tobias Fissler, Birgit Rudloff

Estimating different risk measures, such as Value at Risk or Expected Shortfall, for reporting as well as testing purposes is a common task in various financial institutions. The question of evaluating and comparing these estimates is closely related to two concepts already well known in the literature: elicitability and identifiability. A statistical functional, e.g. a risk measure, is called elicitable if there is a strictly consistent scoring function for it, i.e. a function of two arguments, a forecast and a realization of a random variable, such that its expectation with respect to the second argument is minimized only by the correct forecast. It is called identifiable, if there is a strict identification function, i.e. again a function of two arguments such that the root of its expectation with respect to the second argument is exactly the correct forecast. We introduce these concepts for systemic risk measures defined by Feinstein, Rudloff and Weber (2016). A banking system with n participants is represented by a random vector Y and the quantity of interest is its aggregated outcome, using some nondecreasing aggregation function. The measure of systemic risk is defined as the set of n-dimensional capital allocation vectors k such that the aggregated outcome of Y+k is acceptable under a given scalar risk measure. We establish the link between the elicitability and/or identifiability of the systemic risk measure and the underlying scalar risk measure.

3 - Generalized Little's law and an asset picking system to model an investment portfolio: a large-scale model
Maria Luisa Ceprini, John D C Little

So far our research remains the only application of Little's Law in finance and financial engineering fields. In the first part we created an Asset Picking System (APS) structure that, combined with Little's Law (LL), Generalized Little's Law (GLL) and its corollaries, generates the GLL-APS model, a financial engineering tool bridging operations research and finance. The basic ideas of Little's Law are incredibly useful in financial engineering by coupling data science and analytics with the Law's principles. The APS structure uses a set of decision rules to select assets and # of share of each to be in the portfolio. The rules are optimized via a Mixed Integer Linear Programming (MI-LP) providing a nice link to OR. The innovative ideas are validated via the development of a simulated portfolio modeling process and checking the resulting output against the expected investment goals. In the first part of the project we run a simple prototype with only one customer, chosen within three different customer profiles, for checking the working assumptions. In this second part, final step of the project we are focusing on key advanced topics to introduce in the model. We were conscious of the long list on our table waiting to be settled. Last, we will test the GLL-APS model with more advisers, customers and assets from the global market, planning an orderly rollout in multiple sectors, from financial institution to industry and university.

4 - Dynamic properties of classical and robust Orlicz and Haezendonck-Goovaerts risk measures
Fabio Bellini, Roger Laeven, Emanuela Rosazza Gianin

In this paper we study dynamic properties of classical and robust Orlicz and Haezendonck-Goovaerts risk measures. Haezendonck-Goovaerts risk measures have been originally introduced in the actuarial literature as a natural extension of the Average Value at Risk in Haezendonck and

Goovaerts (1982) and Goovaerts et al. (2004), and further studied in Bellini and Rosazza Gianin (2008). Robust Orlicz and Haezendonck-Goovaerts risk measures have been considered in Bellini et al.(2018). In this work we extend these notions to a dynamic setting and we analyze the resulting time-consistency properties.

■ TA-19

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S207

Vector and Set-Valued Optimization V

Stream: Vector- and Set-Valued Optimization
Chair: *Phan Quoc Khanh*

1 - Dynamic origin-destination-matrix estimation for commuter train planning: an entropy-maximization approach
Abderrahman Ait Ali

The estimation of the dynamic Origin-Destination-Matrix, hereafter ODM, is an important task in many transport planning models. It is for instance the second step in the widely used four-stage travel demand transportation model (McNally, 2008). ODMs describe where the trips that are generated in the first step are going to. In contrast to a static ODM which corresponds to the number of trips going from one place to another over a certain period of time (e.g. working weekday), the dynamic describes the number of trips in each period of time (e.g. every 15 minutes). Hence, it is a tridimensional matrix rather than a 2D static ODM. This study aims to estimate a dynamic ODM using an Entropy-Maximization (hereafter EM) approach. The EM optimization model is solved using an iterative algorithm based on Lagrangian relaxation. The model is tested on a case study of the commuter train service in Stockholm. The available input data is the total number of trips from each station at different time periods of a full working day (i.e. every 15 minutes). The dynamic ODM estimation model finds the overall trip distribution between the different stations in the network. The iterative solution method showed better performance compared to directly solving the dual problem.

2 - On generalized-convex constrained multi-objective optimization and application in location theory
Christian Günther

In this talk, we study constrained multi-objective optimization problems involving componentwise generalized-convex (semi-strictly quasi-convex or quasi-convex) vector-valued objective functions that are acting between a real linear topological pre-image space and a finite-dimensional image space. By using a new vectorial penalization approach, we show that the set of Pareto efficient solutions of our initial multi-objective optimization problem with a not necessarily convex feasible set can be computed completely by generating the sets of Pareto efficient solutions of two corresponding multi-objective optimization problems with a new feasible set that is a convex upper set of the original feasible set. We emphasize the importance of our approach by applying it to a special class of multi-objective location problems where the aim is to locate a new facility in a continuous location space in the presence of a finite number of demand points. For the choice of the new location point, we are taking into consideration a finite number of forbidden regions. For such a nonconvex multi-objective location problem, under the assumption that the forbidden regions are pairwise disjoint, we give a complete geometrical description for the set of Pareto efficient solutions.

3 - Lipschitz properties of cone-convex set-valued functions
Anh Tuan Vu, Thanh Tam Le

This manuscript is an overview of recent results concerning Lipschitz properties and convexities of set-valued functions. We define several set relations and set differences. Theses concepts are beneficial for us to introduce many concepts of cone-convexity and Lipschitz property of set-valued functions. In this paper, we study the Lipschitz property of a set-valued function F : X Y, where X,Y be topological vector spaces and F is C-convex such that C is a proper convex cone in Y. This problem has been investigated by different methods for the case of set-valued functions since there exits several types of set relations and set differences. Minh et al. (2002), Kuwano et al. (2012) have studied Lipschitz properties of the function F, where X is a finite dimensional space. In addition, Kuwano et al. (2012) assumed that the cone C is normal. Tuan et al. (2016) have generated these results where X,Y are normed vector spaces, C is a proper convex cone and not necessarily normal. In this paper, we present here a selection of concepts and recent results on the Lipschitz property of a cone-convex set-valued functions. We not only derive some results on Lipschitz property in the sense of Kuwano et al. (2012) but also relax the normal assumption on the cone C. Furthermore, by means of appropriate functionals, we study G-Lipschitzianity of F when it is Cs-covex.

4 - Linear and nonlinear metric regularity and optimality conditions
Phan Quoc Khanh

We propose a general nonlinear model of regularity including a functional regularity modulus instead of a linear modulus and a distance-like instead of a metric. Sufficient conditions for this regularity property are established based on the induction theorem instead of the Ekeland variational principle (EVP) used in most of the recent contributions to the topic. Moreover, the equivalence of our induction theorem and the EVP is proved. Next, we apply this general nonregularity condition to obtain nonclassical Karush-Kuhn-Tucker (KKT) optimality conditions in nonsmooth optimization. Imposing the special case of directional Holder metric subregularity and using the Studniarski derivative, we get higher orders of such KKT conditions. Moreover, assuming directional linear metric subregularity and using contingent-type derivatives we demonstrate nonclassical higher-order KKT conditions with additional complementarity slackness. We also discuss higher-order envelope-like effects.

■ TA-20

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S301

Decision Analysis Applications I

Stream: Decision Analysis and Decision Support Systems
Chair: *Antti Punkka*

1 - The global value of offshore wind energy
Zana Cranmer, Erin Baker

This work estimates the value of permitting offshore wind farms in terms of mitigating climate change. Offshore wind is one of many options for reducing emissions. It can also lower the cost of reducing emissions if used instead of a more expensive abatement technology. This work develops a method for estimating the value of offshore wind energy, accounting for both the cost of damages and the cost of abatement. This value can be compared with the local environmental impacts of offshore wind as part of a sustainable permitting process for offshore wind farms. We estimate that the global value of offshore wind energy ranges from US$283 billion to US$2.9 trillion. The value of offshore wind varies across the regions of the world and we explore the drivers of that value across different regions, policies, and technology costs. This has implications for who and when they should invest in offshore wind energy.

2 - Energy network management of an oil refinery
Elif Mete

Tupras Izmit Refinery operates a complex utility system to satisfy its dynamic energy demand in the form of steam and electricity. The design of the utility plants allows multiple operational configurations to secure the continuity and flexibility of refinery processes. The main objective of the project is developing a decision support tool to monitor the complex energy network of the refinery and manage it efficiently by determining the optimum operational combinations of the equipment. The project contains 3 parts: data management, optimization and modeling and interface and reporting. In the first part, process data are collected from different sources and filtered according to the operational rules. After validation of the data, the mass and energy balances calculate energy demand of the system. The problem is formulated as mixed integer linear programming model in GAMS and solved by CPLEX 12. The model determines the operational configuration of the system by minimizing the operational cost. The interface of the tool allows designing a process flow chart with 25 different equipment via a drag-and-drop toolbar. The optimization report contains a detailed the comparison of the online plant data and the optimization result for each equipment. The tool has been used since May 2016 and achieved up to 220 $/hr cost reduction. The effective management of the energy network decreases the CO2 emission due to the effective use of fossil fuels, as well.

3 - Data-driven decision support for maintenance management using unsupervised learning and integer programming

Subanatarajan Subbiah, Talha Badr, Ralf Gitzel

Asset managers and/or maintenance managers constantly face the challenge to decide on assigning a suitable maintenance policy to the assets in their production facility to ensure the availability of the assets, to avoid any unplanned downtimes and to also optimally utilize the given maintenance budget. This talk addresses the challenge mentioned earlier and the contribution through our scientific work is twofold. First, we propose an approach to use a suitable unsupervised learning technique to cluster the assets based on features extracted from the failure data and life data from the computerized management system (CMMS). The most appropriate maintenance policy (corrective maintenance, time-based or usage-based maintenance, condition-based maintenance etc.) is then assigned to the clusters. The assignment of the clustered assets with a suitable maintenance policy is performed in an agnostic fashion without considering the maintenance budget into consideration in the first step. The second-fold of the contribution considers the maintenance budget into consideration and an integer programming formulation is proposed to find an optimal solution such that the hard constraint on the budget is respected. The proposed approach was tested on synthetic data considering several failure patterns and on data from a real-world industrial case using a mature CMMS. The challenges in using real world data with respect to data quality is also discussed.

4 - Development of a flexible multi-objective duty roster planning tool

Antti Punkka, Aleksi Porokka

We describe the development of a multi-objective duty roster planning tool, which produces cost-efficient personalized 3-week long duty rosters for the about 1000 train drivers from 25 depots who drive the long-distance passenger and freight trains of Finnish state-owned railway operator VR. The optimization model for producing the plans considers several aspects related to the drivers' well-being and the resulting plans satisfy different constraints set by law, collective bargaining, equal treatment of drivers, drivers' competences and their personal preferences on working rhythm. We also discuss how the developed optimization tool (i) enhanced interaction possibilities between driver representatives and duty roster planners through cooperative iterative planning, as new plans can be produced in a few minutes, (ii) decreased planning time and improved possibilities to react to late changes in personnel availability, freight transportation demand and timetables, and (iii) decreased operating costs significantly.

■ TA-21

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S303

Workforce Scheduling and Line Balancing IV

Stream: Project Management and Scheduling
Chair: *Sergey Kovalev*

1 - Parallel machine scheduling with job splitting, sequence-dependent setup times, and limited setup resources

Hyun-Jung Kim, Jun-Ho Lee

We examine a parallel machine scheduling problem with job splitting, sequence-dependent setup times, and limited setup resources. Jobs can be split into arbitrary sections that can be processed on multiple machines at the same time. It is necessary to change setups between processes of different jobs on a machine, and the setup time is sequence-dependent. The setup is performed by an operator, and the number of setup operators is limited. In the problem, the lengths and processing orders of job sections on machines should be determined while satisfying setup resource constraints in order to minimize makespan. This problem is motivated by casting processes in an automobile piston manufacturing factory, and it can also be found for systems that manufacture textile, semiconductors, printed circuit boards and network computing. For this problem, we propose a mathematical programming model for the first time and then develop an efficient heuristic algorithm. We analytically derive a worst-case performance ratio of the algorithm and evaluate its performance with optimal solutions for small problems and with lower bounds for large problems. We finally show that the proposed algorithm can be efficiently and effectively used in practical applications.

2 - A cutting plane approach for the multi-machine precedence-constrained scheduling problem

George Vairaktarakis, Prahalad Venkateshan, Joseph Szmerekovsky

A cutting-plane approach is developed for the problem of optimally scheduling jobs with arbitrary precedence constraints on unrelated parallel machines. While the single machine version of this problem has attracted much research efforts, enabling solving problems with upto 100 jobs, not much has been done on the multiple machines case. A novel mixed-integer programming model is presented for the problem with multiple machines. For this model, many classes of valid inequalities that cut off fractional linear programming solutions are developed. This leads to increase of the linear programming lower bound from 89.3% to 94.6% thereby leading to a substantial reduction in the resulting branch-and-bound computational time to solve the problem instances to optimality. This enables us to report optimal solutions for problem instances with upto 25 jobs and 5 machines, which is more than twice the size of problems for which optimal solutions have been reported in literature thus far.

3 - Workforce management in call centers

Marc-Philip Piehl, Michael Manitz

One of the main problems of workforce management is cost minimization subject to a service level constraint. We consider a call center with two levels, an overflow mechanism, and impatient customers. Based on performance evaluation of such a system via a continuous-time Markov chain, an optimal configuration of agents is found by complete enumeration. To reduce the computation time, we develop a heuristic approach that tests on which level the increase of one agent adds more value in relation to the service level threshold. The result of the heuristic is a reduction of the computing time by a huge amount.

4 - Order batching & sequencing in bucket brigade order picking

Yossi Bukchin, Eran Hanany, Eugene Khmelnitsky

Order picking is the most labor cost consuming element in warehouse operations. The studied environment addresses a single picking aisle consisting of multiple pick faces. Each picker is characterized by stochastic walking and picking speeds. The picking mechanism is the bucket brigade (BB), with pickers ordered from slowest to fastest according to their expected speeds. The environment is assumed static, with a given set of orders to be picked, where each of a finite number of order types is characterized by some workload distribution along the line.

We first consider a sequencing problem assuming deterministic forward speeds and infinite backward speeds. Under these assumptions we prove that: (1) no blockage occurs for any set of identical orders with a general workload distribution; and (2) for any set of orders with different workload distributions, as long as the total workload is identical, there is a sequence with no blockage.

We then consider general speeds with the objective of minimum makespan. The suggested batching and sequencing approach utilizes the properties of the deterministic environment. The solution approach minimizes the number of batches, and at the same time suggests batches with similar workload distribution. We formulate the problem as Constraint Programming (CP) model, and show that it can efficiently solve non-linear models of relatively large instances.

■ TA-22

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S304

Multicriteria Optimization for Scheduling and Transportation Problems

Stream: Multiobjective Optimization
Chair: *Vitor Basto-Fernandes*

1 - A multi-objective approach for a sustainable flexible parallel assembly line: a real case study

Ahmed Mohammed, Irina Harris

In recent years, the design of assembly lines have become major challenges for decision makers since it has been increasingly important to consider the sustainability aspect to cope with the increasing regulations for the era of sustainability. This work investigates a real life design problem of a flexible ten stages assembly line in a chemical manufacturing company in the UK. A multi-objective optimization model was developed to design an assembly line in allocating the optimal number of workstations that should be established to fulfill orders within a particular cycle time. The developed model aims to consider the triple bottom line sustainability. Therefore, the model seeks a trade-off among three objectives: minimization of total cost, ecological impact (CO_2 and energy consumption) and maximization of social impact (job created). The model is also developed subject to constraints of fulfilling the customers' demand within four weeks lead time. The ϵ-constraint method is employed to optimise the developed model in terms of obtaining Pareto solutions. Finally, technique for order of preference by similarity to ideal solution (TOPSIS) is used to reveal the final solution in a set of Pareto solutions. A real case study was implemented to examine the applicability of the model.

2 - A network approach to group decision making portfolios and its application in multiobjective scheduling

Michael Emmerich, Iryna Yevseyeva

Group decision making is a difficult task because it needs to take into account multiple objectives of multiple decision makers. The goal is to achieve a consensus among the decision makers on at least one of the decision alternatives. From the perspective of a moderator or mediator, it is desirable to present decision alternatives that are likely leading to consensus. Moreover, if the number of options is large, it would be wise to select only a small subset of promising options (decision portfolio) not to overload the decision makers with information. A model based on Bayesian belief probabilities on acceptance probability distributions was presented by the authors in the past, that provides a rational framework for reasoning about decision portfolios. In this talk, we analyse how the analysis of correlation can improve the decision portfolio selection, and how network analysis techniques can help to visualise the trade-offs in the portfolio and decision specific relations between decision makers. The model can be used in the context of engineering design or in decision making in airline scheduling.

3 - Modelling and solution methods for efficient utilization of multiple servers

Nursen Aydin, Ibrahim Muter, Ilker Birbil

Improving energy efficiency and lowering operational costs are the main challenges faced in systems with multiple servers. One prevalent objective in such systems is to minimize the number of servers required to process a given set of tasks under server capacity constraints, which is known as bin-packing problem. In this study, we consider a generalization of this problem with a time dimension, in which the tasks are to be performed in predefined time intervals. This new dimension brings about new performance considerations, one of which is the uninterrupted utilization of servers. This study is motivated by the problem of efficient assignment of virtual machines to physical servers in a cloud computing facility. We address the virtual machine placement problem and present a binary integer programming model to develop assignment policies. By analysing the structural properties of the problem, we also propose an efficient heuristic method for large-scale problems. Our numerical study indicates that the proposed models performs well in realistic set-ups.

4 - Evolutionary multi-objective scheduling for anti-spam filtering throughput optimization

Vitor Basto-Fernandes, Iryna Yevseyeva, Michael Emmerich

This work presents an evolutionary multi-objective optimization problem formulation for the anti-spam filtering scheduling problem, addressing both the classification quality criteria (False Positive and False Negative error rates) and email messages classification time (minimization). This approach is compared to single objective problem formulations found in the literature, and its advantages for decision support and flexible/adaptive anti-spam filtering configuration is demonstrated. A study is performed using the Wirebrush4SPAM framework antispam filtering and the SpamAssassin email dataset. The NSGA-II evolutionary multi-objective optimization algorithm was applied for the purpose of validating and demonstrating the adoption of this novel approach to the anti-spam filtering optimization problem, formulated from the multi-objective optimization perspective. The results obtained from the experiments demonstrated that this optimization strategy allows the decision maker (anti-spam filtering system administrator) to select among a set of optimal and flexible filter configuration alternatives concerning classification quality and classification efficiency.

■ TA-23

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S305

Course Timetabling

Stream: Timetabling
Chair: *Sanja Petrovic*

1 - A multi-objective approach for university course timetabling problem

Erika Tatiana Ruíz Orjuela, Diego Andrés Carreño Dueñas, Luis Amaya Gonzalez

At the beginning of each semester, the institutions of higher education are confronted with the problem of time scheduling and assigning classrooms to the courses offered. The main objective of this research is to use the application of the problem known as University Course Timetabling, specifically in the optimal assignment of classrooms for the academic programme: Industrial Management of the Universidad Pedagógica y Tecnológica de Colombia. This programming must satisfy a series of requirements, identified by the University's policies, by the type of employment link of the teachers, as well as the needs of the students. To solve the multi-objective combinatorial optimization problem, an algorithm is proposed. This integrates the use of a particle swarm optimization (PSO) with evolutionary crossing and mutation operators, the above for eliminating one of the main limitations of PSO associated with the high dependence that exists with respect to the definition of the parameters of metaheuristics; this hybrid method is known as Evolutionary Particle Swarm Optimization. For testing, we perform preliminary experiments on standard benchmark course timetable problems and able to produce promising results, likewise the metaheuristic allows flexible modeling and presents feasible solutions, and it serves as support for the decision.

2 - Course timetabling in a flexible semester structure
Marco Chiarandini

In course timetabling, it is common to assume a weekly periodicity of the schedule and classes of fixed duration. These models are inadequate at our institution, where teachers are free to express different requests for the number of classes in each week of the semester and different duration for each specific class. In this setting, the presence of public holidays in some weeks cannot be ignored. Canceling the class because scheduled on a day that is not actually available compromises the requested planned number of confrontation hours and would require difficult post-scheduling. Further, within each week, introductory classes must precede training classes. We formulate the problem in mixed integer programming terms modeling the flexible duration of classes by a particular choice of variables and the weekly flexibility of the schedule by extending the time horizon of the formulation to a whole semester. We deal with room assignment and precedence constraints with a classic two-phase (lazy) approach. We report computational experiments on this approach on our practical instances generated by the schedule of an elective course at our institution. The performance of state-of-the-art mixed integer programming solvers have been satisfactory so far for our practical needs but is neither robust nor scalable.

3 - Bi-criteria simulated annealing algorithms for the robust university course timetabling problem
Can Akkan, Ayla Gülcü

A bi-criteria version of the curriculum-based course timetabling problem of ITC-2007 is solved to identify an approximation to the optimal Pareto front. The two criteria are the penalty function as defined in ITC-2007 (International Timetabling Competition) and a robustness function. Robustness is needed to deal with disruptions that occur in the form of a feasible period that is used by a course becoming infeasible for that course. In such situations, the timetable has to be updated, in essence, re-optimized, while ensuring that the changes are not excessive. A timetable is said to be robust if, when disrupted, it can be re-optimized without significantly lowering its quality in terms of the objective function and keeping it relatively stable. We define a robustness function that takes into account both the solution quality and stability concerns. In the first part of this research, we assume only a single disruption occurs. This problem was first defined in Akkan and Gülcü (2018) and solved using a hybrid Multi-objective Genetic Algorithm (MOGA). Here we propose a Multi-objective Simulated Annealing algorithm that outperforms the hybrid MOGA. Then, the second part of the research extends the MOSA algorithm to the multiple disruptions case, which we define as a multi-objective stochastic combinatorial optimization (MOSCO) problem. We develop a MOSA algorithm that makes use of a Monte Carlo sampling approach to solve this case.

4 - An integer programming based scheduling of university wide orientation course activities
Aydin Ulucan, Eren Miski Aydin, Bulent Cekic

University orientation programs are the main tool for facilitating student's engagement in university life. Generally, orientation programs consist of a series of lectures and activities that are designed to help become acquainted with life and studies at university. In a mid-large scale university, the arrival of thousands of new students and organization of hundreds of activities assignments/plans should be planned before the orientation starts. This problem is classified as a scheduling/timetabling problem. In this study we develop a novel application of academic timetabling problem; university-wide orientation course activities scheduling. In order to solve this assignment problem, an integer programming model has been developed. The modeling involves the assignment of 7082 students in 110 different programs to 85000 capacity activities. We also test the applicability of the model with various objectives.

■ TA-24

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S306

Financial Mathematics and OR V

Stream: Financial Mathematics and OR
Chair: *Zhongfei Li*

1 - An assessment of long-term investments risk in longevity risk protection
Justyna Majewska, Grażyna Trzpiot

The impact of longevity risk (defined as the risk that members of some reference population might live longer on average than anticipated) has gained attention in academic research as well as in the public debate for the past few years. From individuals' perspective, longevity fuels the need for long-term investments. Economy predictions for the next decades suggest individuals save more for retirement, retire later, or reduce consumption during retirement. The aim of the paper is twofold. Firstly, the impact of changing longevity assumptions on investment strategy is examined. Secondly, we analyze the structure of long-term investment portfolios and assess the risk of the portfolio depending on longevity improvements. The examples of selected European populations demonstrate changes in the traditional approach of portfolio management theory that relies on fostering long-term investment and responding to the challenges of longevity.

2 - Portfolio selection with minimum regularised covariance determinant estimators
Marco Neffelli, Marina Resta, Maria Elena De Giuli

The aim of this work is to test the robustness of the Minimum Regularised Covariance Determinant (MRCD) estimators' class against the sample covariance matrix for portfolio allocation. Focusing on the Global Minimum Variance Portfolio (GMVP) problem. Our sample is based on 300 constituents drawn from the S&P500 index: we considered monthly observations, from 01/01/1996 to 31/10/2017 for an overall number of 262 data points. In order to test the robustness of our approach for several covariance matrix sizes, we selected as investment universe the early most capitalised 30, 50, 100, 150, 200 and 300 assets from the original sample and we run the following investment strategy: at the beginning of each month, we estimate the covariance matrix with sample and MRCD techniques, allocating the wealth according to the GMVP. With the aid of a monthly rolling window, we repeat the process for an overall number of 202 out-of-sample periods. Therefore, the investment performance is evaluated only out-of-sample by way of the average monthly turnover, the global variance and the deflated Sharpe ratio. Results show that the MRCD is a more efficient alternative than the sample covariance, with reduced turnover and global variance, and higher deflated Sharpe ratio. The improvement is more evident when the sample size is large.

3 - A variance decomposition in stock portfolios
Javier Giner

In this paper we propose a space partitioning of a bivariate normal distribution representing the return of two stocks portfolios. Four Euclidian quadrants around the central mean point are considered with their correspondent truncated distributions. We can think about pairs of stocks as events where both go up together, both decline or one rise up and the other decline. So we try to answer the question, what is the contribution of each quadrant to the global mean return? And, what is the contribution of each quadrant to the global variance? We considered the mixture of four truncated bivariate normal distributions, and the weighting coefficients coincide with the quadrants probabilities. Through the law of total variance and the first and second moments of each truncated distribution, we obtain the requested decomposition formulas. These results are validated with straightforward simulations. Moreover, low variance strategies can be better interpreted with this variance decomposition, and the CAPM framework can also be developed within these quadrant scheme.

4 - A multinomial-tree gambling model
Zhongfei Li

The binominal-tree gambling model proposed by Barberis (2012) not only explains why people gamble, but also provides a new framework for analyzing gambling behavior. In reality, however, a gamble is usually complex and has many outcomes. This paper extends the binominal-tree gambling model to a multinomial-tree one. To solve our model, we first introduce some variables and give their computation formulae based on the special structure of our model. Then we design a tabu search algorithm. Using the algorithm, we compute and compare the optimal strategies under thousands of parameter sets, showing that our algorithm is fast and has high accuracy. In addition, we compare the results under different initial solutions and find the most appropriate initial solution for our algorithm. As an application, we reinvestigate the question of when people are willing to gamble under the parameter values of Kahneman and Tversky's (1992). Barberis (2012) gives an answer to this question and guess an associate gamble strategy. Using our algorithm, we give the same answer but find a better gamble strategy even without any prior information about the structure of the optimal strategy, showing the advantage of our algorithm. Finally, this paper analyzes the influence of "draw" on optimal gambling strategy. We find that the impact is complicated and an appropriate probability of the "draw" outcome can raise income of casinos.

■ TA-25

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S307

Combinatorial Optimization and Logistics Operations

Stream: Combinatorial Optimization II
Chair: *Jiyin Liu*

1 - On emptying a container bay by neural network
Yat-wah Wan, Wen-Fu Yang

To streamline its operations, a container terminal often faces the following problem: Containers in a given bay have a well-defined retrieval sequence. The objective is to empty the bay with the minimal number of reshuffles, where any reshuffle can only be carried out within the bay.

Various optimization techniques, heuristics, and metaheurtics have been applied to the above problem. Generally, there is tradeoff in quality and run time of the solution techniques. Seldom a method can have short computation time and yet excellent solution quality.

Inspired by the recent success of AlphaGo for the extremely complicated Go game, this paper investigates the possibility of training a neural network, deep-learning or not, to empty a container bay. As the training of the neural network is carried out in the backstage, a trained neural network takes no time in identifying a way to empty the bay. Thus, conceptually, the approach can be quick, optimal, and applicable in real time.

The paper defines the inputs and outputs of the neural network; describes the procedures to generate such input-output pairs to train, test, and validate the neural network; and carries out numerical experiments to access the validity of the idea. It also discusses the various subtleties in input-output definition and training to improve the performance of the neutral network.

2 - Inventory sharing policy for medical supplies in Hong Kong hospitals
King-Wah Anthony Pang, Ping Zhang, Hong Yan

Sharing economy is an upcoming area which attracts more attention from the research community in recent years, with its extensive applications in different industries including transportation, accommodation, co-working spaces, etc. The concept is to share the use of assets by individuals or groups through a peer-to-peer transaction in order to lower their cost. In Hong Kong medical system, hospitals order short lead-time medical supplies from dealers almost every day to minimize the inventory cost, but demand may exceed supply when a large-scale accident occurs, such that the hospital may need to place urgent orders to a dealer with extra transaction cost or to borrow inventories from other hospitals. This paper investigates the feasibility of sharing the medical supplies between hospitals in order to minimize the total cost of operations that satisfy the urgent demand. We propose a framework of sharing inventory model that hospitals order medical supplies non-cooperatively with dealers but cooperatively share their inventory when urgent demand occurs. Hospitals need to decide whether place an urgent order to dealer or request for inventory sharing with other hospitals. The objective is to minimize the total cost of operations which includes the normal and urgent transaction cost, inventory cost and shortage cost. We develop a hospital equilibrium inventory policy such that a hospital j is willing to share its own inventory to hospital i who faces an urgent demand.

3 - Field scheduling with time windows to minimise the service risk of missing appointments
Chenlu Ji, Rupal Rana, Jiyin Liu

This research models the risk minimisation objective in the Stochastic Vehicle Routing Problem (SVRP) where technicians drive to customer sites to provide services. Service times and travel times are subject to stochastic events. For each customer there is an agreed time window to start service. Skill levels and task priorities are also considered which increase the complexity of this problem. The risk of missing a task is defined as the probability that the technician assigned to the task arrives at the customer site later than the time window. The problem is to generate a schedule that minimises the maximum of risks and sum of risks over all the tasks. Each task duration or travel time is supposed to follow a known normal distribution. However, the distribution of the start time of the service at a customer site will not be normally distributed due to time window constraints. An estimation method is proposed and tested to model the start time as normal distributed. Moreover, a linear model is obtained assuming identical variance. Additionally, hill climbing search and simulated annealing methods are applied to solve the problem. Results of this work have been applied to an industrial case of SVRP where field engineering individuals drive to customer sites to provide time-constrained services. This original approach gives a robust schedule and allows organisations to pay more attention to increasing customer satisfaction and become more competitive in the market.

4 - A new approach for the vehicle sharing and workforce scheduling problem
Pol Arias, Rupal Rana, Jiyin Liu

The possibility of sharing vehicles has drawn attention both from industry and research institutions. Recent problems arising from infrastructure capacity and population growth have forced governments and companies to deal with a better resource utilisations of their vehicle fleet. We present a variant of the Vehicle Routing Problem which allows drivers to share their vehicles within their work schedule, called the Vehicle Sharing and Workforce Scheduling and Routing Problem (VSWSRP). Workers are assigned to perform tasks at various locations and the routing aims to reduce the number of vehicles by allowing workers to share vehicles. In this work, we present a novel formulation for the vehicle sharing and workforce scheduling problem which enables vehicle sharing throughout the working period of workers. Due to the complexity of the problem we propose a heuristic approach to tackle bigger instances of the problem. In addition, an in-depth analysis is presented where interesting insights are derived which show that sharing vehicles is affected by the duration of the jobs and how jobs are geographically distributed.

■ TA-26

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S308

Crew Planning

Stream: Public Transportation I
Chair: *Twan Dollevoet*
Chair: *Thomas Breugem*

1 - A matheuristic for the driver scheduling problem with staff cars

Shyam Sundar Govindaraja Perumal, Jesper Larsen, Richard Lusby, Morten Riis, Kasper Sørensen

In the public bus transport industry, it is estimated that the cost of a driver schedule accounts for approximately 60% of a transport company's operational expenses. Hence, it is important for transport companies to minimize the overall cost of driver schedules. A duty is defined as the work of a driver for a day and the driver scheduling problem (DSP) is concerned with finding an optimal set of driver duties to cover a set of timetabled bus trips. Numerous labor regulations and other practical conditions enforce drivers to travel within the city network to designated bus stops to start/end duty, to take a break or to takeover a bus from another driver. This paper focuses on the driver scheduling problem with staff cars (DSPSC), where staff cars can be utilized by the drivers to fulfill their travel activities. However, staff cars should always be returned to the depot and can perform multiple round trips during the day. The problem is restricted by the number of cars available at the depot. We present a matheuristic for solving the DSPSC and the proposed method is tested on instances from Danish and Swedish companies. A comparison with a state-of-the-art mixed integer programming (MIP) solver indicates that the matheuristic provides better solutions for 6 out of 10 large instances. For instances that have more than 6 staff cars and 1200 bus trips, the improvement is 6-11% on average.

2 - A column generation approach for railway crew replanning

Thomas Breugem, Twan Dollevoet, Dennis Huisman

The operational plan of a railway operator is often modified to allow for planned maintenance. This implies, among other things, that the crew schedules have to be adjusted shortly before the actual day of operations. Blocked tracks due to maintenance, for example, imply that the crew schedules are no longer feasible, as certain trips can no longer be performed. Hence, modified crew schedules have to be constructed, which are feasible for the new situation, and cover as much work as possible. Currently this is done on a day-to-day basis, where new crew schedules are constructed for each day separately. We propose an integral approach, in which we directly reschedule the crew over a period of multiple days, thereby adjusting both the duties and the rosters. This increases the complexity of the rescheduling process, as additional constraints have to be taken into account, but can lead to better overall solutions. We call this problem the Crew Replanning problem, for which we propose a solution method combining column generation with Lagrangian relaxation. We show the benefit of our proposed methodology on practical instances from NS.

3 - Novel formulations for railway crew rostering

Twan Dollevoet, Thomas Breugem, Dennis Huisman

The crew planning process at a railway operator usually distinguishes between two phases: Crew Scheduling and Crew Rostering. Crew scheduling generates a set of duties that together contain all the work to be performed. Each duty corresponds to one day of work and should satisfy many rules, for example on a meal break and the duty length. In crew rostering, these duties are then assigned to the individual crew members. Here, rules involving multiple duties are taken into account, such as sufficient rest time between duties and a maximum amount of work in each week. In the crew rostering phase, the main objective is to find a feasible roster that is attractive for the crew members. In order to solve large instances of the crew rostering problem, we propose a novel formulation based on so-called roster sequences. Such a roster sequence describes the duties to be performed by a crew member for a sequential set of days in the roster. By choosing this set of days suitably, many complex labor rules can be modeled implicitly in the roster sequences. As a consequence, our formulation is much tighter than a naïve one based on assigning duties individually. We develop a Branch-Price-Cut algorithm to solve the model, in which roster sequences are generated dynamically by solving a resource constrained shortest path problem with surplus variables. We demonstrate the effectiveness of our approach on real-life instances of Netherlands Railways.

■ TA-27

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S309

Logistics

Stream: Production, Service and Supply Chain Management
Chair: *Sangmoo Shin*

1 - Competition, decision rights, and supply chain structure

Sudheer Gupta

We study two questions: 1) When would decentralization of decision rights benefit supply chains, when firms make pricing and inventory decisions? 2) Which decision rights should a manufacturer delegate to a retailer? We analyze a model with two competing supply chains where retailers compete for customers through prices and availability of stock. Retailers face stochastic demand with known distribution and decide on inventory levels before demand uncertainty is realized. We analyze three scenarios: Integrated; Decentralized (where both prices and inventory decisions are delegated); and Partial Decentralization (where either prices or inventory decisions are delegated). We show that when both decisions are delegated, supply chain profits are lower than in Integrated case. These results refute the "strategic decentralization" effect that focuses on delegation of pricing decisions alone. We then study partial delegation and show that delegation of price decision alone to retailers while retaining control of inventory decision (i.e., a vendor-managed inventory contract) restores the strategic benefits of decentralization. Decentralized supply chains, where manufactures control inventory decisions but delegate pricing to retailers, make higher profits than integrated supply chains do. Our model provides a novel, strategic explanation for VMI contracts that have primarily been explained via efficiency-enhancing arguments. Contracts could play a dual role in supply chains.

2 - Lifetime extension and an application to PC upgrading

Sha Zhu, Rommert Dekker, Willem van Jaarsveld

In the field of maintenance, a lot of literature consider the physical deterioration of capital asset, e.g. using the Weibull distribution to model the deterioration process. However, in some cases physical deterioration is not the key reason for maintenance. For example, a PC customer wants to replace the CPU not because of its breakdown but the launch of a new version of CPU with higher performance. Comparing with physical deterioration we call it commercial deterioration. We consider asset life time extension based on commercial deterioration which aims to increase the economic life of asset. The trade-off is between replacing the asset completely and conducting a partial upgrade. We build a Markov decision model to obtain the upgrading policy which has a positive impact on life time extension. We apply our model to the PC case including upgrading the CPU, GPU and HDD. We fit the curve of commercial deterioration of CPU, GPU and HDD with hand collected dataset. Based on the commercial deterioration, we obtain the performance level above which life time extension policy leads to upgrading the component instead of replacing a PC.

3 - Optimal allocation of spares to maximize the window fill rate in a two-echelon exchangeable-item repair system
Michael Dreyfuss, Yahel Giat

We solve the spares allocation problem in a two-echelon, exchangeable-item repair system in which the lower echelon comprises multiple locations and the higher echelon is a single depot. We assume that customers tolerate a certain wait and therefore the optimization criterion is the window fill rate, i.e., the expected portion of customers who are served within the tolerable wait. We suggest two algorithms to solve this problem. The first algorithm is formula-based and is sub-optimal. The second algorithm combines simulations into the first algorithm and obtains a higher degree of accuracy at the cost of extra running time. We characterize the near-optimal solution by its degree of pooling and concentration. Pooling happens when spares are allocated to the depot and are therefore shared by all the lower-echelon locations. Concentration takes place when spares are allocated to only a few lower-echelon locations whereas the other lower-echelon locations receive no spares. We use numerical examples to compare the algorithms and to illustrate how budget size, shipment time, local repair and customer patience affect the optimal solution and degree of pooling in varying ways.

4 - How does the Korean textile industry build competitive capabilities? Comparative case studies
Sangmoo Shin, Euisung Jung

Korea is known for the major manufacturing capabilities in automotive, semi-conductor, construction and shipbuilding industries. However, little is known about the competitive capabilities of textile and apparel industry. In this global market environment with information technology, the textile and apparel industry strives to attain competitiveness by building up an efficient and yet flexible supply chains. The firms in the industry attempt to improve collaboration relationship along the vertical supply chains such as fiber, textile, apparel manufacturing, and retailing. Textiles and apparel industry involves complicated and thin supply chains from raw material processing to fabric manufacturing to apparel design to distribution to produce final goods for customers. The complexity of the process necessitates a smooth cooperation among up-, middle-, and down-streams of supply chains. Many problems can arise while going through these supply chains, and some examples are lead-time, inventory control, and flexibility issues. This study illustrates series of competitiveness enhancement initiatives starting from RFID implementation in the textile and apparel industry. Several case studies from multiple countries were compared and analyzed to understand the Korean textile and apparel firms' approach to competitive capabilities in terms of strategic direction, innovative priorities and operational focus. Lessons and implications as well as future research issues are discussed.

■ TA-28

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S310

Service Operations and Supply Chains: A Cross-Section

Stream: Service Operations Management
Chair: *Itir Karaesmen*

1 - Data-driven process mining: discovering treatment approaches for preference-sensitive medical conditions
Feryal Erhun, Katherine Bobroske, Lawrence Huan, Michael Freeman, Anita Cattrell, Jenny Wang, Rich King, Stefan Scholtes

In the United States, detailed medical claims provide a unique opportunity to trace a patient's journey across service locations, diagnostic tests, specialists, and treatment approaches. However, given the high level of variability, longitudinal nature of the data, and the detailed information contained in the claims, the dataset has proven challenging to analyze. Drawing together insights from traditional clinical episode groupers and the emerging field of process mining, we propose a data-driven algorithm that generates a process map of the patient journey across distinct events relating to the patient's diagnosis and care. The proposed methodology requires only limited clinical inputs to group individual medical claims into distinct events that reflect the patient experience. A flexible set of rules then define distinct episodes, mapping a longitudinal picture of the patient journey. Process mining techniques cluster the journeys into groups of similar patterns, allowing researchers analyze treatment effectiveness and identify opportunities for process improvement. In the example application of the preference-sensitive condition of back pain, a subset of patient journeys is found to be highly correlated with the patient's increased risk of opioid dependence.

2 - Improving access of low back pain patients through prioritization at a neurosurgery clinic
Esma Gel

Low back pain (LBP) is often cited to cause significant health impairments for a large fraction of the population. Studies point to the unnecessary use of costly imaging studies and surgical assessment. This mismatch results in critical access problems for patients that truly need surgical interventions within a reasonable timeframe. We present findings from a project to improve access of LBP patients at a neurological surgery clinic. Our analysis points to the importance of prioritizing surgical patients and demonstrates the potential improvements in patient access using real-life data. We present a highly accurate method to assign patients to priority classes and some initial results on effective prioritization protocols.

3 - Optimal assignment of human resources to a public service organization: the case of using quantitative methods in a qualitative problem
Stelios Koukoumialos, Athanasios Spanos, Michael Vidalis

In this study,we optimize a non-profit organization's ability to allocate its human resources in order to maximize its effectiveness.We create lists of selection criteria for each position or task,based on internal regulations/instructions,and then assign a specific value for each criterion based on its correlation to maximum performance in the corresponding position.We calculate the weighting value for each position of the organization and the weighting value for every criterion relevant to each position.The annual evaluation report of the employees-which includes unbiased scoring of C.V.and subjective scoring of the head of the department-is formulated into an employee evaluation table for each task.Following an anthropocentric leadership model,we consider each employee's application form, and specifically their stated working position of preference. Constraints concerning the working hours, days off and personnel requirements are also considered.We then use this information to develop an integer programming assignment model.Implementation is realized in a governmental security service station for two scenarios and a logical extension. The second scenario differs from the first in the fact that the criteria are interdependent in a weightiness relationship and the extension concerns the case of the security patrol where we consider particular information. The final report and the sensitivity analysis provide useful suggestions,concerning internal or external changes.

4 - Coordinating broker's procurement and logistics decisions
Itir Karaesmen

We study the procurement and distribution decisions of a broker (intermediary). The procurement decision involves choosing the bid price to procure supply from multiple suppliers and distribution decisions involve shipping procured goods (based on the outcome of the bids) to existing customer locations to meet customer demand. We analyze the structural properties of optimal bids. We also show the value of coordinating the procurement and bidding decisions using computational experiments.

■ TA-29

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S311

Models in Game Theory: Solutions

Stream: Game Theory, Solutions and Structures
Chair: *Amparo Urbano*

1 - A two-step proportional rule for division with multiple characteristics
Miguel A. Hinojosa, Amparo Mármol

When dividing a commodity between a set of agents, the proportional rule provides a result in which all the agents obtain the same proportion with respect to their reference with respect to a certain characteristic. However, when multiple characteristics have to be considered at the same time, there is no obvious way to define proportionality. In this paper we propose a two-step proportional rule for division with multiple references which incorporates the extensions of two crucial properties which are inherent to proportionality: the proportions obtained with respect to the different references cannot be improved simultaneously, and the result does not depend on the scale in which each of the characteristics is measured. In our approach, the choice of the two-step proportional allocation for the division problem is understood as a negotiation between parties, each one supporting one of the characteristics. We prove that the two-step proportional rule coincides with the Kalai-Smorodinsky solution applied to the problem of selecting the proportions which the characteristic will attain with respect to their references.

2 - Strategic vector-valued games with Rawlsian preferences
Amparo Mármol, Asunción Zapata, Luisa Monroy, Maria de los Angeles Caraballo

We analyse the equilibria of non-cooperative games in which the preferences of the agents include not only self-interest, but also the well-being of others. At a first step, these preferences are modelled as vector-valued utilities where the components represent the utilities of the different agents. It is often the case that no possibility of compensation between the utilities exists. Therefore, in order to model agents' social preferences, we adopt a weighted Rawlsian function which includes the relative importance that each agent assigns to the utilities of the others. In this framework, we characterise the type of agents in terms of the weights they may apply, and analyse the consequences of including these other-regarding behaviours on the equilibria that the agents will finally attain.

3 - Opinion formation and targeting when persuaders have extreme and centrist opinions
Agnieszka Rusinowska, Akylai Taalaibekova

We consider a model of competitive opinion formation in which three persuaders characterized by (possibly unequal) persuasion impacts try to influence opinions in a society of individuals embedded in a social network. Two of the persuaders have the extreme and opposite opinions, and the third one has the centrist opinion. Each persuader chooses one individual to target, i.e., he forms a link with the chosen individual in order to spread his own "point of view" in the society and to get the average long run opinion as close as possible to his own opinion. We examine the opinion convergence and consensus reaching in the society. We study the existence and characterization of pure strategy Nash equilibria in the game played by the persuaders with equal impacts. This characterization depends on influenceability and centrality (intermediacy) of the targets. We discuss the effect of the centrist persuader on the consensus and symmetric equilibria, compared to the framework with only two persuaders having the extreme opinions. When the persuasion impacts are unequal with one persuader having a sufficiently large impact, the game has only equilibria in mixed strategies.

4 - Multiproduct trading of indivisible goods with many sellers and buyers
Amparo Urbano, Ivan Arribas

This paper analyzes oligopolistic markets in which indivisible goods are sold by multiproduct firms to a finite set of heterogeneous buyers, extending the analysis of Arribas and Urbano (JET, 2017) and Arribas and Urbano (mimeo, 2017). We show the existence of efficient subgame perfect equilibria by formulating the problem as the linear programming relaxation of the standard Package Assignment model. We prove that a set of modified versions of the dual programming problem characterizes the efficient (non-linear) equilibrium prices.

Our paper illustrates how to modify the integer programming problem and its dual to find such a set. Since we are interested in the solutions where the firms' profits are Pareto-undominated, we characterize the vertex of the polyhedron of optimal solutions of the dual problem whose corresponding coordinates are non Pareto-dominated.

If the optimal solution of the linear relaxation of the integer programming problem is not integer, then equilibrium fails to exist. Therefore, we give some sufficient conditions in terms of the consumers' value functions which guarantee that both the integer programming assignment problem and its linear relaxation have the same (integer) optimal solution.

■ TA-30

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S312

Operations Research Games I

Stream: Game Theory and Operations Management
Chair: *Ana Meca*

1 - Full null player in partition function form
M' Gloria Fiestras-Janeiro, Mikel Álvarez-Mozos, Andrés Jiménez-Losada, José María Alonso-Meijide

We introduce the concept of full null player in the framework of partition function form games. Using other well-known properties as linearity and symmetry, we build a family of values for games in partition function form games.

2 - Delay allocation in stochastic projects
Juan Carlos Gonçalves, Ignacio García-Jurado, Julian Costa

In this lecture we introduce several procedures to distribute the cost resulting from the delay with respect to a pre-established due date in a project whose activities have stochastic durations. We also compare those procedures in a simulation study.

3 - Warning against recurring risks: an information design approach
Francis de Véricourt, Saed Alizamir, Shouqiang Wang

The World Health Organization seeks effective ways to alert its member states about global pandemics. Motivated by this challenge, we study a public agency's problem of designing warning policies to mitigate potential disasters that occur with advance notice. The agency privately receives early information about recurring harmful events and issues warnings to induce an uninformed stakeholder to take costly preemptive actions. The agency faces then a trade-off between eliciting a proper response today and maintaining its credibility in order to elicit responses to future risks.

We formulate this problem as a dynamic Bayesian persuasion game, which we solve in closed form. We find that the agency sometimes strategically misrepresents its advance information about a current threat. When its credibility is low (i.e., below a threshold), the agency downplays the risk and actually downplays more as its credibility improves. By contrast, when its credibility is high (i.e., above a second higher threshold), the agency sometimes exaggerates the threat. In this case, a less credible agency exaggerates more. These findings provide prescriptive guidelines for designing warning policies and suggest a plausible rationale for some of the false alarms or omissions observed in practice.

4 - A tractable network game of atomic dynamic flows
Bo Chen

Selfish routing, where agents compete in a network for traveling from their origins to destinations as fast as possible, is dynamic in nature. However, capturing such dynamics with a tractable model is challenging, especially when agents are atomic. We propose a network game model, which not only makes a good simulation of the dynamics, but also possesses some nice properties with theoretical and algorithmic tractability. Our edge-priority tie-breaking rule on congestion is key for tractability, which stands in contrast to previous related negative results in the literature.

We study Nash equilibrium (NE) for non-adaptive agents, who select and fix their own origin-destination paths simultaneously at the start. We constructively prove that an NE exists for multiple-origin single-destination networks. We characterize, supported by efficient algorithms, all NEs with many desirable properties, such as weak Pareto efficiency and global First-In-First-Out.

We further investigate an unexplored area of atomic dynamic routing games–the sub-game perfect equilibrium (SPE) for adaptive agents, who make an online decision at each nonterminal vertex they reach as to which next edge to take. We prove that, in a single-destination network, an SPE always exists, and that every NE of non-adaptive agents is realizable by some SPE of adaptive agents. This allows us to build a bridge between non-adaptive and adaptive models.

Joint work with Z. Cao, X. Chen and C. Wang.

■ TA-31

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S313

Behaviour in Models II

Stream: Behavioural OR
Chair: *Pekka Laitila*

1 - Does corporate social responsibility impact preferences in ESG portfolio optimization?
Gordon Dash, Nina Kajiji

Contemporary firm managers attempt to operate in a socially and environmentally sustainable manner. Firms with such strategies offer investors comparable returns in a given risk class. However, the literature has not addressed investor portfolio diversification when securities represent both strong and weak environmental, social, and governance (ESG) performing firms. In the presence of weak ESG performing firms portfolio managers desire a broader statistical view of systematic risk factors. The purpose of this paper is twofold. The first is to understand the weighted impact of firm specific ESG factor performance on the investor's hierarchical diversification problem. The second objective solves a preference-ordered nonlinear hierarchical goal programming model to derive a constrained and ranked efficient frontier. The procedure begins by extracting the latent dimensions that independently characterize liquidity among ESG factor returns. We continue by following the extant literature to calibrate the arbitrage return-generating framework using linear principal components analysis (PCA). Next, we apply a Varimax rotation to reduce the co-linear structure of historical market returns to simple structure. From the simple structure matrix, we are able to derive 'ideal variables' by a factor score algorithm. We conclude by simulating performance characteristics of a weighted and hierarchical efficient ESG portfolio for an actual investor.

2 - Simulation of cultural processes and their social impact
Leonidas Sakalauskas

In this talk I will discuss a research project that aims to analyse and model the impact of cultural events that considerably contribute to the formation of individual and societal states affecting social capital and social cohesion. The project pursues the creation of a modelling tool to understand cultural formation processes and their impact, and its potential application as a decision support and recommendation system for the development of policy.

3 - Affective decision making models with applications to social robotics
Si Liu, David Rios Insua

It has been shown that emotions have a major role in decision-making processes. Advances in areas such as affective decision-making, neuroeconomics and affective computing draw on this principle. Our paper provides a model for an autonomous agent that makes decisions partly influenced by affective factors when interacting with humans and other agents. The factors included are emotions (expected, immediate, referential and complex), mood, personality traits (HEXACO) and activation sets for impulsive behavior. Our development is based on our previous multi-objective expected utility and adversarial risk analysis (ARA) model. However, in this paper utility weights are regulated by the agent's affective states. Our final aim is to provide a believable approach implementable within non-expensive social robotic platforms. Affective mechanisms seem essential to improve the interaction among human and robotic agents. With a proliferation of computer science and neurological studies, social robots are no longer treated as lifeless and emotionless. Affective robots should not only provide better performance in assisting humans, but also might enhance robots' abilities to make decisions. These approaches could enable an intelligent agent to adapt dynamically to users and its environment and potentially be used to enhance a wide range of applications. We describe several simulations performed with our model, showing its relevance and capacity to improve agent adaptivity.

4 - On practical applicability of ranked nodes method for constructing conditional probability tables of Bayesian networks
Pekka Laitila, Kai Virtanen

Bayesian networks (BNs) provide good means to support risk assessment and management in situations where there is a poor amount of suitable historical data but an abundance of expert knowledge. A BN represents the relationships of causes and effects both visually and numerically, enabling the rigorous quantification of risks and a clear communication of results. When BNs are constructed based on expert judgement, the main difficulty concerns the quantification of the portrayed cause-effect relationships in conditional probability tables (CPTs). The number of probabilities to be given for a single CPT can rise up to hundreds or thousands. Assessing so many probabilities coherently and without biases may be an overwhelming problem for the expert due to cognitive burden or lack of time. We study so-called ranked nodes method (RNM) that enables the automatic generation of CPTs based on a small amount of key parameters elicited from the expert. The generation functions used in RNM are based on qualitative descriptions by which experts often characterize given probabilistic relationships. In order to get a general idea of the practical applicability of RNM, we explore how well CPTs generated with it can fit to CPTs found from various real-world BN models. The results indicate that a good average fit is obtained to a large portion of the investigated CPTs. This suggests that RNM can alleviate the challenges of BN construction by expert judgement in many practical applications.

■ TA-32

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S314

Picking and Location Assignment

Stream: Routing, Logistics, Location and Transportation
Chair: *Zehra Duzgit*

1 - Cooperation strategies for improving the order-picking operations in a synchronized zone picking warehouse
Ying-Chin Ho, Chih-Feng Chou

The environment of this study is a synchronized zone-picking warehouse in which the picking area is divided into several zones. When an order enters this system, it may have to be divided into several sub-orders. Each sub-order is picked in the zone that has the items it needs. When a sub-order of an order has completed its picking operations, it will be sent to the consolidation area. Once the sub-orders of an order have all arrived at the consolidation area, they will be consolidated into one order. In a traditional synchronized zone-picking warehouse, pickers belonging to one zone are not allowed to enter neighboring zones to perform picking operations. In this traditional setting, the cooperation between pickers of neighboring zones is not allowed. In this study, we devise several cooperation strategies for pickers in neighboring zones to help each other. We want see if the performance of a synchronized zone-picking warehouse can be improved if the cooperation between pickers of neighboring zones is allowed. We will also study whether several zone design issues (e.g., the assignment of items to zones) can affect the performance of the proposed cooperation strategies. Computer simulations are conducted to test the performance of the proposed cooperation strategies and the proposed zone design methods. We hope that the knowledge learned from this study can assist distribution centers with similar environments in improving their synchronized zone-picking operations.

2 - An integrated cluster-based storage assignment policy
Masoud Mirzaei, Nima Zaerpour, René de Koster

Order picking is a labor intensive process in many warehouses. Its efficiency depends largely on the storage assignment policy used. Current storage assignment policies, such as turnover-frequency class-based storage policies ignore information on product affinity, that is the frequency by which products are ordered jointly. We propose an integrated cluster allocation (ICA) storage assignment model that uses both information on product turnover and affinity to assign products to the storage locations. As the problem is NP-hard and the number of products and locations is very large in practice, we use a heuristic to solve it. We generate a greedy high-quality construction heuristic which is used as an initial solution for a solver which yields considerable savings. Compared to class-based and full turnover-based storage policies, the ICA storage policy can save up to 22%, and 30% respectively, in load retrieval time, for low and medium product affinity levels, assuming an automated storage and retrieval system is used. The ICA storage policy appears to be quite robust against new incoming orders. In a real-life test, using order and product data of a large wholesale company with low affinity level, we found that the ICA policy outperforms class-based and full-turnover based storage for an automated storage and retrieval system. However, the ICA storage policy is data intensive and obtained benefit depends largely on the order patterns.

3 - A new method to solve for exact upper bounds for interval transportation problem with uncertain supplies and demands
Kushani De Silva, Mohomed Juman

When demands and supplies of a transportation problem are uncertain and are provided in an interval, the minimum transportation cost can be delivered in an interval. Therefore, attaining bounds on the total minimal cost of the interval transportation problems has recently received the attention of many researchers. Determining lower bounds is of less interest because it is reducible to a linear programming model and thus can be easily solved. On the other hand, determining the exact upper bound is an NP-hard problem. In the literature, there are very few approaches to find the upper bounds of these types of transportation problems. A new approach formulated as a nonlinear programming problem is suggested to find the upper bound of interval transportation problems. This new approach is implemented in MATLAB and tested the interval transportation problems of different sizes that have been solved for near-optimal values in the most recent literature. The new approach was able to outperform the upper bounds of the previous literature.

4 - Design of a warehouse order picking policy system using genetic algorithm
Zehra Duzgit, Ahmet Can Saner, Ozgur Toy

In this study, we consider to improve order picking process which is an essential operation critically impacting warehouse performance. The problem of reducing travelled distance of an order picker is examined in a multi-block warehouse which employs low-level picker-to-parts manual picking system. The solution approach is composed of two phases: In the first phase, the shortest path between each pair of items is determined in a pick list. In the second phase, given the shortest distance between each pair of items, a genetic algorithm is implemented to decide the best picking sequence and the routing of all items in a pick list which yields the shortest total travelled distance. We report the performance of the proposed genetic algorithm with various crossover and mutation operators and compare them to two well-known heuristics used for multi-block warehouses, namely S-Shape and Largest Gap.

■ TA-33
Tuesday, 8:30-10:00 - SOUTH BUILDING UV S315

Data Mining and Statistics IV

Stream: Data Mining and Statistics
Chair: *Edward Thommes*

1 - Public transport passenger flow analysis and prediction using alternating Markov-modulated linear regression
Nadezda Spiridovska, Irina Jackiva

The research presents alternating Markov-modulated linear regression application for the tram's line passenger flow analysis. Markov-modulated linear regression suggests that the parameters of regression model vary randomly with the external environment, the impact of which is described by a Markov chain with continuous time and final state set. For each state of the environment the regression model parameters are estimated. The whole trajectory of the environment is unknown, that's why the expected sojourn times in various states are additionally estimated. The developed model is used for passenger flow forecasting taking into account weather conditions as the external environment. Data from the Latvian Environment, Geology and Meteorology Center database about weather conditions in the Riga city is used for the description of the environment: it is assumed two states: "no precipitation" and "precipitation". The model of the external environment is tested for the markovian properties. Real data of passenger flow provided by local public transport operator company. On the first step data is analysed by means of descriptive and inferential statistics. Then model is developed on the basis of Markov-modulated linear regression approach. Acknowledgement: this work is funded by the post-doctoral research aid programme of the Republic of Latvia (project No. 1.1.1.2/VIAA/1/16/075).

2 - An application of process mining and association rule mining for indoor customer data
Onur Doğan, Basar Oztaysi

One of the most important factors for a company to maintain its existence is to increase customer loyalty. The basic issue for that is to understand the customers. Behavior analysis is an analysis to understand the needs of the customers and to provide the best solutions to these needs. Customer behavioral analysis produces information on where customers are in the store, how much time they spend in the place, where the next visit is, and even how many people are looking from the outside but not buying. However, in general, in all physical stores, collecting data to understand the customers is a critical problem. In the study, iBeacon technology is used to collect data in a shopping mall in Istanbul. The beacons collected a one-month data showing the locations and timestamps of customers. We used only one-day data belonging 694 different customers and applied Association Rule Mining (ARM). We created some association rules that indicate visited stores with together. Process Mining (PM) was used to create customers' trajectories, after data cleaning. Customers' behavior was analyzed using the obtained trajectories. Finally, PM results are filtered and compared with the results of ARM. Some obtained results of the study are: - The most followed trajectories in different days, - Visiting store Y of those who visited store X, - For a specific customer, the trajectories and spent time on different days when the same customer visits the shopping center.

3 - Assessing the prior event rate ratio method via probabilistic bias analysis on Bayesian networks
Edward Thommes, Salaheddin Mahmud, Yinong Young-Xu, Julia Thornton Snider, Robertus van Aalst, Jason Lee, Ayman Chit

Whether in healthcare, econometrics or the social sciences, observational studies conducted using real-world data are subject to bias due to confounding. Prior event rate ratio (PERR) adjustment is a technique which has been used to control for unmeasured confounding. However, it has been shown that in some cases PERR may actually increases bias. Here, we seek to clarify the factors leading to good vs. bad PERR performance. We begin with a directed acyclic graph (DAG) representation of an observational study possibly subject to unmeasured confounding. Previous work used Monte Carlo simulation to calculate joint probabilities for specific combinations of DAG edge weights (which control the strength of the association between the corresponding parent-child pair of variables). Instead, we use Bayesian network calculations to obtain joint probabilities analytically. This allows us to conduct probabilistic bias analysis using a large number of combinations of edge weights, and thus obtain a comprehensive picture of PERR performance. We apply our methodology to a recent study which used PERR in evaluating elderly-specific high-dose (HD) influenza vaccine in the US Veterans Affairs population. That study obtained an HD relative effectiveness of 25% against flu- and pneumonia-associated hospitalization, relative to standard-dose (SD) flu vaccine. In this instance, we find that the PERR-adjusted result likely underestimates rather than overestimates relative effectiveness.

■ TA-34

Tuesday, 8:30-10:00 - SOUTH BUILDING UV S113

Reverse Logistics and Remanufacturing Networks

Stream: Sustainable Supply Chains
Chair: *Salvatore Cannella*

1 - Strategic design of multiple lifecycle products for remanufacturing operations
Neil Geismar, M. Serkan Akturk, James Abbey

Based on observations from practice, this study analytically investigates product design philosophies for remanufacturing original equipment manufacturers to determine how the optimal design choice depends on market conditions. Though designing to increase the level of remanufacturability can yield increased profitability by lowering remanufacturing costs, several complicating factors exist. We examine how these market factors—industry clockspeed, the level of competition, and the product's original market value— interact with characteristics whose values are determined by the choice of design paradigm: time-tomarket, manufacturing cost, and remanufacturing cost. A key determinant of the optimal design choice is the number of profitable lifecycles that each design choice provides under specific combinations of values for the market factors.

2 - Inspecting the boomerang when it returns: on the impact of core quality grading on the bullwhip performance of closed-loop supply chains
Borja Ponte, Mohamed Naim, Aris Syntetos, Salvatore Cannella, Roberto Dominguez

We consider a hybrid manufacturing/remanufacturing system where the returned products (cores) are classified into two quality grades. This results in a parallel structure in the reverse flow of materials, with different remanufacturing lead times depending on the condition of the input material. We examine the implications of this grading system on the dynamics of closed-loop supply chains, by benchmarking this against the baseline system where all the returns are pushed through the same remanufacturing process. Through control engineering techniques, we evaluate the Bullwhip performance of the supply chain by observing the step response of the orders and inventories (the shock lens), analysing the frequency behaviour of these signals (the filter lens), and measuring their long-term variability (the variance lens). We discuss the operational benefits and costs derived from quality grading in terms of smoothing the supply chain operation. We observe that the documented 'lead-time paradox' of the remanufacturing process results in a 'quality paradox' in this new closed-loop context. This is especially relevant for low-frequency demand signals. Interestingly, we analytically derive the optimal setting of the pipeline estimation for avoiding long-term inventory drifts. Through a sensitivity analysis, we highlight the potential benefits of information transparency for improving supply chain performance. Finally, we extensively reflect on the managerial implications.

3 - On the dynamics of closed-loop supply chain with stochastic remanufacturing lead times
Roberto Dominguez, Salvatore Cannella, Borja Ponte, Mohamed Naim, Aris Syntetos

One of the main new sources of uncertainties that differentiate the traditional open-loop supply chain (OLSC) and the closed-loop supply chain (CLSC) is the quality of returns (i.e., depending on usage, cores may return to the remanufacturing process in different degrees of quality). This new uncertainty plays a crucial role in the development of remanufacturing networks, since the capacity required by returns with different qualities might be significantly different. Thus, the high variability in the quality of used cores is a major issue for uncertainties in the remanufacturing processing times. In the field of supply chain dynamics, the impact of the uncertainty in the remanufacturing processing time on performance remains unknown, since lead times are assumed to be deterministic. In this paper we perform a simulation study (via multi-agent systems) to analyse a serial CLSC, exploring the impact of stochastic remanufacturing lead times on performance. To do so, we benchmark the CLSC with an OLSC. We show that for low uncertainties in the remanufacturing process it is still possible for the CLSC to obtain a better performance than the OLSC. However, when the variability of the remanufacturing process exceeds some limits, the benefits normally obtained by the CLSC are undermined by these uncertainties, and thus it may show a lower performance than the OLSC.

4 - Bullwhip effect and closed-loop supply chains: systematic review and simulation analysis
Salvatore Cannella, Roberto Dominguez, Borja Ponte, Jose M Framinan

This work analyses the inventory and order flow dynamics in closed-loop supply chains (CLSCs). In this kind of supply chains the reverse flow of materials entering the system for recycling purposes complicates the way in which inventories should be managed and replenishment policies should be designed. Specifically, we analyse the relationships between some reverse logistics' factors (remanufacturing lead-time, return rate of recycled products, reverse order policy, and number of supply chain tiers) on the order and inventory variance amplification. We firstly perform a systematic literature review of the related studies. Secondly, by adopting a difference equation math approach and design of experiment we perform a robust what-if analysis of a CLSC under a variety of operational and market conditions. Results show that, ceteris paribus, CLSC outperforms a forward supply chain, both in mono-echelon and multi-echelon structures and under both stationary and turbulent market demands. Furthermore, reducing remanufacturing lead-time and promoting information transparency may be crucial to improve CLSC dynamics. Finally, we use the research findings to provide interesting managerial consideration about how to reduce unnecessary operational members' costs.

■ TA-48

Tuesday, 8:30-10:00 - 4D UPV B.3

Exploring Dynamic Behaviors in Humanitarian Operations

Stream: Humanitarian Operations
Chair: *Tharcisio Fontainha*

1 - Joint fundraising appeals: allocation rules and conditions that encourage aid agencies' collaboration

Tina Wakolbinger, Fuminori Toyasaki

Recently, collaborative fundraising mechanisms - known as joint fundraising appeals - have received increasing attention as innovative ways to reduce fundraising competition between aid agencies. While some aid agencies participate in joint fundraising activities, others consider that the disadvantages outweigh the benefits. Based on the analysis of two-stage sequential game theory models, the paper identifies key factors which affect aid agencies' decisions about participation in a joint fundraising mode. Our analysis indicates that expected effects of the joint fundraising mode depend on aid agencies' efficiency levels. For efficient aid agencies, the joint mode functions as a buffer to prevent them from fierce competition. In the case of inefficient aid agencies, the competitive mode is preferable under certain circumstances because it saves aid agencies from underinvestment in fundraising activities. We also identify that representative allocation rules currently applied in the humanitarian context can be classified into three types. Our analysis shows that these allocation rules only lead to beneficial allocations for limited circumstances.

2 - Improving disaster response processes through the application of the design structure matrix

Tharcisio Fontainha, Paulo Goncalves, Adriana Leiras

The process analysis in disaster response promotes several benefits to humanitarian operations, including the enhancement of cooperation, transparency, and communication. Nevertheless, the research on the disaster response process has focused on the initial stages of process design and some initiatives for system configuration, resulting in a gap in the discussion of process enactment and diagnosis. Thus, this paper analyses the structure of the disaster response processes according to the procedure of the Design Structure Matrix (DSM). The research considers a reference process model for disaster response and data collected through interviews with experienced professionals of humanitarian organizations to structure the process flow in the DSM. The analysis of the disaster response processes enables the identification of potential process rearrangement, necessary assumptions and verification tasks to minimize failures in the disaster response and humanitarian projects. Besides the benefits for the research in disaster and humanitarian operations, the application of the DSM in this context represents an innovative field for application of such project management tool.

■ TA-49

Tuesday, 8:30-10:00 - 4D UPV B.4

OR in Agriculture II

Stream: OR in Agriculture, Forestry and Fisheries
Chair: *Concepcion Maroto*

1 - Risk evaluation of livestock farms by integrating GIS and multicriteria techniques

Áurea Gallego Salguero, Marina Segura, Concepcion Maroto, Consuelo Calafat Marzal, Israel Quintanilla

Food security and environmental risks are increasing concerns for society, as the regulations on livestock sector in the European Union show. This paper presents an approach to assess the global risks of livestock farms taking into account the legislation related to distances between farms and population centres, as well as environment problems and emission of odours to populations. Sectorial criteria include the compliance of the legal distances between farms of the same and different species, the distance between farms and the population centres, and urban planning. Aquifers' vulnerability and odour emission are categorised as environmental and social risks respectively. The methodology integrates Geographical Information Systems (GIS) and multicriteria tools to derive an aggregated indicator for sectorial, environmental and social risks of farms. Spatial data are obtained by GIS, which also show the results of multicriteria analysis in maps. We obtained the weights of criteria by AHP and from experts and we used them in PROMETHEE to evaluate risks of livestock farms. We have applied this new approach to 4,983 farms of the main species (pigs, poultry, cattle, sheep, goats, rabbits and horses) in the Valencian Community (Spain). The results provide a risk indicator associated with each farm, which allows identifying the most conflicted areas of the region, characterized by intensive livestock production, as well as reducing risks by implementing appropriate policies.

2 - Which is better for planning the bottling lines of an export-oriented winery: a stochastic linear programming model or a robust optimization model?

Sergio Maturana, Nicolas Villavicencio, Alejandro Mac Cawley

Production planning for an export-oriented winery is complex, particularly due to the different labeling requirements that the different markets have. There are not only language issues, but also legal requirements and marketing strategies that make it necessary to have different labels for each market. Production planning in a winery refers mostly to the bottling stage of the wine supply chain. It generally assumes that the different types of wine produced by the winery are available in storage tanks.

Wineries may choose to use a make-to-stock or make-to-order production strategy. Each has its advantages and disadvantages. However they may also use a postponement strategy, by postponing labeling. The advantage is that it might be possible to postpone labeling until the order arrives, and the market to which the wine will be exported becomes known. This allows keeping an undifferentiated stock of bottled wines as opposed to keeping a stock of wines for each of the possible markets.

In this work we present a stochastic linear programming model and a robust optimization model to assess the benefits of using a postponement strategy for wine production planning. We determine the effects of the variability of the demand, set-up costs, inventory costs, and back-order costs on the optimal solution. We also study how the tank storage capacity, production-line capacity, among others, impact on how the models behave. Preliminary results are shown.

3 - Multi-objective optimization for the selection of wells for a water monitoring campaign of the Patiño aquifer, Paraguay

Christian von Lucken, Liz Báez, Cynthia Emilia Villalba Cardozo, Juan Pablo Nogues

In Paraguay, the Patiño aquifer supplies water for 43% of the population covering the largest and most densely populated urban area of the country. A previous work [1] identified 42% of the aquifer with greatest contamination risk considering Total Nitrogen (TN) and Total Coliforms (TC) concentrations. There also exists around 2800 deep wells that extract water from the subsoil with very little sanitary treatment. Due to economic and practical constraints it is not possible to analyze all deep wells. Thus, this work aims to select 70 wells to conduct a groundwater quality sampling campaign considering to maximize: contamination risk indices by concentrations of TN and TC, the coverage area and the wells which are publicly accessible. A Multiobjective Optimization Problem was defined to obtain the possible selections, and the Nondominated Sorting Genetic Algorithm II [2] was implemented to solve it. Executions of the algorithm with 100, 200, 300 and 400 generations were produced. The selected wells cover 67% of the aquifer area with high contamination risk indexes and 48 wells are publicly accessible. References 1. Báez, L., et al., Mapeo del Riesgo de Contaminación del Acuífero Patiño. 2014; https://goo.gl/stWkZM. 2. Deb, K., et al., A fast and elitist multiobjective genetic algorithm: NSGA-II. IEEE transactions on evolutionary computation, 2002.

4 - Aggregated linear programming models to estimate emissions of livestock production from animal diets
Concepcion Maroto, Marina Segura, Concepción Ginestar, Baldomero Segura

The European Union has decreased greenhouse gases emissions in the majority of sectors since 1990. In particular, the reduction amounts to 20% in agriculture, whose main source of emissions of carbon dioxide, methane, and nitrous oxide is livestock production. As feed intake is an important variable in predicting emissions, which depend on animal nutrition, the objective of this research is to design and explore the contributions of linear programming models to improving the quality and accuracy of livestock emissions at country level. Firstly, we have developed a linear programming model to estimate the most important emission factors attributable to diet in animal production. Secondly, we have applied this model to Spanish intensive livestock farms, concentrating on pork and poultry because of their relevance in the European Union, where the consumption of pork meat is the highest followed by poultry with 21 and 13.7 million tons respectively in 2016. Both types of meat are also the most important worldwide. Model data come mainly from EUROSTAT and FAOSTAT. LINGO was used to formulate and solve the models, as well as to carry out the sensitivity analysis. Finally, the developed models generate relevant information for improving the accuracy of emissions inventories. In addition, they are suitable tools to study the effects on greenhouse gases and pollutant emissions due to changes in feed price, expert nutrition recommendations and agricultural policy.

■ TA-50

Tuesday, 8:30-10:00 - 4D UPV 1.1

Optimization of Biomass-Based Supply Chains

Stream: Biomass-Based Supply Chains
Chair: *Magnus Fröhling*

1 - Designing optimal contracts between biomass processors and producers in the US biofuels industry
Sinem Tokcaer, Ozgur Ozpeynirci, Hayri Onal

In 2005, the US government introduced blending mandates to achieve energy security and cleaner transportation fuels. The Renewable Fuel Standard (RFS), a federal law, requires blending large amounts of biofuels obtained from cellulosic biomass with oil-based fuels. However, since the inception of RFS, commercial production of cellulosic biofuels has been stalling due to high conversion costs, low oil prices, limited availability of agricultural resources, absence of a competitive biomass market, and the perennial nature of energy grasses. The cellulosic biofuel industry can become an economically viable reality only if bio-refineries guarantee a steady flow of biomass at a reasonably low price while biomass producers receive adequate returns over a medium time horizon. Contracting between producers and bio-refineries is proposed as a mechanism to accomplish these. In this paper we find an optimal contracting scheme, in particular the price of biomass and the duration of the contract. Because of the hierarchy and independence of the decisions made by biomass producers and bio-refineries, we formulate the problem as a bilevel optimization model. We apply the model to a mid-size cellulosic bio-refinery surrounded by numerous risk-averse farmers that may contract with the biorefinery. We present the empirical results along with the computational performance of the model.

2 - The effect of postponement strategies under sequence dependent setup times in the wine industry
Alejandro Mac Cawley, Sergio Maturana, Benjamin Bastidas, Mauricio Varas

Wineries face a problem during the planning of the bottling process, because they must deal with a large number of products to be processed, high-demand variability and sequence dependent setup times. Under these conditions, managers must generate scheduling plans which are both cost efficient and can fulfill the demand of the client. In some cases, they can resort to the postponement of the labeling of bottled wines; in order to gain productivity but in the process, they must incur in a extra double handling cost. In this research, we look to assess the impact of implementing production planning models that integrate postponement strategies in high demand variability and sequence dependent setup times conditions. We analyze the performance impact of postponing the labeling of bottled wines by developing a multi-stage mixed-integer stochastic programming model with full recourse for demand scenarios. The underlying data and policies are based on an unnamed Chilean export-focused winery. The model supports lot-sizing under several winery production policies. Results show benefits of implementing postponement strategies under given capacity of the system, demand variability and setup times.

3 - Households' decision processes in an agent-based simulation using PROMETHEE
Beatriz Beyer, Lars-Peter Lauven, Jutta Geldermann

In Germany, heating demand is largely covered by fossil fuels, which causes 40 % of all energy-related greenhouse gas emissions. Some 80 % of the central heating systems in Germany use combustion technologies, and 70 % of its 20.7 million residential heating systems are older than 15 years and correspondingly energy inefficient. Households' decisions for a heating system are long-term investments and influence the sustainability of the market over a long time. In order to obtain deeper insights on the market dynamics for a more sustainable heating market, we developed an agent-based simulation model and applied it to Lower-Saxony, a region in northwestern Germany. Different agents in the model represent various households and their dissimilar decision behavior concerning investments into heating systems. The individual decision processes are modeled as multi-criteria decisions using PROMETHEE. With the combination of an agent-based simulation and multi-criteria decision processes of individual households, the possible effects of different legislations can be observed more closely. Different scenarios concerning demand and price fluctuations, behavioral changes, and incentive programs are simulated. Thus, this agent-based simulation of the heating market allows for a better understanding of the interdependencies and can therefore be used a decision support system for industry or legislator.

4 - Combining GIS and location planning to evaluate biomass utilisation chains
Magnus Fröhling, Andreas Rudi, Charlie Liebscher

The presentation investigates the combination of Geographical Information Systems and Operations Research Techniques for Location Planning for the evaluation of Biomass Utilisation Chains. Thereby it is aim to make use of as much spatial information stored in the GIS and the underlying maps as possible while at the same time using combinatorial optimisation approaches to find optimal configurations of the biomass value chain. The presentation introduces the topic, potential approaches and provides insights through an example application for the German Federal State of Saxony and different bio-refinery concepts.

■ TA-51

Tuesday, 8:30-10:00 - 4D UPV 1.2

OR for Energy Systems Integration

Stream: Environmental Sustainability in Supply Chains
Chair: *Mel Devine*

1 - Energy sector integration - opportunities and challenges arising from an electrification of heating and transport sectors
Hans Christian Gils

A drastic reduction of energy-related CO2 emissions is a central requirement for the limitation of global warming. This not only implies the need for fully renewable power supply, but also a phasing out of the fossil fuels usage for heating and transport purposes. Available alternatives include a direct electrification and the usage of synthetic fuels. This talk addresses the role of an enhanced integration of the power, heat and transport sectors in future energy systems with high renewable energy shares. The analysis relies on the application of the energy system model REMix. REMix was developed for the evaluation of energy supply scenarios in high spatial and temporal resolution. The model uses linear optimization to determine least-cost supply systems from a central planners' perspective. Starting from a profound analysis of power supply and particularly intermittent renewable generation, REMix has been continuously enhanced in scope and detail, and now includes all major sector integration options. The talk provides insight in different case studies evaluating the potential role of flexible energy sector integration in different parts of the world. It shows to what extent and under what conditions flexible sector integration can contribute to the integration of intermittent renewable power generation. Furthermore, the recently completed implementation of the production, storage, transport and conversion of synthetic fuels is introduced and presented for discussion.

2 - Multi-objective optimal congestion management in the German transmission grid
Manuel Ruppert, Viktor Slednev, Valentin Bertsch, Wolf Fichtner

In many countries, the ongoing expansion of renewable generation is creating increasing challenges for congestion management in the transmission grid. In Germany, for instance, most wind generation takes place in the North of the country because of the attractive wind resources in on- and offshore locations, whereas the main consumption centres are located in the South. This leads to a significant amount of market adjustments from thermal power plant redispatch and renewable curtailment with rising expenditures, system inefficiencies, and carbon emissions.

To address this issue, a multi-objective nonlinear optimal power flow approach of the congestion management, accounting for minimal deviation from the market result, as well as cost and emission caused by congestion management, has been developed. The results of the congestion management optimisation in a significantly congested system show that the multi-objective solution accounting for all dimensions has substantial advantages in comparison to the optimisation towards a single objective. An example of this is the minimisation of the deviation from the market result as it is performed in today's congestion management regime in Germany. Compared to this one-dimensional minimisation, the multi-objective solution can result in more than 80 % lower emissions and 20 % reduced cost with minimal changes to the deviation from the initial market result.

3 - Soft-linking capacity expansion problems: development of local energy systems connected to the central grid
Stian Backe, Pedro Crespo del Granado, Dimitri Pinel, Asgeir Tomasgard, Magnus Korpås

The success of reducing greenhouse gas emissions might rely on the transition to a low-carbon energy system and improvements in energy efficiency. To some extent, both options have put the end-user at the centre of the energy transition. This has translated into the adoption of distributed generation technologies and into policies directed to promote sustainable solutions for neighbourhoods. In this regard, this paper analyses scenarios towards the vision of Zero Emission Neighbourhoods (ZENs) as part of the interconnected electricity system with possible investments in distributed generation and improvements in energy efficiency. For these cases, we look at how investments in distributed generation for ZENs affect the demand faced by stakeholders of the greater electricity system, and how investments at the neighbourhood scale affect electricity prices and long-term development of the interconnected electricity system. We analyse these questions using a neighbourhood model and an electricity infrastructure model. We soft-link these two optimization models to examine the effects of distributed investments in the grid dominated by centralized generation. Results show a reduction on average demand volume towards the interconnected grid, but this development induce higher peak demand periods leading to a need for a more flexible electricity system.

4 - Modelling demand-side flexibilities from wastewater treatment plants in an integrated energy system
Dana Kirchem, Valentin Bertsch, Juha Kiviluoma, Muireann Lynch, Eoin Casey

Wastewater treatment is an electricity-intensive process. Conditional on treatment level and plant size, estimate electricity costs amount to 2-60 % of total operating costs. Additionally, the electricity consumption of municipal wastewater treatment plants (WWTPs) can account for about 1 % of total electricity consumption of a country per year. Thus, wastewater treatment is a big electricity consumer and could be an interesting source of flexibility from a system perspective. The potential of WWTPs to participate in demand response (DR) programs has been investigated only in a few case studies so far. We propose a new avenue for research by identifying the DR potential from WWTP not only for the WWTP operator, but also for the power system, by means of an integrated energy systems model. We use a new generic, data-driven energy network optimization model called Backbone, which minimises total system costs as a mixed-integer linear optimization program (MILP). We model the Irish power system as a case study, including data on conventional as well as renewable energy generation. WWTPs are modelled as individual energy-consuming units within the electricity grid. Benchmark data is used to incorporate time series demand profiles, which allows for changes in the diurnal consumption patterns to identify the effects on key system parameters. Market and system outcomes like energy system costs and price volatility are studied along with environmental effects.

■ TA-52

Tuesday, 8:30-10:00 - 4D UPV 1.3

Treatment Scheduling

Stream: OR for Health and Care I
Chair: *Bruno Vieira*

1 - Improving the efficiency of the operating room environment with a generalizable optimization and machine learning model
Margaret L. Brandeau

The operating room is a major cost and revenue center for most hospitals. Thus, more effective operating room management and scheduling can provide significant benefits. In many hospitals, the post-anesthesia care unit (PACU), where patients recover after their surgical procedures, is a bottleneck. If the PACU reaches capacity, patients must wait in the operating room until the PACU has available space, leading to delays and possible cancellations for subsequent operating room procedures. We develop a generalizable optimization and machine learning model to sequence operating room procedures so as to minimize delays caused by PACU unavailability. Specifically, we use a machine learning approach to estimate the required PACU time for each type of surgical procedure, we develop and solve two integer programming models to schedule procedures in the operating rooms so as to minimize maximum PACU occupancy, and we use discrete event simulation to compare our optimized schedule to the existing schedule. We built the model with data from Lucile Packard Children's Hospital Stanford and are currently developing plans to implement it at the hospital.

2 - Stochastic appointment scheduling in a team primary care practice with two nurses and two providers
Ana Muriel, Hyun Jung 'Joanne' Alvarez Oh, Hari Balasubramanian, Ekin Koker

We consider the team primary care practice scheduling problem where each patient is seen by one of two available nurses before seeing her provider. Both steps have uncertain durations. The patients can crossover in schedule, so the order of patients seen by the nurse might not be the same as the order in which the provider sees patients. We develop a two-stage stochastic integer programming model to solve the challenging scheduling problem of determining patient appointment times, given in 15-min time intervals, so as to minimize a weighted combination of patient wait and provider idle times for the team practice. To overcome the computational complexity associated with solving the problem under the large set of scenarios required to accurately capture uncertainty in this setting, our approach relies on a lower bounding technique based on solving an exhaustive and mutually exclusive group of scenario subsets. Our computational results identify the structure of optimal schedules and quantify the impact of nurse flexibility, patient crossovers and no-shows. We conclude with practical scheduling guidelines for team primary care practices.

3 - Effective and equitable appointment scheduling in rehabilitation centers
Pinar Keskinocak, Idil Arsik, Kirthana Hampapur, Kristin Goin

Appointment scheduling in rehabilitation centers is a complex process; unlike in a primary care clinic setting, each patient needs a combination of services that is specific to his/her condition to be scheduled over multiple days and time slots with different providers/equipment/aides. Providing ideal care to patients with different needs and ensuring timely access to treatment is critical for patient outcomes. In a collaborative project between the Shepherd Center, a rehabilitation institute for patients with brain injuries, and Georgia Tech, we developed a decision support-tool which employs heuristics and mixed integer programming models for efficient and effective scheduling while efficiently utilizing resources. Shepherd Center has been using the tool since late 2017 and the enhancements to the tool is ongoing.

4 - Improving timeliness in radiotherapy using discrete-event simulation modeling
Bruno Vieira, Derya Demirtas, Jeroen B. van de Kamer, Erwin W. Hans, Wim van Harten

In radiotherapy (RT), the minimization of the time between referral and start of treatment (waiting time) is increasingly important to mitigate tumor growth and avoid psychological distress in cancer patients. However, the RT process, involving a chain of preparation steps before the treatment can start, is subject to uncertainties (e.g. due to patient inflow) that hamper the design of a simple workflow control system. RT pre-treatment workflow is driven by the scheduling of the first irradiation session, which is usually set right after consultation (pull strategy), but can alternatively be set after (some of) the pre-treatment operations have been completed (push strategy). In this work, we use discrete-event simulation to test several configurations of workflow control and assess the optimal allocation of the doctors' activities (consultation and contouring) in each configuration. A case study using data from a large RT department of a Dutch hospital has been undertaken, in which fluctuations in patient inflow and resource availability are considered. By comparing both strategies for lung cancer patients, preliminary results show that a push strategy leads to a 22% reduction in the average waiting times and 25% fewer appointment cancellations, whilst a pull strategy leads to 5% less patients breaching the waiting time targets and, unlike push, avoids the need for overtime work. These findings help us identify the optimal balance between the push and pull strategies.

■ TA-53

Tuesday, 8:30-10:00 - 4D UPV 1.4

Product Line Design, Strategic Consumer Behavior, and Distribution Channel

Stream: Operations/Marketing Interface
Chair: *Ovunc Yilmaz*

1 - The impact of distribution channels on trial-version provision with a positive network effect
Fan Li, Zelong Yi

Many software developers provide end-users free trials with limited functionality to facilitate distribution of their commercial products. Meanwhile, in the international market, some developers authorize local agents to resell software products to consumers. In this paper, we explore a software developer's optimal trial strategy in the presence of agent participation. Due to agent participation, the double marginalization effect may result in a higher price and a lower demand of the commercial software. We find that, if the network effect intensity is strong, the developer will release a trial and attract trial users to secure greater positive externality, which is consistent with the case without agent participation. However, if it is weak, the developer may still release a trial to public, which stands in sharp contrast to the case without agent participation. The trial is released in order to countervail the negative double marginalization effect. We also extend this work by endogenizing trial quality, examining differentiation induced by different firms in the supply chain to make the trial releasing decision and investigating the effects induced by consumers' differentiated using costs towards the free trial version and the commercial version.

2 - Managing risk of change based on similarity of propagation effects
Qing Yang

During the design process, changes from the product's requirements may cause redesign to many independent activities. Identifying and managing propagation risks of change is a great challenge for the product development (PD) projects. Any PD project can be described as a set of activities, where the dependencies between them can be represented by a Design Structure Matrix (DSM). The proposed model utilizes similarity matrix of propagation effects from a risk propagation DSM to depict the change propagation between dependent activities. In this model, we assume that each team is involved in multiple activities. Based on the analysis results, the project manager select and implement the scheme of design change with the least workload and the highest similarity rank. The effectiveness of the integrated model has been described with an illustrative case example. Such prediction and quantification of change risk would help project managers and engineers overcome project completion and risks for a proposed change.This paper propose an improved CPM method by integrating three path's level to measure the integrated risk propagation of change in the development design process.

3 - Empirically estimating strategic behavior for hotel standby upgrade programs
Ovunc Yilmaz, Mark Ferguson, Pelin Pekgun, Guangzhi Shang

A recent innovative approach in the hotel industry is Nor1's standby upgrade program, where discounted availability-based upgrades and add-ons (e.g., parking) are offered to guests, and guests are only charged if the upgrade or add-on is available upon their arrival to the hotel.

This program is marketed as being beneficial for the hotel by monetizing premium room inventory that may otherwise go unused and creating awareness for add-ons. Hotel chains see value in standby upgrades for selling auxiliary services, however they are aware of the potential cannibalization of premium room bookings because of strategic guests who are savvy enough to choose a standard room over a premium room with the expectation of being offered a discounted premium room through standby upgrades.

In this research, we investigate the existence and the extent of strategic behavior, utilizing 16-month booking and standby upgrades data over a set of hotel properties and identify the characteristics of hotels where strategic behavior is prevalent. In addition, we offer a new pricing policy which bring significant revenue improvements.

■ TA-54

Tuesday, 8:30-10:00 - 4D UPV 1.6

OR in Sports

Stream: OR in Sports
Chair: *Stephan Westphal*

1 - Home-away pattern sets: properties, experiments, and flexibility
Frits Spieksma, Dries Goossens

Scheduling a round robin tournament has attracted a lot of attention in the scientific literature. More specifically, deciding upon the matches to be played in each round of a double round robin (DRR) tournament is known to be of great practical importance in scheduling soccer competitions. A popular approach to do so is the first-break-then-schedule approach. In such a hierarchical approach, a first decision concerns the Home-Away Patterns (HAPs) to be used by the teams, and a second decision concerns the scheduling problem: which match to be played in which round. Clearly, the latter decision crucially depends on the HAP-set that is chosen in the first phase - indeed, two teams whose patterns dictate they both play home in a particular round, cannot meet in that round. In particular, it is conceivable that in the scheduling phase, a constraint is revealed that is incompatible with the given HAP-set. This would need to be solved by either changing the HAP-set, or by putting energy into mitigating the effects of violating that specific constraint. The theme of this note is that not all HAP-sets are created equal. Indeed, different HAP-sets have different chances of leading to incompatible constraints. We take stock of the HAP-sets that are being used in practice, and we propose measures for the flexibility of a HAP-set.

2 - Fair players allocation in ATP tournaments generation
Gabriele Dragotto, Federico Della Croce, Rosario Scatamacchia

Single-elimination tournaments are a popular type of tournament among sports, with emphasis in tennis. Despite the current draws mechanism prevents seeded players from matching in early rounds, match repetitions in consecutive tournaments in time may occur among the other players. Therefore, the allocation process for non-seeded players plays a fundamental role in avoiding match repetitions and in increasing the diversity of matches. This work develops a methodology for enforcing fairness in single-elimination tennis tournaments in terms of match repetitions reduction in consecutive tournaments. The considered tournament allocation problem amounts to solving a clustering problem by means of mathematical programming. We report results and solutions for real-life instances related to Grand Slams in 2017. An alternative constructive approach followed by a local search step is also proposed. This approach shows up to generate reasonably good solutions in a limited amount of time. Computational testings indicate that appreciable improvements are obtained for both the expected number of match repetitions and a related measure of fairness. As a result, the proposed approach can be seen as a valid alternative to pursue a fair allocation in ATP tournaments generation without significantly altering the draw procedure.

3 - Avoiding combinatorial clashes for The Champions Hockey League group stage draw
Stephan Westphal, Martin Dahmen

For the season 2016/2017, the Champions Hockey League (CHL) was performing a Group Stage Draw in which 48 teams had to be drawn out into 16 groups of three teams each. The allocation of the teams to the groups had to be done in a way such that teams coming from the same league were not drawn out into the same group. Furthermore, clubs from leagues where the national teams were participating in the final olympic qualification tournament could also not be drawn out into the same group. Whenever during the draw the assignment of a team to a group is not possible because it raises a league conflict or an olympic qualification conflict in this particular group, we will call this a "direct conflict". These are easy to see and can thus be prevented easily. But there are also "combinatorial conflicts" which are hard to detect. These are conflicts which arise when a team is allocated to a group in which it does not provoke any direct conflict but the set of remaining teams in the pots cannot be assigned without direct conflicts anymore. Since the Draw was broadcasted live, the CHL needed to know immediately if an assignment would have led to a direct or a combinatorial conflict and to which group the teams had to be allocated directly after they have been drawn out of the pots. In this talk we discuss the algorithm based on an integer programming model, which was used by the CHL for the 2016/17 Group Stage Draw.

■ TA-55

Tuesday, 8:30-10:00 - 4D UPV 2.1

Technical Issues in Practice

Stream: Making an Impact I
Chair: *Sofiane Oussedik*

1 - Always count the cost - shortest path calculations in transport logistics
Stefan Hug

What is the main goal of our customers in Transport Logistic Sector when it comes to route optimization? Not surprisingly - saving money. In order to achieve this goal it is essential to be able to calculate 'practically adequate' shortest paths in huge road networks extremely fast. Practical adequacy requires the consideration of a plethora of additional data such as predicted and live traffic information, vehicle- and time-dependent toll prices as well as physical and legal limitations. Since this data is becoming increasingly accurate and available it is essential to exploit this technological progress in the calculation to get the most realistic result. As vehicle characteristics and start times vary in shortest path web services with every single calculation the use of speed-up techniques often has limitations in real life use-cases. In this session we present challenges we as PTV Group had to face when incorporating different data in our shortest path algorithm, we show how we dealt with these challenges in our applications and use-cases and invite you to comment and share your own experiences.

2 - IT architectures for OR applications deployment
Sofiane Oussedik

The session is aimed at OR practitioners who deploy applications to business users. Deploying applications requires a functional architecture and the corresponding technical architecture to be well defined. Most of the Euro conference is dedicated to OR techniques and applications; this will be a short introductory session to the 50-70% of work that needs to be done to get an OR model to deliver value to a business user. Participation in the discussion from practitioners is very welcome.

■ TA-56

Tuesday, 8:30-10:00 - 4D UPV 2.2

Optimization of Energy Systems

Stream: Optimization in Renewable Energy Systems
Chair: *Welington de Oliveira*

1 - Energy plant operation and installation plan via stochastic programming
Tomoki Fukuba, Shuichi Isomura, Takayuki Shiina

The spread of renewable energy is an important problem on a global scale. In large facilities such as factories and shopping centers, introduction of renewable energy is desired. However, when renewable energy is introduced, the energy plant operation plan needs to consider the uncertainty of its output. We develop a stochastic programming model of energy plant at large facilities when solar power generation and storage battery are introduced. The uncertainty of the output of solar power generation is represented by a set of discrete scenarios, and the expected value of the operation cost is minimized. The stochastic programming model is formulated using nonlinear constraints because it is necessary for a real operation plan. This model can be transformed into a mixed integer programming problem. For the nonlinear constraints, we use piecewise linear approximation and reformulate the model using SOS2 constraint. As a result, it became possible to obtain exact solutions. In this model, the decision variable increases according to the number of scenarios and points of piecewise linear approximation, and it becomes a very large mixed integer programming problem. We show the usefulness of the stochastic programming model by comparing it with the deterministic model. As an economic assessment, we show the recovery period for the initial investment of solar power generation and storage battery.

2 - On the determination of Turkish natural gas balancing and wholesale market prices
Kürşad Derinkuyu, Rabia Taspinar, Furkan Ezer, Melike Yıldız, Seher Onay, Sevde Nur Ozbolat, Pelin Tekin

European exchanges and system operators are responsible for balancing of natural gas consumption activities. Starting from 2018, Turkey has been establishing natural gas balancing and spot markets. System operator (BOTAS) and Turkish exchange (EXIST) developed a Continuous Trading Platform (CTP) to balance natural gas imbalances as well as to manage trading activities in the wholesale market. This study first gives a brief summary of the natural gas market structures. Then, we provide the alternative formulation and solution approaches to the natural gas balancing and wholesale markets, where difficulties appear in practice. Three auction mechanisms are introduced and modeled by using mixed integer non-linear programming (MINLP). Also, a simulation model is designed to understand behavior of market participants. Lastly, we discuss the future trends in the natural gas wholesale markets.

3 - Optimization of biogas production by anaerobic digestion
Helenice Florentino, Daniela Cantane, Felipe Teles, Leandro Marcucci

Biodigesters are bioreactors able to transform organic garbage into biogas and biofertilizer. Organic garbage is processed from the activity of a microbial consortium that promotes the decomposition of complex organic substances into simple, chemically stabilized compounds. In this context, biodigesters are important because promote waste treatment, reducing its hazardous effects on the biosphere and produce biogas, that is a renewable energy source. Biogas is, basically, a mix of methane, carbon dioxide, and hydrogen. Methane can be used for combustion in boilers, cogeneration, to drive means of transport and can be used as a source of hydrogen. Hydrogen is considered the fuel of the future because it is a renewable and clean energy source. Hydrogen can be used in internal combustion engines or fuel cells producing virtually no greenhouse gas emissions when combusted with oxygen, once only water vapour is produced. In short, biodigesters today play an important role in generating energy and protecting the environment. On other hand, anaerobic biodigestion is a complex process and requires control of many factors for better efficiency in the conversion of organic matter into biogas. The objective of this work is to propose optimization techniques to determine optimal planning of biodigesters construction and operation, in which the total conversion of organic effluents to biogas occurs efficiently.

4 - Stochastic dual dynamic programming with modified cuts applied to the Brazilian long-term hydrothermal scheduling problem
Welington de Oliveira, Felipe Beltrán, Guilherme Fredo, Erlon Finardi

In systems with hydraulic predominance, the long-term hydrothermal scheduling problem (LTHS) is usually formulated as a multistage stochastic program whose objective is to obtain an implementable power generation policy providing minimal costs (on average, or based on some risk measure). A classical optimization technique for solving LTHS problems is the stochastic dual dynamic programming (SDDP), which employs two main steps: a forward step for generating trial policies, and a backward one to construct Benders-like cuts. As the SDDP is a sort of cutting-plane method, it can exhibit slow convergence when dealing with large-scale optimization problems. In order to accelerate the SDDP method, we modify its cuts in the forward step by employing some ideas related to the Chebyshev center of the SDDP subproblems' feasible sets. Essentially, the cuts are lifted by a parameter that vanishes along the iterative process without compromising convergence analysis. Numerical assessments on the large-scale Brazilian LTHS problem with individualized decisions per plant, over a five-year planning horizon with monthly decisions, indicate that the new proposal significantly accelerates the SDDP method performance. The new technique computes better lower bounds and (approximately optimal) implementable policies in less than 40% of the CPU time required by the classical method.

■ TA-57

Tuesday, 8:30-10:00 - 4D UPV 2.3

Public Health Networks

Stream: Computational Biology, Bioinformatics and Medicine
Chair: *Justyna Rój*

1 - Minimizing health-compromising behaviors via school-based programs: an optimization approach
Banafsheh Behzad

School based health-education programs are united by their desire to promote health and related outcomes amongst youth. They are also united by the fact that their success is contingent on successful program implementation, which is often constrained by a multitude of real-world barriers. In this paper, an optimization approach is used to calculate the optimum levels of program implementation needed to achieve a desired outcome, subject to known levels of implementation constraints. We present a detailed example of the first known application of Linear Programming (LP), which is an optimization technique, to Positive Action, a social emotional and character development program that includes a six-unit, teacher-delivered, classroom curriculum. We detail how we used LP to calculate the optimal levels of program implementation needed to minimize substance use, subject to known levels of implementation barriers. Specifically, we found teaching 3-4 lessons weekly per unit minimized substance use. Findings from this exploratory study support the utility of applying LP during the program planning and implementation processes.

2 - Markovian decision models to design public policies on critical patient units in a public health network
Alejandro Cataldo, Antoine Sauré, Jonathan Patrick

Patients arriving in a critical state to the urgency ward of a hospital must be treated in one of the two types of critical patients' care unit: intensive care or intermediate treatment. In general, patients are treated in the corresponding unit, using the diverse resources of the hospital.

Since, generally, the resources are scarce (beds, equipment, and medical staff), we have developed public policies that allow the management of these types of medical care units as a network. These policies consider, among other things, movement of patients between hospitals within the network, the modification of the capacity of the network over time, the modification of the beds types, the possible creation of new care units, and the design of contracts for outsourcing capacity with private clinics.

To support the design of these policies for the Public Health system in Chile, we have constructed Markov decision models to represent the system, and we have used them to evaluate the expected impact of certain decisions

3 - Financial performance index for hospitals: DEA approach. Case of Poland
Justyna Rój

Abstract: Hospitals' financial conditions is very important, in terms of their availability. Moreover, in Poland, inpatient's services consume is an important part of National Health Fund resources. The objective of the study is to use a financial performance index (FPI) for regional hospitals using Data Envelopment Analysis (DEA), and to evaluate and then to compare also this measure with various financial ratios commonly used to indicate performance levels. This employed approach of FPI is based on the financial ratios and DEA method and was proposed by Ozcan and McCue. This method allows to overcome the weaknesses of financial ratios analysis. The DEA model generated FPI scores are based on four maximizing oriented financial performance ratios: return on assets, operating cash flow per bed, operating margin and total asset turnover ratios. The research has been conducted on the nonprofit general regional Polish hospitals, using data covering the period of the 2017 year. The results will allow to identify efficient and poor performing hospitals and also to provide their financial ratios characteristics and optimal combination.

■ TA-58

Tuesday, 8:30-10:00 - 4D UPV 2.4

Teaching OR/MS III

Stream: OR Education
Chair: *Marta Pascoal*

1 - Students' preferences for learning operations research elicited by using qualitative and AHP methods
Marina Segura, Concepcion Maroto, Concepción Ginestar, José Ramónn Navarro

The increasing availability of online resources for learning Operations Research, developed mainly for online courses and flipped classroom approaches, is having a great influence on students' performance in face-to-face teaching. The objectives of this paper are to elicit students' preferences for learning resources, which include books, slides, videos and exams, as well as assessing their influence on students' performance in learning Operations Research in Business Administration and Management degree. Preferences for different types of learning resources have been elicited by qualitative and quantitative methods. Firstly, we have used the Likert scale as the most frequent procedure to measure students' perceptions of higher education studies. Secondly, the AHP method provides a new and quantitative approach, appropriate for eliciting individual preferences and aggregating them to build group preferences. In addition, AHP allows us to analyse inconsistent responses from students. We have carried out appropriate statistical analyses in both cases. The results show that students use a blend of traditional and online materials, although there are significant differences in the preferences for resources amongst different groups of students. Finally, we discuss the students' performance, which depends on the relative degree to which they used specific resources and their personal goals for the subject mark, as well as strategies to improve Operations Research learning.

2 - How dropping their worst homework might be prejudicial to your students: an application of Simpson's paradox and its impact on equity
Javier Rubio-Herrero

Dropping the worst homework, or the homework with the lowest grade, is a common practice that instructors do when they intend to increase their students' grades. The following article shows that if this measure is taken at some stage during the course, other than at the end of it, the grade of some students worsens after dropping their worst homework and the perception of their performance is biased. To illustrate this phenomenon, we provide an example in which this decrease can be of almost 4% and we find that this effect is more felt if a student has performed poorly in a midterm exam, i.e. it targets those to whom this policy is supposed to help. While in terms of equality this policy is usually extended to all the students, we conclude that its performance fails when it comes to assessing its equity. This is due to the effect of the so-called Simpson's Paradox.

3 - OR for children: robotic warehouse simulation using Lego Mindstroms
Lin Xie

In this paper, we aim at introducing one of the well-known OR-methods, called simulation, to children. Instead of using classical programming language, we choose the hand-on simulation to teach 20 children, between 8 and 12 years old, to simulate a robotic warehouse, similar to Amazon Kiva System. In such system, robots are sent to carry storage units from the inventory and bring them to human operators, who work at picking stations. At the stations, the items are packed according to the customers' orders. Such hand-on simulation utilizes storage and retrieval robots made from Lego Mindstorms'. The children are divided into groups to simulate different parts of the robotic warehouse, such as picking station, storage area, in a given control system (called "RawSim-O"). Because of utilizing such hand-on simulation, the children should understand the process of e-commerce and operations within a robotic warehouse.

4 - Introducing network optimization problems to middle school students
Marta Pascoal

In this work we describe a set of activities for middle school students, with the goal of presenting them graphs/networks and simple optimization problems that can be defined on those structures. The problems are presented from the most intuitive to solve to the most complex one, showing the students the increasing difficulty of the problems. This motivates the introduction of both exact and heuristic methods. This general structure has been used in lectures at schools and in problem solving workshops for students with interest in Mathematics.

■ TA-59

Tuesday, 8:30-10:00 - 4D UPV 2.5

Policy-Enabling Models for the Power Sector

Stream: Technical and Financial Aspects of Energy Problems
Chair: *Afzal Siddiqui*

1 - Analysis of storage and water value in power systems for policymaking on renewable energies
Diego Tejada, Afzal Siddiqui, Sonja Wogrin, Efraim Centeno Hernáez

As variable Renewable Energy Source (vRES) production, e.g., solar and wind, increases, additional Energy Storage (ES) capacity may be desirable in order to manage vRES intermittency. Moreover, since Battery Energy Storage Systems (BESS) cost is expected to decrease in the next 10 to 15 years, intra-day storage, e.g., BESS, dispatch could affect inter-day storage, e.g., hydropower, dispatch and its opportunity costs, i.e., water value. Existing medium- or long-term hydrothermal dispatch models provide the water value only on a weekly or monthly basis and, consequently, neglect hourly water-value signals due to this coarse time resolution. However, short-term BESS decisions in energy and reserve markets have an impact on the water value (or opportunity cost) of long-term storage and should be reflected with a higher degree of precision. We develop a novel, computationally tractable framework for hydrothermal coordination in which hourly storage values (short-term signals) are co-optimized with seasonal storage (long-term water value signals). Thus, hourly opportunity costs, i.e., storage and water values, for inter- and intra-day storage can be obtained considering both short- and long-term signals. We analyze a reduced version of Spanish power system, and the results are used to identify possible policy drivers for ES and vRES investments considering the interaction of inter- and intra-day storage.

2 - Switching options in peaking power plants: enticing availability by capacity remuneration
Stein-Erik Fleten, Erik Haugom, Alois Pichler, Carl Ullrich

In this paper we use a nonparametric structural estimation model and data from the northeastern United States to estimate the costs of shutting down, starting up, and abandoning peaking power plants. Switching costs are difficult to determine in practice and can vary substantially from plant to plant. The paper develops a real options model to explain switching and maintenance behavior of plant managers. The constrained optimization approach to estimate crucial costs accommodates non-parametric dynamics for the expectations of the plant managers regarding future profitability. The empirical analysis is based on a database of the annually reported status of power plants to the United States Energy Information Administration (EIA) during 2001–2016. From our estimates of switching (and maintenance) costs we can infer the costs which would be avoided if a peaking plant were taken out of service for a year. This so-called avoidable cost plays an important role is electricity capacity markets such as the Reliability Pricing Model in PJM. Our avoidable cost estimates are less than the default Avoidable Cost Rate (ACR) in PJM. This indicates that consumers may be overpaying for system reliability.

3 - Utility-scale energy storage in an imperfectly competitive power sector
Ahti Salo, Vilma Virasjoki, Afzal Siddiqui

As many other industries, the energy sector is increasingly subject to environmentally sustainable operations. This has spurred the share of variable renewable energy sources (VRES) in power generation over the last years. Nevertheless, VRES are non-dispatchable, which creates new challenges for power producers and energy systems management. Consequently, interest in utility-scale energy storage systems has increased.

We construct a complementarity model to study optimal energy storage investments. Our focus is on utility-scale battery storage technologies. The optimization problem is bi-level: the lower level depicts competitive power markets, modelled as a welfare-maximizing independent system operator (ISO); at the upper level, we have a storage investor, who can either (i) maximize its profit or (ii) maximize social welfare. Thus, depending on the objectives of the upper-level decision maker, storage can be used for arbitrage, as peaking or ramping capacity, or as a mechanism to avoid power transmission congestion. In order to solve the bi-level model, we formulate the problem as a mathematical program with equilibrium constraints (MPEC) and thereafter as a mixed-integer quadratic program (MIQP) via disjunctive constraints for the KKT conditions of the MPEC.

As a case study, we apply the model to a Western European test grid to see which would be optimal storage investment sizes and locations in cases (i)-(ii).

4 - Economic and environmental consequences of market power in the South-East Europe regional electricity market
Afzal Siddiqui, Verena Viskovic, Yihsu Chen, Makoto Tanaka

We investigate market power in electricity and CO2 emissions permit markets in the South-East Europe Regional Electricity Market, which comprises both EU members subject to the EU Emissions Trading System (ETS) and non-EU members exempt from it. We examine how a dominant firm can affect market outcomes by manipulating both electricity and permit prices in a game-theoretic framework. We formulate (i) a perfect competition equilibrium model and (ii) a bi-level model, with a dominant firm from Italy. The former is rendered as a quadratic program (QP) and the latter a mixed-integer quadratic programming problem (MIQP). We have two scenarios: no cap (NC) and binding cap (BC) on ETS emissions (10% reduction from NC). Under QP-BC, a permit price of EUR 8.64/t decreases ETS production, increases ETS electricity prices, and entices non-ETS production resulting in more exports to ETS. Consequently, 38.6% of the ETS emissions reduction is leaked to non-ETS. Comparing MIQP-NC with QP-NC, the leader withholds generation by 6% in order to raise prices and increases its profit by 1%. Under MIQP-BC, the leader further withholds its output and lowers the permit price to EUR 6.55/t. This way, the leader raises electricity prices in Italy and increases its profit by 2.15% vis-à-vis QP-BC. However, in other ETS countries, the lower permit price translates into lower electricity prices. This inflates electricity consumption leading to higher non-ETS production, which increases leakage to 40.6%.

■ TA-60

Tuesday, 8:30-10:00 - 4D UPV B.5

EURO Excellence in Practice Award I

Stream: EURO Special Sessions
Chair: *Ulrich Dorndorf*

1 - A combinatorial exchange for fishery access rights
Martin Bichler, Douglas Ferrell, Vladimir Fux, Jacob Goeree

We present the design and implementation of a combinatorial exchange for trading catch shares in New South Wales (NSW). The market provided a market-based response to a substantial policy problem in fisheries worldwide: the reallocation of catch shares among fishers in a cap-and-trade system designed to prevent overfishing. The design needed to address several key challenges to overcome a long struggle about the right way to reallocate shares. Participants wanted to be able to submit all-or-nothing package bids. Also, prices were required to be anonymous and linear such that sellers of two identical packages would get the same payment. These features were crucial for the adoption of the market design but difficult to accommodate in a market design. The requirements led to a computationally challenging allocation and pricing problem that addressed the key concerns of the stakeholders. The market was organized in summer 2017 by the government and successfully put the shares into the hands of those who needed them most. The design nicely illustrates how computational optimization can provide new policy tools, able to solve complex policy problems that were considered intractable only a few years ago.

2 - Scheduling the South American qualifiers to the 2018 FIFA World Cup by integer programming
Guillermo Durán, Mario Guajardo, Denis Saure

Every four years, the 10 national teams of the South American Football Confederation (CONMEBOL) compete for a slot in the final phase of the FIFA World Cup. The competition consists of a double round robin tournament. The matches are scheduled in 9 closely spaced pairs known as double rounds. Every team plays twice in each double round. The tournament is spread over 2 years, so the double rounds are months apart. After using the same mirrored schedule for about twenty years, and persistent complaints from its members, CONMEBOL decided to change the schedule for the 2018 World Cup. We used integer programming to construct schedules that overcome the main drawbacks of the previous approach. After exploring many design criteria, we proposed a candidate schedule that considerably improved the balance (usually perceived as fairness) of the schedule. In particular, it satisfies that every team plays once at home and once away on each double round, a feature that we show is impossible to capture in the format used by practitioners before. In addition, our schedule resembles symmetric features of long-lasting tradition. Our proposal was unanimously approved by CONMEBOL members and was used in the qualifier tournament for the 2018 FIFA World Cup Russia. The tournament was arguably one of the tightest in history, with the majority of the teams keeping chances to qualify until the last match. Contents of this application have been disseminated widely, helping promote OR as an effective tool for approaching practical problems through activities that have reached thousands of students and media users.

3 - Operational research as a driver for rural regeneration
Valentina Ferretti, Elisa Gandino

This intervention deals with the development of an integrated analytics approach designed and deployed to support planning and management of a new World Heritage site, the vineyard landscape of Langhe, Roero and Monferrato in the Piedmont Region (Italy). The stunning landscape of the area is the result of a strong commitment to the land by countless generations of winemakers and centuries of constant hard work, necessary for the implementation of an agrarian transformation of exceptional size. Nevertheless, local marginalized communities are at risk due to recent strong migration trends from rural villages towards big cities. Unfortunately, this phenomenon leads to the abandonment of many buildings and infrastructures worldwide. Regeneration strategies are thus becoming a key priority for governments and local authorities at the global level. This project integrates soft analytics with hard ones and participative methodologies to facilitate structuring and blending of human judgment with formal mathematical models. In particular, the project combines problem structuring tools, visualisation analytics and behavioural decision analytics to support all phases of territorial management in a challenging and unstructured decision environment. The obtained results illustrate the importance of integrated approaches for the development of accountable public decision processes and consensus policy alternatives.

Tuesday, 10:30-12:00

■ TB-01

Tuesday, 10:30-12:00 - UPV Nexus

Putting Operations Research to work

Stream: Keynotes
Chair: *Geir Hasle*

1 - Putting Operations Research to work
Iris F.A. Vis

Visits to companies and non-profit organizations typically provide inspiration for challenging research projects. In this presentation, information will be given on the organization of public-private partnerships addressing societal challenges. Several examples of projects will be shown in which solving the real-life questions required the design of new OR-based models and solution approaches. Specifically, we will discuss the design of distribution networks for sustainable fuels for transportation, replenishment operations at ATMs, physical internet operations and logistics for education. For each of those projects, we will explain the start of the project, the creation of the consortium, the formulation of the research questions and methodology, the actual research and results obtained.

■ TB-02

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S101

DEA, Banking, Financial Institutions II

Stream: DEA: Applications
Chair: *Lucie Chytilová*

1 - Discriminate analysis and data envelopment analysis with specific data and its application for companies in the Iranian stock exchange
Mohammad Fallah, Farhad Hosseinzadeh Lotfi, Alireza Amirteimoori, Mohsen Vaez-Ghasemi, Bijan Rahmani Parchikolaei, Mohammad Mehdi Hosseinzadeh

Data Envelopment Analysis is a technique for calculating the relative efficiency of a set of homogeneous decision making units. All decision making units are divided into two categories: efficient and inefficient. Discriminate analysis is a technique for making a distinction between two or more sets. This distinction is made by defining the differentiation function. With the help of this distinction function, joining of a new member can be done in one of the default sets. Models that are designed with the help of Data Envelopment Analysis Technique and Discriminate Analysis to create partitioning hyperplanes are used for joining of the new member. In this research, it is assumed that the parameters available to each member of society are in certain circumstances. These conditions include bounded index or integer or being in a desired set. In this research, the membership value will be defined to predict the membership of a new member to a set. The membership value represents the degree of confidence belonging to a set. In the following, the proposed method is used for the companies in Iran's stock exchange and OTC (Over the Counter) market. These companies are classified into successful and unsuccessful classes. These classes will be the criterion for determining the distinction function. Indicators affecting the classification of financial ratios. After discovering the distinction function of these sets, it is used to determine a new company in stock exchange or OTC market

2 - Comparative analysis for mapping the relative positions of bank brands: an application of attribute-based perceptual mapping using factor analysis and DEA
Jinal Parikh

There have been no studies in India which map the relative positions of bank brands based on the perceptions of customers. To this aim, we first apply Attribute-based perceptual mapping using factor analysis and Data Envelopment Analysis to map the relative positions of ten bank brands. Second, we report an empirical comparison of the results obtained from the analysis of the results obtained through both these techniques in terms of their similarities and differences. Accordingly, the common inference drawn from both the techniques is that the brands HDFC, ICICI and BoB are relatively strong in terms of customers' perceptions while the brands PNB, Canara, BoI and Dena are relatively weak in terms of customers' perceptions. A closer examination of the results obtained indicates and corroborates the differences amongst the various bank brands. For instance, although SBI has 100% relative perceptual efficiency obtained through DEA, the results of attribute-based perceptual mapping through factor analysis suggest that it is negatively rated in terms of staff related attributes. Finally, we examine the results obtained through gap analysis in attribute-based perceptual mapping using FA and DEA to find out the gaps in the current position of each of the bank brand and to suggest the scope for improvement in their current positioning strategy.

3 - The banking sector in Columbia from the perspective of relative efficiency
Gloria Rodriguez-Lozano

In every modern economy, the banking sector plays an important role in achieving and maintaining its development. It is the sector that advances the task of intermediation between surplus agents and deficit agents. This research analyzes the behavior of banks in Colombia during the last fifteen years, through the application of Data Envelopment Analysis (DEA), nonparametric methodology of linear programming, which through a double optimization process generates efficiency indicators. The results show that for the year 2014, 71% of the banks were efficient, being this the highest result within the studied period. Overall, it can be determined that the average relative efficiency of the Colombian banking sector in the last 15 years is 86%; despite having waged the first global financial crisis of this century and are experiencing a sharp economic recession worldwide. It was also established that it is not necessary to be the most important bank, nor the largest asset level, nor have obtained the most voluminous profits, nor belong to the most powerful financial group, nor have years of evolution, to be efficient.

4 - Efficiency evaluation using DEA with interval dual-role factors at banking sector of Visegrad Group countries
Lucie Chytilová

Data Envelopment Analysis became a popular and practical approach for assessing the relative efficiency of Decision-Making Units which employ multiple precise inputs to produce multiple precise outputs. However, in addition to inputs and outputs, some situations might include certain factors to simultaneously play the role of both inputs and outputs. Also, these these variables may not be known precisely, for example these these variables are define as intervals. This problem can not be solved by the usual DEA model. There have already been define some ways how to solve this problem - model by Cook et al. (2006) or Toloo et al. (2017). This article have focused on this problem and these methods had been compared. Their advantages and disadvantages had been discussed as well. To see more clearly the differences of the models the application had been done. More precisely, we have focused on the Visegrad Group banking sector, which is still undergoing a process of change and restructuring so there are problems with the data set.

■ TB-03

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S103

Facility Location in Transportation Networks

Stream: Location Analysis and Optimization
Chair: *Sanja Petrovic*

1 - Analysis of location model for charging facility considering driving distance
Yohei Kakimoto, Hiroyuki Goto, Yoichi Shimakawa, Hirotaka Takahashi

Most facility location problems assume the static demands like the population and express the demands to a target network. On the other hand, in the case of EV charging facilities assuming the vehicles as the demands, it is realistic to express the demands as the traffic flow to a network described by nodes and links, which are consisted of intersections and roads. In the problem, it must be considered that the phenomenon called "Cannibalization" that the distinct facilities consume same vehicles driving a same route. The facility location problem dealing with these demands and considering "Cannibalization" is proposed as "the flow-capturing location-allocation model (FCLM)" by Hodgson et al.. However, since the EV has the constraint that the driving distance is short, it is difficult to straightforwardly apply the FCLM assuming the gasoline-powered vehicle as the demands to the EV charging facility. Within this context, targeting the data of traffic network of Bangkok, Thailand, we have proposed the model that avoid unnecessary cannibalization and locate the facilities that EV can travel not to occur to run out of battery by modifying the FCLM. In this study, we focus on the driving distance of EV and verify the effectiveness of modifying model by conducting sensitivity analysis and comparing with modifying model and the FCLM.

2 - Greedy, exact and hybrid solution methods applied to the traffic counters location problem in transportation networks
Bruno Vieira, Thayse Ferrari, Glaydston Ribeiro, Romulo Orrico, Nilo Campos Júnior, Leonel Teixeira Júnior, Leonardo Perim

The economic growth recorded in Brazil in recent decades promoted an increase in demand for products and services throughout the country. Considering that the road network is the most used by Brazilians both for cargo and for passenger transportation, it is necessary to manage and control traffic in order to monitor the flow of vehicles on the roads, as well as plan measures to mitigate negative externalities. Several counting methods can be used to monitor traffic on highways. As traffic surveys tend to be costly, traffic counters are one of the most accessible options for monitoring traffic. The Traffic Counters Location Problem (TCLP) seeks to indicate optimal locations to count traffic in order to estimate origin/destination (O/D) matrices. The purpose of this paper is to carry out a comparative analysis of the results found with the application of different solution methods to TCLP in order to verify which of them best suits and analyzes the behavior of the instances. In order to perform the analysis in a more realistic context, the data used was extracted from the Brazilian georeferenced road base for 2015 regarding O/D pairs; these data were made available by the Brazilian National Department of Transport Infrastructure. The instances tested are part of a group of 26 real cases referring to the Brazilian states in which each point of origin or destination is a municipality and each edge is a state or federal highway segment present in the state.

3 - A branch and cut approach for location planning of electric vehicle recharging infrastructure
Paul Göpfert, Stefan Bock

To leverage the adoption of electric vehicles for day-to-day use is one of the main aims of contemporary environmental politics. But the use of electric vehicles by individual drivers will be limited as long as an adequate recharging infrastructure is missing. Without the possibility to recharge on the way, people usually do not consider electric vehicles for traveling on long distance relations.

In this talk we consider a Branch and Cut Approach for the determination of an efficient network of recharging stations for long distance traveling. By partial dualization of an Integer Programming model from literature we obtain a Branch and Cut Approach that incorporates separation algorithms, Integer Programming based cutting planes and a problem specific branching scheme. A computational study shows, that our algorithm is powerful enough to solve the considered problem even on realistically sized networks.

4 - A capacitated directed cycle hub location problem under congestion and uncertainty
Cihan Butun, Sanja Petrovic, Luc Muyldermans

This study is concerned with the liner shipping network design and optimisation. For this purpose, two problems are defined. First, a capacitated directed cycle hub location problem under congestion is defined and a mixed nonlinear programming model is formulated. The problem is to find the optimal number and locations of hub ports, determine allocations of non-hub ports to these hubs, and routing of cargo flows so as to minimise the total cost of transportation. Congestion is incorporated into the model by modelling each hub as an M/M/1 queuing system. To solve this problem a Tabu search algorithm is proposed. Due to the complexity of the problem, Tabu search is used to improve hub locations and node allocations only, and hub-level route is formed by local improvement at each iteration of the algorithm. The search is diversified using a long-term memory of hub locations. The second problem is defined by incorporating uncertainty into the first problem. Pairwise demand and transportation costs are identified as sources of uncertainty. The problem is studied by assuming: only demand, only transportation costs, and both parameters being uncertain. A suitable modelling approach is presented and solution methods are discussed. Computational experiments are done using four data sets and results are analysed using important concepts of hub location problem and liner shipping. Finally, future research opportunities are discussed.

■ TB-04

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S104

Investments and Asset Allocations: Methods and Applications

Stream: New Challenges in Investment Strategies, Risk and Financial Modelling
Chair: *Anna Maria D'Arcangelis*

1 - Multivariate count processes analysis of defaults
Ana Escribano, Mario Maggi

This paper analyzes credit rating default dependences in a multi-sectorial framework. Using the Mergent's FISD database, we study the default series in the US over the last two decades, disaggregating defaults by industry-sector groups. During this period, two main waves of default occurred: the implosion of the "dot com" bubble, and the global financial crisis. We estimate a Multivariate Autoregressive Conditional Poisson model to the weekly number of defaults occurred in the different sectors of the economy, from 1996 to 2015. We discuss the contagion effect between sectors in two ways: the degree of transmission of the probability of default from one sector to another, i.e., the "infectivity" of the sector, and also the degree of contagion of one sector from another, i.e., the "vulnerability" of the sector. Our results show some differences between the sectors' relations during the first and the second part of our sample. We add to the analysis some exogenous variables and evaluate their contribution to the goodness of fit.

2 - Optimal investment and deferred annuity choice with inflation and labour income risks
Chul Jang, Andrew Clare, Iqbal Owadally

We construct an optimal investment portfolio model with deferred annuities for an individual investor saving for retirement. The investor's real labour income has two exogenous shocks: permanent and temporary. The objective function consists of power utility in terms of secured retirement real income from two types of the deferred annuities: nominal-fixed and inflation-protected, as well as before-retirement bequest from liquidable assets of cash, nominal bond, inflation-linked bond, and equity funds. The asset universe is governed by a vector autoregressive model. We use multi-stage stochastic programming to solve the optimization problem numerically. Scenarios are generated by introducing a new structure combining a scenario tree with scenario fans to cover economic scenarios over the individual's whole life. We devise a quadratic optimization program to generate the labour income shocks scenarios. Our numerical results show that the optimal investment and deferred annuity choice depends on the individual's preferences, labour income shocks, and financial markets expectations. Average optimal asset allocations represent decreasing-risk profiles with age. Analysis on certainty equivalent values also proves that his welfare is diminished by 40% if deferred annuities are not available. The results are consistent with previous studies, but also provide novel support for deferred annuities as a major source of retirement income.

3 - Intertemporal analysis of mutual funds investing in European stocks: the analysis of herding through centrality measures
Giulia Rotundo, Anna Maria D'Arcangelis

The present analysis shows some results on an intertemporal sample of equity mutual funds investing in European stocks from 2007 to 2016. The work aims at understanding the relevance of centrality measures in herding detection. The idea is to examine to which extent methods and measures originally developed for networks may contribute to the detection and measurement of herding in mutual funds returns. We started through an analysis of the existing literature considering two indicators of herding that are most used in literature: the CSSD measure of Christie and Huang (1995), that is a Cross Sectional Standard Deviation against the market index, and the similar CSAD measure of Chang et al. (2000) that detects dispersion through a Cross-Sectional Absolute Deviation. Our analyses introduce the network component adding centrality measures as explanatory variables to the classical regression analysis used for herding. To this aim, the centrality measures were calculated on the network build from the correlation matrices, properly filtered through appropriate thresholds. Since it can be expected that the dynamics of funds is due to the role of the benchmark in the management, we repeated the analysis on the residuals of the Single Index Model returns. As the residuals represent the idiosyncratic component of the returns, this last analysis highlights the different behaviour of mutual fund managers due to active management.

■ TB-05

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S105

Vehicle Routing under Uncertainty

Stream: Vehicle Routing and Logistics Optimization I
Chair: *Epaminondas Kyriakidis*

1 - Algorithm for vehicle routing problem under uncertainty
Shuichi Isomura, Tomoki Fukuba, Takayuki Shiina

In the logistics industry, the number of cargos transported is increasing every year due to the spread of internet sales. There are many problems such as long working hours of the employees, lack of delivery employees, increasing CO2 emissions. It becomes necessary to operate transport vehicles efficiently. By setting up a delivery plan that considers uncertain time fluctuations, such as delays in work by customers and employees, delays in moving between customers due to traffic congestion, it is possible to make a more efficient delivery plan. In previous researches, many mathematical programing models were presented to obtain delivery plans that satisfy customer demand. However, there are few studies considering time fluctuation with multiple vehicles. In this research, we develop the model of a vehicle routing problem (VRP) to operate multiple vehicles taking fluctuations of work time and travel time between customers into consideration. The aim of this research is to propose an efficient solution of the problem using the L-shaped method and the regularized decomposition method, and to show the effectiveness of the proposed model by evaluating the value of stochastic solution (VSS).

2 - The vehicle routing problem with dynamic occasional drivers - a multistage formulation
Lars Dahle, Henrik Andersson, Marielle Christiansen, Lars Magnus Hvattum

Technological advances allow for new solutions to lower the costs of last mile delivery. We consider a setting where a company not only uses its own fleet of vehicles to deliver products, but can also make use of ordinary people who are already on the road. This may include people who visit a store and are willing to take a detour on their way home for a small compensation. The availability of these occasional drivers is naturally highly uncertain, and we assume that some stochastic information is known. This leads to a multistage stochastic vehicle routing problem, with dynamic appearance of vehicles. The contributions are a mixed integer programming formulation, together with a discussion of the dynamics of the problem. The results of the stochastic model is compared to deterministic strategies with reoptimization.

3 - A mean-variance objective for robust vehicle routing problem with uncertain demands
Marcella Bernardo, Jürgen Pannek

In the Dynamic and Stochastic Vehicle Routing Problem (DSVRP) a vehicle fleet is routed to serve a set of customers at minimum cost in the presence of exploitable information and dynamic events. For that, dynamic methods repeatedly solve the problem and update the solution as new information becomes available. However, in practice, the ability to modify a solution is constrained when, for example, the rate of events is high. To avoid this issue, our aim is to design an a-priori routing plan that permits smalls changes in the inputs during its execution, i.e. a robust solution. To this end, we use a mean-average formulation for the capacitated DSVRP, which is based on a bi-criterion objective function to trade-off robustness (immunization) and performance (total cost). Contrary to the min-max objective in robust optimization, which computes a single feasible solution for the worst-case scenario, the mean-variance allows to compute different solutions for different degrees of robustness. Based on the formulation we propose a robust method which gives the decision-maker flexibility in choosing between the trade-offs, delivering solutions that can be less/more robust. Considering a designed dynamic benchmark dataset, we compare the performance of solutions obtained for different levels of robustness. The results show that our method provides improvements in efficiency and robustness, compared to a deterministic approach.

4 - A stochastic vehicle routing problem for the collection of two similar products
Epaminondas Kyriakidis, Constantinos Karamatsoukis, Theodosis Dimitrakos

We study a stochastic vehicle routing problem in which a vehicle starts its route from a depot and visits N customers according to a particular sequence in order to collect from them two similar but not identical products. The actual quantity and the actual type of product that each customer possesses are revealed only when the vehicle arrives at the customer's site. The vehicle has two compartments. It is assumed that compartment 1 is suitable for loading product 1 and compartment 2 is suitable for loading product 2. However it is permitted to load items of product 1 into compartment 2 and items of product 2 into compartment 1. These actions cause extra costs that are due to extra labor. The objective is to find the routing strategy that minimizes the total expected cost among all possible strategies for servicing all customers. It is possible to find the optimal routing strategy by implementing a suitable stochastic dynamic programming algorithm.

■ TB-06

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S106

Store Management

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Youssef Boulaksil*

1 - Vertical integration of distribution and inventory management with pooling
Florian Arnold, Kenneth Sörensen, Johan Springael
The vertical integration of inventory management in depots and the delivery from depots to customers can improve the performance of a supply chain. Likewise, the collaboration among different depots has proven beneficial in many situations, especially the pooling of inventory via lateral transshipments. In this work we investigate how to effectively combine both concepts, and setup a vertical integration of distribution and inventory decisions in a supply chain with multiple depots. We propose a simple simulation approach to derive the routing and inventory costs for a periodic review model with neglectable lead times, and perform a set of experiments to gain insights into the best supply chain configuration. We observe that in such systems the pooling of distribution activities can be a more cost-efficient way to balance inventory than the pooling via lateral transshipments, while more inventory should be stored in central depots and depots with a higher variance in demand.

2 - Solving the backroom layout problem in grocery stores
Maria Pires
Competition in the food retail market has increased in recent years. Traditional food retailers have faced fierce pressure requiring them to adapt and develop innovative approaches to face the current challenges. Despite the importance of layout design in several sectors, most of the previous research has been focused on manufacturing and distribution industries. Furthermore, the sales area layout has also been studied due to its direct impact on store sales. Nevertheless, backrooms' layout plays an important role in in-store operations efficiency and store service levels, such as out-of-shelves. Currently in practice, the design of the backroom layout is mainly established empirically, based on the perception of similar stores by the architect. However, it should be carefully studied based on in-store logistics and operations. In this presentation, we present an effective analytic method for designing backroom layouts considering walking distance in the store, departments adjacency, sales areas layout and other physical restrictions. The application of the model proposed is illustrated with a case study of a European retailer.

3 - An optimization approach for product allocation with integrated shelf space dimensioning in retail stores
Alexander Hübner, Kai Schaal, Tobias Düsterhöft
Current literature demonstrated the value of optimization approaches for the management of retail shelves. Recent contributions model the shelf settings already more realistically by applying several different shelf segments instead of a one-dimensional shelf size. In these extensions, each segment can have its individual size regarding height, length and depth. However, these models assume given shelf size and do not model the interdependence of product allocation and shelf segment sizes. For example, the height of one segment may be reduced if there only small products are allocated or products are not stacked. We develop a new model that integrates the shelf size dimensioning into the shelf space allocation. It determines jointly (instead of separately as in current literature) the number of facings for each product, the shelf quantity and the size and number of shelf segments. At the same time, we consider several restrictions of the shelf structure (e.g. technical possibilities of the shelf system) and allocation rules (e.g. minimum and maximum number of facings, merchandising rules given by the retailer). As such, retailers get both, a profit-oriented optimization of the number of facings for each product and a detailed solution how the corresponding shelves must look like. Our solution approach is based on using useful bounds to get feasible and optimal solutions efficiently.

4 - Optimal cash rationing strategies for a two-product, cash constrained retailer's inventory system under stochastic demand
Youssef Boulaksil

We consider a small, traditional retailer, which we refer to as a nanostore, managing its inventory under strict cash-constraints. That is, since suppliers require immediate payment of goods delivered, only on-hand cash available can be used for replenishments. The nanostore is selling two products, which differ in profitability, acquisition price, and demand pattern. The available cash is allocated between replenishments of these two products. More importantly, cash can be rationed (i.e., held back) between replenishments opportunities: by not spending all available on-hand cash, even if the desired order-up to level is not made yet, more cash is available later to replenish the other product.

We formulate the problem as a stochastic dynamic program, optimizing the inventory policy to maximize expected terminal wealth at the end of the planning horizon. We consider two scenarios: firstly, we let the replenishment opportunities of both products coincide, secondly we consider the scenario that there is a non-negligible time between them. For both, we derive the structure of the optimal policy, and for the first scenario we derive some analytical results for the last period as well.

We conduct a numerical study for the second scenario, illustrating the impact of different parameters on the terminal wealth. The main insight is that proper cash rationing leads to a significant improvement of the retailer's operational performance in terms of expected terminal wealth.

■ TB-07

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S107

Applications in Industrial Engineering

Stream: Analytic Hierarchy Process / Analytic Network Process
Chair: *Gülin Feryal Can*
Chair: *Pelin Toktaş*

1 - Selecting the best contractor company for a defense project by using AHP
Nurdinç Şenay, Muharrem Tasyurek

Today's challenging environment forces nations to maintain their military power at the highest level as much as possible. They should invest their constrained budget to numbers of defense projects which need to be selected after making some trade-offs. If they choose the right project, they have to select the best alternative company which will materialize their need. Because, if the contractor company fails after a while, their defense planning may have some gaps which they cannot fill in a short time. In this study, we tried to select the best contractor company for one of our development projects. First, we built our evaluation criteria which have three layers by the help of the Subject Matter Experts (SMEs). Then, since we had both quantitative and qualitative criteria together, we used Analytical Hierarchy Process (AHP) to make an assessment between alternatives according to their previous products, engineering and project management capabilities and pre-contract study performances. After having final weighted scores, we gave decision support to the senior leaders. This study may help the people who will need to select a contractor company for any future development project.

2 - A novel two stages intutitonistic fuzzy approach proposal based on ANP and matehematical modelling for risk assessment
Yelda Yener, Gülin Feryal Can

Risk assessment (RA) is an activity performed to determine the hazards that may exist in the work areas. RA deals with complex expressions including hesitancy as it contains linguistic data. This study proposes a novel two stages intuitionistic fuzzy RA based on Intuitionistic Fuzzy Analytic Network Process (IF-ANP) and intuitionistic mathematical modeling. In the first stage, by considering the effects between each risk factor (RF) and relations between FMs, importance weights of RFs are computed and the rankings of FMs are obtained with IF-ANP. In the second stage, an intuitionistic mathematical model has been established reflecting the real constraints of the company as cost, safety level and the rankings' weights of FMs obtained from IF-ANP to determine the FMs that must be prevent firstly. Goals of the mathematical model are minimizing the cost and the risk level of the assembly area. Environmental, administrative, cost and risk structure related factors are considered as main RFs to rank nine FMs.

3 - AHP based KEMIRA approach for shopping mall selection
Pelin Toktaş, Gülin Feryal Can

In this study, a Task-based Integrated KEMIRA-AHP (TB-KEMIRA-AHP) approach that combines Kemeny Median Indicator Rank Accordance (KEMIRA) and Analytic Hierarchy Process (AHP) method is suggested to the selection of SMs. Two main criteria group are considered as technical criteria and universal design principles. The technical criteria are determined as area size, the numbers of elevators, the numbers of escalators, the numbers of stores, and the parking capacity. Nine SMs in Ankara, Turkey were ranked by five architects as decision makers (DMs). In the proposed approach, DMs are given tasks before making assessment related to SMs. Each task should be an activity relevant with the issue. 10 task scenarios are formed by DMs. The DMs consist of to evaluate SMs. All DMs sort criteria independently reflecting their opinion in KEMIRA. The priority which minimizes sum of distances to the priorities given by all DMs is chosen as median components priority. Criteria weights are determined considering median components priority in a heuristic manner. This study proposed to use AHP to calculate criteria weights reflecting the median components priority with the help of MATLAB code. KEMIRA minimizes the sum of squared ranks differences of two criteria set (technical features and universal principles) for the alternatives while intersection of the set of the best alternatives for two criteria sets is maximized. The AHP weights are searched until the target functions value is minimized.

4 - An integrated intuitionistic fuzzy approach based on AHP and MIACRA: an application for bevarage manufacturing
Gülin Feryal Can, Kumru Atalay

This study proposes a novel intuitionistic fuzzy approach in a more challenging area of decision making as manufacturing sustainability performance comparison. Intuitionistic Fuzzy Analytic Hierarchy Process (IF-AHP) and Intuitionistic Fuzzy Multi Attributive Ideal-Real Comparative Analysis (IF-MAIRCA) methods are integrated with the intuitionistic fuzzy L-shape function. The proposed approach is utilized to compare the manufacturing sustainability performance of four factories producing beverages. In comparison, sustainability across value chain, environmental and water management dimensions of manufacturing are considered. The relations between criteria were reflected by using intuitionistic fuzzy correlation coefficient formed criteria pairwise comparison matrixes of IF-AHP. To structure pairwise comparison matrixes of alternatives, differences of performance values of alternatives for the same criterion are computed in IF-AHP by using intuitionistic subtraction operator. Finally, IF-MAIRCA is carried out to rank factories by using the results of IF-AHP.

Keywords: IF-MAIRCA, IF-AHP, manufacturing sustainability, Intuitionistic Fuzzy Set, L-Shape Function

■ TB-08

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S108

Combinatorial Optimization on Graphs II

Stream: Combinatorial Optimization I
Chair: *Raffaele Cerulli*

1 - Heuristic algorithms for the strong generalized minimum label spanning tree

Andrea Raiconi, Carmine Cerrone, Ciriaco D'Ambrosio

We introduce and study the Strong Generalized Minimum Label Spanning Tree, a novel optimization problem defined on edge-labeled graphs. Given a label set associated to each edge of the input graph, the aim is to look for the spanning tree that contains the minimum number of labels. Differently from the previously introduced Generalized Minimum Label Spanning Tree problem, including a given edge in the solution means that its whole label set is used. To solve the problem, we present a greedy heuristic and two metaheuristics, based on the Carousel Greedy and the Pilot paradigm respectively. Computational results compare the performances of the proposed approaches on a wide set of benchmark instances.

2 - On the single door cross-docking problem

Marcello Sammarra, Manlio Gaudioso, M. Flavia Monaco

A cross-docking terminal is a logistic platform involved in the distribution process of products from the suppliers to the retailers. It can be seen as a facility where products arriving by inbound trucks, generally as less-than-truckload shipments, are arranged with respect to retailers' requirements into full truckloads and directly delivered by outbound trucks, skipping thus the storage phase. Such a distribution strategy needs a high level of synchronization between the inbound and outbound operations, that is truck unloading and loading, respectively. In this talk we address the problem in case the terminal is equipped with two doors, one for the unloading and the other for loading operations. For this basic problem, we propose an Integer Linear Programming formulation and a Lagrangian Relaxation approach. We show that the Lagrangian problem decomposes in two combinatorial sub-problems. We study the mathematical properties of the sub-problems and derive exact solution algorithms for both of them, as well as optimality condition for the Lagrangian Dual problem. Based on the theoretical results, we propose a Lagrangian heuristic algorithm. Finally, we present and discuss some numerical results.

3 - A GRASP for the supervised learning minimum cost SAT problem

Giovanni Felici, Paola Festa, Tommaso Pastore, Daniele Ferone, Antonio Napoletano

A strong connection exists between supervised learning from data represented in logic form and the solution of the Minimum Cost Satisfiability Problem (MinCostSAT). Methods based on such connection have been developed and successfully applied in many contexts. The deployment of such methods to large-scale learning problem is often hindered by the computational challenge of solving MinCostSAT, a problem well known to be NP-complete. We propose a GRASP-based metaheuristic designed for such problem, that proves successful in leveraging the very distinctive structure of the MinCost-SAT problems arising in supervised learning. The algorithm is equipped with an original stopping criterion based on probabilistic assumptions which results very effective for deciding when the search space has been explored enough. Although the proposed solver may approach MinCost-SAT of general form, in this paper we limit our analysis to some instances that have been created from artificial supervised learning problems, and show that our method outperforms more general purpose well established solvers and moreover provides competitive solutions to large scale learning problems when compared with established supervised learning methods.

4 - Optimizing the investments in mobile networks and subscriber migrations for a telecommunication operator

Adrien Cambier, Michael Poss, Rosa Maria Figueiredo, Matthieu Chardy, Adam Ouorou

Worldwide telecommunications groups are both infrastructure operator and service provider. Hence, when planning the network expansion, these groups must also consider the subscribers' dynamics, which they can influence through subsidies. Addressing both aspects together enables them to better optimize the network dimensioning, therefore avoiding unnecessary costs. In this work, the network expansion represents the deployment and/or reinforcement of several technologies (e.g. 2G,3G,4G), assuming that subscribers to a given technology can be served by this technology or older ones. The objective of the resulting optimization problem is to minimize network investments costs and subsides, while being subject to both capacity and strategical constraints, such as minimum coverage and users' averaged throughput. We model the customer behavior in response to subsides with S-shape piecewise linear functions, which are linearized. We assess numerically the resulting Mixed-Integer Linear Programming (MILP) formulation on real-life instances focusing on 3G/4G migrations. Our results show the scalability of the MILP model for 2 network generations and 100 sites. Moreover, they underline the cost-benefit of solving a unique optimization problem over the whole time-horizon (5 years) compared to decomposing the problem year by year.

■ TB-09

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S109

The Role of Data Science in Optimization

Stream: European Working Group: Data Science Meets Optimization
Chair: *Patrick De Causmaecker*

1 - A data-driven model for routing mobile medical facilities

Sibel Salman, Burcin Bozkaya, Eda Yücel, Cemre Gokalp

We study a problem related to the delivery of mobile medical services and in particular, the optimization of the joint stop location selection and routing of the mobile vehicles over a repetitive schedule consisting of multiple days. We consider the problem from the perspective of the mobile service provider company, and we aim to provide the most revenue to the company by maximizing the reach of potential customers to the provided services. The problem is a variant of the team orienteering problem with an objective that accounts for full and partial coverage. We utilize transactional (big) data that originate from the customer banking activities of a major bank in Turkey. We analyze this dataset to determine the priority of areas (districts of Istanbul) where services are to be delivered for maximum coverage, coverage parameters and the potential locations of delivery. We formulate a mixed integer-linear programming model and solve it to optimality using CPLEX in reasonable time. Our results indicate an important trade-off between the total number of days of service along with the number of vehicles used, and service coverage level. We compare the results of several models differing in their coverage functions and demonstrate the efficacy of our model.

2 - Constraint learning using tensor (COUNT)

Mohit Kumar, Luc De Raedt, Stefano Teso

Many problems in operations research require that constraints be specified in the model. Determining the right constraints is a hard and laborsome task. We propose an approach to automate this process using artificial intelligence and machine learning principles. So far there has been only little work on learning constraints within the operations research community. We focus on personnel rostering and scheduling problems in which there are often past schedules available and show that it is possible to automatically learn constraints from such data.

To realize this, we adapted some techniques from the constraint programming community and we have extended them in order to cope with multi-dimensional data. The method uses a tensor representation of the data, which helps in capturing the dimensionality as well as the structure of the data, and applies tensor operations to find the constraints that are satisfied by the data. To evaluate the proposed algorithm, we used constraints from the Nurse Rostering Competition and generated solutions that satisfy these constraints; these solutions were then used as data to learn constraints. Experiments demonstrate that the proposed algorithm is capable of producing human readable constraints that capture the underlying characteristics of the data.

3 - Value of product location information in agrifood logistics decision making: a multi-level perspective
Viet Nguyen, Jacqueline Bloemhof

Product location information (PLI) generated by tracking & tracing systems enables a continuous monitoring of material flows and logistics operations across the supply chains. In agrifood sector, tracking & tracing systems are often associated with implications on product safety and quality, whereas the values from logistics management perspective have been overlooked. These values can be seen from a multi-level decision making perspective and can be further increased by big data analytics methods. Using the tracking & tracing systems from a crossdocking warehouse in the Dutch floriculture sector as an illustrative case, we extensively discuss the value of historical and real-time PLI in supporting logistics decisions at different levels, i.e. strategic, tactical and operational. Currently, workforce scheduling is the most challenging decision at the crossdocking due to the time constraints and the wide daily and hourly fluctuations in inbound product volumes. Employing data-mining based big-data approaches, we develop a framework to integrate the use of historical and real-time PLI in making strategic, tactical and real-time workforce plans. This paper helps managers gain a systematic understanding of the multi-level values and opportunities enabled by PLI and tracking & tracing systems. Moreover, it stresses on the necessity to accelerate the implementation of big data analytics across the supply chain functions to make further uses of PLI and big data from other systems.

4 - Data, information, knowledge and optimisation.
Patrick De Causmaecker

Implicit information in data, explicit knowledge expressed apart from the actual optimisation models all could contribute to the quality of the decision support. In present practice, however, the use of this information and knowledge is very limited. Use of data often targets specific purposes and explicit knowledge on the context can certainly not always be taken into account by present optimisation techniques. Some illustrative examples demonstrate that this may be a missed opportunity. We review existing methods, techniques and procedures presently allowing to incorporate data and knowledge to improve the decision support in accuracy and stability. On-line as well as off-line decision can profit from existing tools. We identify opportunities for improvement as well as some open questions.

■ TB-10

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S110

Decision Aiding Methods VI

Stream: Multiple Criteria Decision Aiding
Chair: *Samira El Gibari*

1 - Optimality and boundedness in interval linear programming: complexity and characterization
Elif Garajová, Milan Hladik, Miroslav Rada

Throughout the last years, several approaches to optimization with inexact data have emerged, covering different sources and types of uncertainty, as well as various demands imposed on the solutions. In this talk, we adopt the approach of interval linear programming, which assumes that the input data can be perturbed independently within the given upper and lower bounds. Generalizing the questions addressed in classical linear programming, we discuss two decision problems concerning the existence of an optimal solution and boundedness of the objective function of an interval program. First, we investigate the problem of checking non-emptiness of the united set of all optimal solutions, also known as the weak optimality property of a program. Apart from ensuring that optimal solutions exist, a constructive version of the problem is also interesting for applications, in which the intervals represent given tolerances and the goal is to find the best setting of the coefficients. The second problem addressed in the talk is the weak unboundedness property, i.e. checking whether there exists a feasible scenario with an unbounded objective function. For both problems, we present some complexity-theoretic results and discuss the closely related questions of formulating a finite characterization of weak optimality and unboundedness, and finding a specific scenario witnessing the properties.

2 - A novel FMEA model for machine tool risk analysis
James Liou, Huai-Wei Lo, Yen-Ching Chuang

With the trend of intelligent manufacturing, machine tool with high reliability and accuracy will be market trends in the future. Failures of the machine tool not only endangers user's commitment delivery due date, but also lead to decline in production efficiency, reduce quality consistency, downtime loss etc. The reliability and maintenance of the machine tool are the key factors that influence the use of life cycle. Failure mode and effects analysis (FMEA) is an effective risk-management technique used in various industries, which is based on the experts' experience to determine the major failure modes and detect the most needed risk factors for preventing any risk occurred. However, the input data provided from experts are usually uncertain due to human subjective judgment or incomplete information, which needs an effective method to integrate those experts' opinions. This study proposed a novel FMEA model based on multi-criteria group decision making (MCGDM), which integrated rough number, best-worst method (BWM) and modified technique for order preference by similarity to an ideal solution (TOPSIS) for ranking the failure modes. The model can remedy some shortcomings of original FMEA and provide a more reasonable result. The proposed model is demonstrated by using a practical case of machine tool company. The results indicate that the proposed model can effectively help managers to assess risk factors and identify the critical failure modes.

3 - Sigma-Mu efficiency analysis: a new methodology for evaluating units through composite indices
Menelaos Tasiou, Salvatore Greco, Alessio Ishizaka, Gianpiero Torrisi

We propose a new methodology to employ composite indices for performance analysis of units of interest using Stochastic Multiattribute Acceptability Analysis. We start evaluating each unit by means of weighted sums of their elementary indicators in the whole set of admissible weights. For each unit, we compute the mean, , and the standard deviation, , of its evaluations. We give each unit the benefit of the doubt in evaluating its score, comprised of a function of and . Clearly, the former has to be maximized, while the latter has to be minimized as it denotes instability in the evaluations as to the variability of weights. We make use of Data Envelopment Analysis to achieve this purpose. As such, we consider a unit to be Pareto-Koopmans efficient with respect to and if there is no convex combination of and of the rest of the units with a value of that is not smaller, and a value of that is not greater, with at least one strict inequality. To increase the explicative power of our approach, we make use of the context-dependent Data Envelopment Analysis, assigning each unit to one of the sequence of Pareto-Koopmans frontiers. This permits us to measure the efficiency of each unit not only with respect to the first frontier, but also with respect to all frontiers among the sets of considered units. We illustrate the potential of the proposed methodology with an application to the data of world happiness report produced by the United Nations' SDSN.

4 - A comparison of the MRP-WES method with other MCDM methods based synthetic indicators.
Samira El Gibari, Francisco Ruiz, Jose Manuel Cabello, Trinidad Gomez

In this paper, we propose a novel methodology based on the multicriteria reference point scheme (the Multiple Reference Point Weak-Strong Synthetic Indicator, MRP-WES), where the decision maker can establish any number of reference levels for each indicator, and the final outcome can be interpreted in terms of the position with respect to these levels. In order to illustrate the behaviour of the scheme proposed, we apply it to the construction of the EU-Regional Social Progress Index, in the Spanish context. Then, we compare our indicators with others obtained using two well-known alternative multicriteria based methods. For a better comparison, we have chosen those that allowed different compensation degrees among indicators. We use the Goal Programming based synthetic indicators and PROMETHEE methods. Our results show that the MRP-WES indicators are synthetic indicators whose properties make them especially useful in view of their real applicability. From the practical point of view, the main advantage of MRP-WES is twofold. First, the MRP-WES indicators can be easily interpreted as the global position of the corresponding unit with respect to hypothetical global reference levels, resulting in a meaningful measure. Second, apart from providing an overall measure, the MRP-WES method provides warning signals which let the decision maker detect bad performances in certain indicators that may remain unnoticed otherwise.

■ TB-11

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S111

Customer Relationship Management

Stream: Business Analytics
Chair: *Dries Benoit*

1 - Integrating textual information in customer churn prediction models: a deep learning approach
Arno De Caigny, Kristof Coussement, Koen W. De Bock, Stefan Lessmann

In customer churn prediction, often only structured information is used to predict the customers that are most prone to leave the company. In this study unstructured textual data in the form of emails between customers and their bank advisor is integrated in a customer churn prediction model. Previous literature has already proven that including textual data processed by traditional text mining methods can improve predictive models, but recently deep learning techniques such as convolutional neural networks have established important improvements in text classification tasks. Therefore this study investigates whether adding textual information processed by convolutional neural networks ameliorate the performance of existing customer churn prediction models and benchmarks it with traditional text mining techniques. The contribution to the literature of this study is twofold. Firstly, this study proves that adding textual information in a customer churn prediction model improves the predictive performance for a large European financial service provider. Secondly, a framework on how to include textual information in existing customer churn prediction models is created. From a managerial point of view, the integrated framework helps decision makers to identify more accurately customers most prone to leave the bank.

2 - Time series classification for early churn prediction in dynamic networks
Tine Van Calster, María Óskarsdóttir, Bart Baesens, Wilfried Lemahieu

Churn prediction in telecommunication is a well-researched application in machine learning, as the saturated telco market gains a great deal more from customer retention than from the recruitment of new clients. Being able to identify which behavioural patterns and which social network features eventually lead to churn has therefore been researched extensively. The faster these potential churners are identified, the sooner the telco company can intervene. However, a client's social circle is constantly changing, which creates the challenge of incorporating this dynamic aspect into essentially static models. In this research, we address this problem by proposing a new methodology that extracts time series of network features based on consecutive networks. Concretely, we use weekly call detail records from several telco providers over a period of six months. From each network, we then obtain time series of eight network features for each client. These time series can then be compared and used to identify churners based on new multivariate adaptations of the recently

3 - Paradoxes of the retention reaction curve
Igor Sloev

Customer Lifetime Value (CLV), the present value of the stream of profits accruing to a firm over the whole period of its relationship with customer, has gained importance in marketing science and business practice. CLV contains the idea of differentiating customers according profitability enabling the firm management to choose the most appropriate marketing strategy for each individual customer. Customer retention rate, the probability that customer will continue its relation with a firm in the next period, is a key driver of CLV. Maintaining a good relationship with a customer allows firms to increase a customer retention rate; however it comes at cost. The CLV concept allows determining an optimal level of such retention expenditures. We study analytically an impact of a shape of the retention response curve on a solution of the maximization. We demonstrate that under reasonable assumptions customers with higher per-period gross profit margin may generate lower net profit margin due to the high level of optimal retention expenditures. We provide rational arguments why such "paradoxical" results may have a place and discuss challenges for implementation of the CLV concepts (and, in general, forward looking metrics) in real business.

4 - Social ties in customer referral programs
Iris Roelens, Philippe Baecke, Dries Benoit

Customer referral programs are marketing programs in which existing customers are rewarded for bringing in new customers. The aim is to attract new customers by leveraging the social connections of existing customers with potential customers. Previous research has shown that referred customers are more valuable to a firm than non-referred customers. However, previous research solely focused on the customer lifetime value of the newly referred customers and does not look at the social network characteristics. A study by Kumar et al. (2010) argues that we should consider two parts of customer value, namely customer lifetime value and customer referral value. The latter can be conceived as a customer's potential to grow the network through referrals. Early work by Granovetter (1973) highlights the importance of weak social connections, like acquaintances, in a network due to their position as bridges, connecting different communities. Extending this knowledge to customer referral programs, we can argue that referrals over weak links are powerful for accessing new communities. In this study, we investigate the effect of referrals and the tie strength between the existing and potential customer on the resulting growth of the network. The finding of this study are particularly useful for start-ups or marketing campaigns aiming to grow the customer base.

■ TB-12

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S112

Fuzzy Sets Theory in MCDA

Stream: Fuzzy Optimization
Chair: *Kurt Nielsen*

1 - Techniques to model uncertain input data of multi-criteria decision making problems: a literature review
Sarah Ben Amor, Renata Pelissari, Maria Celia de Oliveira, Alvaro Abackerli

There are few studies in the literature regarding possible types of uncertainty in input data of Multi-Criteria Decision Making (MCDM) or Multi-Criteria Decision Analysis (MCDA) problems and the techniques employed to deal with each of them. Therefore, the aim of this study is to identify the different types of uncertainty that occur in input data of MCDM/A problems and the most appropriate techniques to deal with each one of these uncertainty types. In this paper, a comprehensive literature review is presented in order to meet this objective. We selected and summarized 134 international journal articles. They were analyzed based on the type of data with uncertainty, the type of uncertainty and the technique used to model it. We identified three distinct types of uncertainty in input data of MCDM/A problems, namely (i) uncertainty due to ambiguity, (ii) uncertainty due to randomness and (iii) uncertainty due to partial information. We identified a new generation of fuzzy approaches including Type-2, intuitionistic and hesitant fuzzy sets, used to model these types of uncertainty besides other approaches such as traditional Fuzzy Sets theory, Probability theory, Evidential Reasoning (ER) theory, Rough Set theory and Grey Numbers. Finally, a framework to help choose the most adequate technique to deal with each type of uncertainty is proposed.

2 - Using Fuzzy-DEMATEL method to explore decisive factors in after market of auto lighting industry
Jing Li, Chi-Hui Wu, Ching-Torng Lin, Jian-Ke Huang

Traditional industry is the mainstay of Taiwan's economy. However, with the advent of the era of the global village, the distance is no longer a gap between firms; the competition has become very intense. Lights industrial maintenance market is changing and become more intense. In order to survival and development, companies must face squarely the business strategy issues. This study literature and practical recommendations from experts in the past, select the key success factors AM lights when industrial operations, and the use of fuzzy decision-making laboratory analysis research and analysis, to explore the key business industry correlation between the factors. The results found that the "product integrity" as the impact of other facets of the most important factors, but by the highest degree of influence facets is "customer satisfaction". In the guidelines for achieving "the bargaining power of suppliers", "cross-border collaboration to develop," "rapid response to customer demand," and other indicators of the program, from the need to "promote the standardization of parts", "mutual support cross-functional teams" and "provisioning global marketing channels" and other indicators of the project were to proceed. The results of this study provide much rich and valuable information, as a reference to select the direction of competition policy in order to make the best of the limited resources allocated to achieve the highest efficiency, enhance the competitiveness of firms.

3 - Risk assessment of pharmaceutical product distribution using intuitionistic fuzzy FMEA and TOPSIS model
Shahrzad Faghih Roohi, Alp Akcay, Yingqian Zhang, Eelco de Jong

This paper presents a group decision making approach for risk assessment in the distribution of pharmaceutical products. By using failure modes and effect analysis (FMEA), the risks can be identified and ranked. A group of decision makers in pharmaceutical distribution industry judge in a linguistic way about identified failure modes with respect to risk factors (severity, occurrence, and detect-ability). Due to the lack of precise evaluations in real world, we define individual judgment term as an intuitionistic fuzzy number (IFN). By using a new intuitionistic fuzzy hybrid TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) approach, we prioritize the risks involved in pharmaceutical distribution. The aim of this paper is to overcome the current weaknesses of FMEA by considering unequal weights of risk factors given by expert team members for different failure modes. Finally, a case study on air cargo distribution of pharmaceutical products is presented to demonstrate the potential applications of the proposed approach, and the merits are highlighted by comparing with the traditional FMEA.

4 - Multi-attribute procurement auctions with fuzzy attributes
Kurt Nielsen

We consider a multi-attribute procurement auction that combines the standard second price auction and MCDM fuzzy decision support systems to include imprecise measures in the selection phase.

The principal announces the attributes that enter the auction and a priori weights on price and other attributes. The bids are extended to describe the inherent uncertainty and an adjusted version of the so-called Fuzzy Weighted Overlap Dominance (FWOD) is used to produce equivalence classes by complete pairwise comparison of bids. The resulting top ranking equivalent class enters an auction that selects a winner following a standard second price auction.

The auction mechanism provides no incentives for the bidders' to bid above true cost. However, a runner-up to the top equivalence class may potentially win the auction by bidding below true cost at the risk of winner's curse. The properties of the auction are analyzed analytically and quantitative by simulations.

■ TB-13

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S201

Algorithms in Continuous Optimization

Stream: Applications Related to Continuous Optimization
Chair: *Juan Carlos Cortés*

1 - Complexity of an inexact restoration method
Luis Felipe Bueno, José Mario Martínez

In recent years, there has been an increase in interest in the analysis of the complexity of nonlinear optimization algorithms. For constrained optimization, there are few results on algorithm complexity. Notable references on this subject deal with simple constraints or do not present an afordable algorithm. Inexata Restoration (IR) methods deal with feasibility and optimality in different phases and therefore can explore specific characteristics of the constraints or the objective function in the corresponding phase. In this work we present an IR algorithm that in the first phase searches for a more feasible point using a first order method with complexity of epsilon to the power minos two to solve a box constrained least squares problem. In the second phase another first-order method with the same complexity is used, but it deals with linear constraints. Combining these ideas we obtain a practical first order IR method for which we present a theory of complexity of the same order for nonlinear optimization with general constraints.

2 - Efficient alternating minimization methods for variational edge-weighted colorization models with sphere constraints
Maryam Yashtini

Alternating minimization algorithms are developed to solve two variational models for image colorization based on chromaticity and brightness color system. The first model is the edge-weighted total variation (TV) model, while the second model is the edge-weighted harmonic model, proposed by Kang and March (IEEE Trans Image Proc 16(9):2251–2261). Both models minimize a functional over a set of variables where take values on the unit sphere. The proposed methods are based on operator splitting, augmented Lagrangian, and alternating direction method of multipliers, where the computations can take advantage of multi-dimentional shrinkage and Fast Fourier Transform under periodic boundary conditions. The existence analysis for a minimizer to the edge-weighted TV model is given and convergence analysis to a Karush–Kahn–Tucker point is established under some assumptions. Numerical experiments on image colorization problems show the effectiveness of the new methods. Moreover, numerical comparisons to quadratic penalty method, augmented Lagrangian method, time marching, and/or accelerated time marching algorithms demonstrate the efficiency of our proposed methods.

3 - Application of novelty search to the particle swarm optimization algorithm
Juan Carlos Cortés, David Martínez-Rodríguez, Clara Burgos-Simon, José-Ignacio Hidalgo, Rafael-J. Villanueva

Evolutionary algorithms are based on the exchange of information between different particles which evolve during the process of finding a minimum or maximum in a function. Novelty Search is raising up as a new field to investigate evolutionary algorithms. The main idea of Novelty Search is to reward those evolutions that evaluates the function in a search space that has not been explored yet. It allows us to avoid the stuck of the particles in a local minimum or maximum by looking for areas that would not be attractive in common evolutionary algorithms. The idea of this work is to implement this philosophy in the evolutionary algorithm Particle Swarm Optimization (PSO). In this contribution we present some modifications in the original algorithm in order to achieve better results in functions optimization. Two different families of particles are deployed: the first ones are the same as the PSO algorithm, and the second ones, instead of following the best function evaluation, are repelled by it at the same time as follows its best individual evaluation. As Novelty measure, the centroid of the historic registration of function evaluations is calculated. This centroid is used as simplification to minimize the computational cost of knowing which are the unexplored areas. To prove the validity of the modification, the CEC 2005 benchmark is performed and the results attached to this study.

■ TB-14

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S202

Sparse Optimisation with Applications

Stream: Nonlinear Programming: Methods
Chair: *Xiaoqi Yang*

1 - Restricted eigenvalue conditions and recovery bounds of l_q regularization problems
Xiaoqi Yang

Recovery bounds are important in the theoretical study of sparse solutions in compressed sensing and machine learning etc. Recovery bounds of convex l_1 regularization problems with and without noises have been extensively studied. We will present their extensions to recovery bounds of nonconvex l_q ($0 < q < 1$) regularization problems. In the case without noise, we establish a global recovery bound for any point in a level set of the unconstrained l_q regularization problem, and we also provide a local analysis of recovery bound for a path of local minima. In the case of noise we investigate stable recovery bounds of l_q ($0 < q < 1$) optimization model, which is an inequality constrained l_q minimization problem due to the noise in a linear system. We present the results in the deterministic and probability cases respectively.

2 - Lower-order regularization method for group sparse optimization with applications in systems biology
Yaohua Hu, Chong Li, Kaiwen Meng, Jing Qin, Xiaoqi Yang

The lower-order regularization problem has been widely studied for finding sparse solutions of linear inverse problems and gained successful applications in various mathematics and applied science fields. In this talk, we will present the lower-order regularization method for (group) sparse optimization problem in three aspects: theory, algorithm and application. In the theoretical aspect, by introducing a notion of restricted eigenvalue condition, we will establish an oracle property and a global recovery bound for the lower-order regularization problem. In the algorithmic aspect, we will apply the well-known proximal gradient method to solve the lower-order regularization problem, and establish the linear convergence rate of the proximal gradient method for solving the lower-order regularization problem under a simple assumption. Finally, in the aspect of application, we apply the lower-order group sparse regularization method to solve two important problems in systems biology: gene transcriptional regulation and cell fate conversion.

3 - On the binary Eisenberg-Noe model and its extension
Yu-Hong Dai
In a financial network, the failure of a key institution can spill over to other institutions and even to the whole network. It is an important problem how to identify these key institutions. In this paper, we analyze the binary case of the linear optimization model introduced by Eisenberg and Noe(2001). We develop a conservative bankruptcy strategy assuming that banks in the network only have two status: bankrupt or totally solvent. Key institutions can efficiently be found out with bailout fund invested in a network under this assumption. Then the system risk management problem can be formulated into a mixed integer linear programming (MILP). In order to maximize the number of totally solvent banks, an L_0 term is added to the objective function, thus leading to a sparse MILP. We prove that this obtained sparse MILP is an NP-hard problem. We also give a series of greedy algorithms based on the contagious property of the market shock. Numerical results are presented to show the efficiency of the algorithms. This is a joint work with Zhilong Dong, Fengmin Xu and Jiming Peng.

4 - Balance analysis of sparsity and robustness for portfolio adjustment problem
Fengmin Xu
Financial institutions manage portfolios that take less risk when volatility is too high, and produce large utility gains through making adjustments. But the adjustment methods may make investors fall into distressful circumstances because some of them seem to be full of incongruity. The goal of our study is to investigate how sparsity and robustness interact to optimal portfolio positions to portfolio adjustment problems. We formulate a sparse and robust portfolio adjustment (SRPA) optimization problem, and generate a high-quality solution via an efficient ADMM. Through balance analysis, we are able to identify two key contributors to portfolio adjustment, the changes of optimal portfolio positions and the move of the transaction critical point, quantifying the market uncertainty effect for various portfolio strategies. We illustrate the above financial phenomena in numerical examples and verify the good performance of the proposed method in actual data sets from China stock market. Our results contribute to a better understanding of sparsity and robustness effects for portfolio adjustment problem.

■ TB-15

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S203

Real-Life Vehicle Routing I

Stream: Vehicle Routing and Logistics Optimization II
Chair: *Kemal Kaya*

1 - Integrated vehicle and pollster routing
Sandra Gutierrez, Luis Torres, Diego Recalde, Ramiro Torres, Pablo Zuleta, Andrés Miniguano
The National Statistics Bureau of Ecuador carries out monthly polls to monitor the evolution of consumer prices of basic commodities. In this work we present a Mixed Integer Programming model for the integrated task of scheduling visits of pollsters to selected stores in the city of Guayaquil, as well as routing the vehicle fleet used to transport them. Due to the complexity of the problem (NP-hard), the approach used to solve it has taken into consideration three separated stages: first, a balanced partition of nodes has been performed; second, we have found using heuristics methods walking paths for pollsters and finally, the routes for vehicles have been determined. This problem has particular conditions that, to the best of our knowledge, have not been treated together previously in the literature. Results obtained in this paper seem a promising contribution for Pick-up-and-Delivery problems.

2 - Ambulance routing under nuclear facility disaster
Gyu M. Lee

A nuclear disaster can cause wide-spread and long-lasting damages to many people and environments over a prolonged horizon. The radioactive materials are dispersed unexpectedly according to winds, geographical features and so on. Many casualties are developed at the disparate severity by the radiation exposure over the impacted area. The government or relief agency needs to plan how to pick up and take the patients from different locations in the impacted area to the radiotherapy-ready hospitals quickly. A routing problem for ambulances in nuclear disasters which considers the distances between the patient locations and the concentration of radioactive materials over the impacted area to assign the patients to ambulances is studied. The objective is to minimize the maximum amount of the accumulated radiation exposure dose for each patient. A mixed integer nonlinear programming formulation has been proposed and the computational experiences of this time-critical planning is provided. The computational results are proposed by using Tabu search algorithm to find good solutions within a reasonable time.

3 - Vehicle routing with an endogenous learning effect: an application to offshore plug and abandonment campaign planning
Steffen Bakker

At the end of the lifetime of an oil and or gas field, the individual wells have to be plugged and abandoned(P&A), to prevent leakages from or into the reservoir. When considering subsea wells, rigs and vessels with high day rates have to be rented to perform these plugging operations. This leads to incentives for operators to perform large scale plugging campaigns.

In this work we present an application of the uncapacitated vehicle routing problem with time-windows to the planning of an offshore plug and abandonment campaign. The execution times of the individual plugging operations are dependent on the number of times a similar operation has been performed before. We therefore take a logic-based approach to account for this endogenous learning effect.

We test the model on a stylized case study consisting of wells on the Norwegian Continental Shelf, and show that there is considerable value in potential collaboration between operators. We investigate the use of a branch-and-cut algorithm that adds subtour elimination constraints to solve larger instances of the problem.

4 - A rich vehicle routing problem involving split deliveries, heterogeneous fleet, and outsourcing option
Kemal Kaya, Gultekin Kuyzu, Salih Tekin

We study a rich vehicle routing problem motivated by a real-life problem, in which by the customer deliveries is done by a heterogeneous fleet with possible split deliveries. The routes can be performed by owned vehicles or outsourced vehicles, the routes of which can be closed or open, respectively. The routes of each hired vehicle ends at the last visited customer while the owned vehicles must return to the depot. Both the owned and the hired vehicles are of types that differ from each other in terms of capacity and cost per unit distance, exhibiting economies of scale. A fixed number of owned vehicles are available for use, while an unlimited number of hired vehicles can be used, albeit at a higher cost per unit distance than an owned vehicle of the same type. Our aim is to construct a set of routes with minimum total cost. We firstly develop a mixed integer linear programming model, and demonstrate the value of allowing flexible splits in deliveries with the help of this model on small instances. Because of the complexity of the problem, the model fails to find optimal solutions for larger instances in a reasonable time. In order to obtain high quality solutions efficiently, we propose an Adaptive Large Neighborhood Search (ALNS) algorithm with novel operators.

■ TB-16
Tuesday, 10:30-12:00 - SOUTH BUILDING UV S115

Maritime logistics

Stream: Green Logistics
Chair: *Harilaos Psaraftis*

1 - Optimal choice of speed reduction ports for shipping liners
Shuaian Wang

Increasing ship transportation contributes greatly to air pollution. Slow steaming can be used by vessel operators to mitigate gas and particulates emissions. A designed speed reduction zone may reduce SOx, NOx and PM by one third. In order to reduce ship emissions near coastal areas, Port of Los Angeles proposed a voluntary Vessel Speed Reduction Program (VSRP) in 2001. The program designs a speed limit for ocean-going vessels to slow their speeds as they approach or depart Port of Los Angeles, generally at 20 n miles from the port. A mixed-integer non-linear mathematical model on minimizing total costs is presented considering three determinants, i.e., the compliance of Vessel Speed Reduction Incentive Programs, the maximum physical speed of ships and the limited number of ships. Then an exact algorithm and a piecewise-linear approximation algorithm are put forward to solve the model. The proposed model can be applied to other shipping companies for schedule design.

2 - A game theoretic approach to improve compliance to sulphur regulations
Thalis Zis

The purpose of this paper is to develop a game theoretic modelling framework that improves the effectiveness of sulphur regulations enforcement. The existing legislative framework poses several challenges, stemming (mainly) from a highly non-homogeneous and spatially differentiated system, with cases where the penalty fines are as low as the benefit that the violator enjoyed from not complying. This paper presents the status quo of enforcement in different countries, where the regulation applies, and develops a game theoretic approach for a uniform violation fine system. A mixed strategy game with two players is proposed, representing the ship operator (who can choose to comply or not comply to the regulation), and an enforcement agency (that can opt to inspect or not inspect the ship) respectively. The equilibrium results in an improved penalty system (for both violators and enforcing agencies). Such a system can ensure a level playing field for ship operators that currently have invested heavily in an abatement of options to comply with the sulphur regulations, by promoting good practices among ship operators, while at the same time improve compliance rates and maximize societal environmental benefits. A discussion on the implications of the global sulphur cap of 2020 is concluding the paper, and recommendations for transferability of this framework to other regulations are provided.

3 - Real-time schedule recovery in liner shipping service with regular uncertainties and disruption events
Chen Li

This paper studies real-time schedule recovery policies for liner shipping under various regular uncertainties and the emerging disruption event that may delay a vessel from its planned schedule. The aim is to recover the affected schedule in the most efficient way. One important contribution of this work is to explicitly distinguish two types of uncertainties in liner shipping, and propose different strategies to handle them. The problem can be formulated as a multi-stage stochastic control problem that minimizes the total expected fuel cost and delay penalty. For regular uncertainties that can be characterized by appropriate probabilistic models, we develop the properties of the optimal control policy; then we show how an emerging disruption may change the control policies. Numerical studies demonstrate the advantages of real-time schedule recovery policies against some typical alternatives.

4 - The profit maximizing liner shipping problem with flexible frequencies: balancing economic and environmental performance
Harilaos Psaraftis, Massimo Giovannini

The literature on liner shipping includes many models on containership speed optimization, fleet deployment, fleet size and mix, network design and other problem variants and combinations. Many of these models, and in fact most models at the tactical planning level, assume a fixed revenue for the ship operator and as a result they typically minimize costs. This treatment does not capture a fundamental characteristic of shipping market behavior, that ships tend to speed up in periods of high freight rates and slown down in depressed market conditions. This paper develops a simple model for a fixed route scenario which, among other things, incorporates the influence of freight rates, along with that of fuel prices and cargo inventory costs into the overall decision process. The objective to be maximized is the line's average daily profit. Departing from convention, the model is also able to consider flexible service frequencies, to be selected from a broader set than the standard assumption of one call per week. It is shown that this may lead to better solutions and that the cost of forcing a fixed frequency can be significant. Such cost is attributed either to additional fuel cost if the fleet is forced to sail faster to accommodate a frequency that is higher than the optimal one, or to lost income if the opposite is the case. The impact of the line's decisions on CO2 emissions is also examined and illustrative runs of the model are made on three existing services.

■ TB-17

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S205

Applications of Stochastic Optimization

Stream: Stochastic and Robust Optimization
Chair: *Patrizia Beraldi*

1 - Stochastic optimization of simulation models: management of scarce water resources under risk and uncertainty
Alexei Gaivoronski, Giovanni Sechi, Jacopo Napolitano, Paola Zuddas

We consider a complex dynamical system, which depends on decision variables and random parameters. The state of this system evolves according to a set of complex rules, which may involve the solution of optimization or game theoretical problems. The evolution of the system over some time horizon is described by a simulation model implementing these rules. Some performance criterion is defined on the sample paths of this simulation model and we are interested in finding such values of decision variables, which yield the optimal expected value of this criterion, possibly under some risk constraints. On the software side, we show how stochastic gradient methods can be effectively employed in order to optimize complex simulation models and describe stochastic optimization solver STOGRAD, which implements these methods. This solver is specifically designed to handle optimization of simulation models, but it is not limited to them. We apply this methodology to the optimal management of water resources network in Southern Sardinia. This network consists of several interconnected reservoirs and operates under substantial uncertainty about water inflows and general scarcity of water resources. The purpose of this network is to satisfy several different types of demand: agricultural, industrial, public, observing at the same time certain environmental constraints.

2 - The capacitated supplier selection problem with total quantity discount and activation costs under demand uncertainty: exact and approximate approaches
Daniele Manerba, Guido Perboli

In the Capacitated Supplier Selection problem with Total Quantity Discount policy and Activation Costs (CTQD-AC), a company needs to purchase a certain quantity of different products from a set of potential suppliers offering discounts based on the total quantity purchased. The buyer company wants to minimize the total expenditure that satisfies its products demand, also considering the fixed costs needed to activate the business activities with the selected suppliers. We study the problem from a long-term perspective and thus consider the products demand as non-deterministic. Recent works have shown the importance of explicitly incorporate demand uncertainty in this economic setting, along with the evidence about the computational burden of solving the relative Stochastic Programming models for a sufficiently large number of scenarios. In this work, we propose different solution strategies to efficiently cope with these models by taking advantage of the specific structure of the stochastic problem. More precisely, we propose and test several variants of a Progressive Hedging (PH)-based heuristic approach as well as a more classical Benders algorithm. The results obtained on benchmark instances show how the proposed methods outperform the existing ones and the state-of-the-art solvers in terms of efficiency and solution quality. The PH, especially, achieves optimal (or very near-optimal) solutions for all the previously non-closed instances in a reasonable amount of time.

3 - A stochastic optimization model for healthcare facility network design in a disaster environment
Muge Acar, Onur Kaya

In a disaster situation, providing quick and efficient healthcare service for the patients is critical for the emergency response. In this study we analyze the location, capacity and service decisions for healthcare centers considering pre and post disaster response. This problem addresses critical decisions of governments and relief organizations for disaster preparedness, in designing health care network and improve quality of health care service for the affected patients. We introduce a network design problem considering demand and network uncertainities in the post disaster environment. We propose a two-stage stochastic programming model to maximize availability of service for patients in a short time period considering the locations and work loads of the health care centers. We also conduct numerical experiments to demonstrade the results of the model based on different scenarios.

4 - Risk averse management of virtual power plants using stochastic programming
Patrizia Beraldi, Maria Elena Bruni, Antonio Violi, Gianluca Carrozzino

In the last decades, the energy sector is facing significant changes because of the market liberalization, the increasing penetration of renewable sources and the deployment of smart technologies, such as distributed generation, smart meters, storage facilities and electric vehicles. The traditional centralized model of power generation and delivery through monopoly conditions is giving way, especially on a local level, to more diverse, dynamic, and complex systems with multiple actors. A novel trend is represented by the creation of Virtual Power Plants (VPPs), defined by the aggregation of distributed resources, (i.e. generation, storage, or demand) that are centrally operated in order to improve the technical and economic performance.

In this presentation, we address the problem of the optimal management of a VPP. In order to properly account for the uncertain nature of the main parameters involved in the decision process (demand, market prices, generation from renewable sources), we formulate a two-stage stochastic programming model that incorporates in the objective function the Conditional Value at Risk (CVaR) as risk measure to control potential losses caused by unfavorable events.

Computational experiments have been carried out on a real case study. The analysis of the numerical results clearly shows the effectiveness of the proposed approach as support tool in a real-setting.

■ TB-18

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S206

Theoretical Developments in Problem Structuring Methods

Stream: Soft OR, Problem Structuring Methods
Chair: *Leroy White*

1 - Constructing problems and choosing methodologies for complex decision contexts
John Mingers

Ever since the development of a range of soft OR methodologies in the 1970's and 1980's, there have been efforts to provide analysts and decision makers with tools or frameworks to help them choose which methods to use within a particular decision context. For example, Jackson's system of systems methodologies, Mingers' methodology maps or White's behavioural OR framework. The main weakness so far is that these tend to be too abstract - they identify very general dimensions of the context such as the degree of complexity, or the relationships between stakeholders in the situation - but do not get down to the level of the specific issue(s) that need addressing. On the one hand, within a problematic situation there may be a range of tasks to perform; on the other, methodologies have specific affordances and liabilities, some being quite general, others very specific. In this paper we aim to provide a framework or template for helping to choose methods more appropriately. What we shall seek to do is to articulate a range of functions or tasks that may be necessary throughout a particular intervention and which (generally soft) OR methods may be able to perform. Our theory-led framework lies between the two domains acting as a linking mechanism between them.

2 - Systemic risk analysis: analytical support to identify priorities from causal risk maps
Susan Howick, Colin Eden, Igor Pyrko

Recent research has shown that when assessing risk, taking account of the interaction between risks - risk systemicity - is important. This presentation reports on the development of a novel risk systemicity tool for use by cities across Europe. When developing the tool, one possible approach was to pay attention to risk systemicity through detailed research of past risk outcomes. However, such an approach can be expensive and data was not available, so there was a need to draw together judgment from a range of 'experts'. In this case the experts came from a number of European cities, who participated in a series of one-day workshops. This resulted in the development of a causal risk map that represented a risk systemicity network which was then broken down into risk scenarios (sub-systems of risks) to create the tool. When using the tool managers are required to make judgments about the likelihood of these scenarios occurring. However, after experts have judged that a range of risk scenarios are likely to occur, how should analysis of the network inform the prioritisation of mitigation planning? This presentation focuses on the different plausible analyses that could provide robust analytical support to help identify these priorities

3 - Integrating problem structuring methods and concept-knowledge theory for enabling collective decision-making process for policy design: some hints from Cyprus case study
Irene Pluchinotta, Raffaele Giordano, Dimitrios Zicos, Tobias Krueger, Alexis Tsoukias

Evidence suggests that policies aiming to manage environmental resources largely failed to achieve a sustainable use, mainly due to an over simplification, or in some cases even neglect, of the uncertainty and complexity associated with stakeholders' behavioral aspects. Complexity is due to the densely interconnected networks in which several decision-makers with conflicting objectives and different values systems operate. Uncertainty is caused by the unknown actions of other decision-makers involved in the network, making it difficult to predict whether the choices pay off or not. Ambiguity is a type of uncertainty that indicates confusion among actors in a group regarding what the possible issues or solutions might be. It reflects the multiplicity of interpretations that different actors bring to a collective decision-making process. This work describes a methodology based on integration between Problem Structuring Methods (PSM) and Concept-Knowledge theory (CKT) based tools, as means to transform ambiguity from a barrier to an enabling factor of collective decision-making processes. PSMs, and specifically Fuzzy Cognitive Mapping, are implemented to elicit and structure individual problem understandings, to detect and analyze differences among different stakeholders' concerns and interests. CKT framework is then meant to facilitate the alignment of the different problem understandings and available knowledge and to enable the creative process for developing innovation

4 - Strong RLT1 bounds from decomposable Lagrangean relaxation for some quadratic 0-1 optimization problems with linear constraints
Monique Guignard-Spielberg, Jongwoo Park

The RLT method of Sherali and Adams (1986) constructs a hierarchy of models of increasing sizes providing monotonically improving continuous bounds on the optimum of quadratic 0-1 optimization problems. To our knowledge, only results for bounds of levels 1, 2, and 3 have been reported in the literature. We are proposing, for certain quadratic 0-1 problem types, a way of producing stronger bounds than standard RLT1 bounds in a fraction of the time it takes to compute RLT2 bounds. The approach constructs a decomposable Lagrangean relaxation or decomposition of a specially constructed RLT1-type model. This two-step procedure, reformulation plus decomposable Lagrangean relaxation, produces linear Lagrangean subproblems with a dimension no larger than that of the original model. If the overall Lagrangean problem does not have the integrality property, and if one can afford to solve it as a 0-1 rather than a continuous problem, one may be able to obtain 0-1 RLT1 bounds of roughly the same quality as standard continuous RLT2 bounds in a fraction of the time. We present numerical results for several types of quadratic 0-1 optimization problems. This approach may make it computationally feasible to compute strong 0-1 RLT1 bounds for problem instances too large for computing standard continuous RLT2 bounds.

■ TB-19

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S207

Vector and Set-Valued Optimization VI

Stream: Vector- and Set-Valued Optimization
Chair: *Elena Molho*

1 - Metric subregularity of the diagonal subdifferential operator and applications
Rita Pini, Monica Bianchi, Gabor Kassay

We shed some light on the relationship between metric subregularity of the diagonal subdifferential operator associated to a bifunction, and some properties of the solutions of the related equilibrium problem. As applications, we prove first a calmness result for the solution map of a parametric equilibrium problem. Furthermore, we provide sufficient conditions entailing the existence of weak sharp efficient points of a multiobjective optimization problem.

2 - Limit vector variational inequality problems
Monica Bianchi, Igor Konnov, Rita Pini

We solve a general vector variational inequality problem in a finite-dimensional setting, where only approximation sequences are known instead of the exact values of the cost mapping and feasible set. We establish a new equivalence property, which enables us to replace each vector variational inequality with a scalar set-valued variational inequality. Then, we approximate the scalar set-valued variational inequality with a sequence of penalized problems, and we study the convergence of their solutions to solutions of the original one.

3 - Some duality results in set optimization with applications

Elena Molho, Elisa Caprari, Lorenzo Cerboni Baiardi

We prove an extension to set optimization of some classical strong duality results for scalar programs. For our results to be valid we require the cone-convexity of the set-valued objective and constraint functions. Moreover, each single image set of a given set-valued map should have an ideal maximizer. We aim at applying such a methodology to uncertain convex vector programs where both the objective and the constraint depend on uncertain parameters. The resulting analysis is limited to those uncertain problems where, at each given value of the decision variable, a single worst case exists and is comparable with all the other occurences of the parameters. Despite this restriction, the result can be applied to a wide variety of practical instances such as, for example, the case of interval-wise uncertainties, that includes multiobjective linear programs with interval coefficients. An application to a multiobjective supplier selection model is provided.

4 - Primal worst and dual best in robust vector optimization

Elisa Caprari, Elena Molho, Lorenzo Cerboni Baiardi

We consider a convex vector optimization problems where the objective and the constraint depend on uncertain parameters. We study the relationship between the robust counterpart of the uncertain primal problem and its uncertain dual problem. The relation involves the notion of optimistic counterpart where, in contrast with the robust approach, the decision maker faces the indeterminacy by assuming that the occurrence of the uncertain parameters are the most favorable ones. Beck and Ben-Tal (2009) proved that, for an uncertain scalar convex program, operating with a pessimistic view in the primal is the same as operating with an optimistic view in the dual (primal worst equals dual best). However, in the framework of uncertain vector optimization problems, the values of the uncertain objective at each choice of the decision variable individuate a set and the optimization of worst (and best) scenarios have an intrinsic set-valued nature. Following a set optimization approach, the set-valued images of the robust counterpart and those of the optimistic dual problem are compared according to a partial quasiorder among sets. Moreover, the analysis here considered is limited to those uncertain convex problems where, at each given value of the decision variable, a single worst case exists that can be compared with all the other scenarios.

■ TB-20

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S301

Decision Analysis Applications II

Stream: Decision Analysis and Decision Support Systems
Chair: *Miguel Martínez-Panero*

1 - The effects of operations analysis on the 5th generation aircraft design

Muharrem Tasyurek, Nurdinç Şenay

Today, space and aviation industry have become one of the locomotives of rapid progress in technology. Although it is anticipated that every new generation aircraft will be the last manned-aircraft in the sky, the fact that the evolution of artificial intelligence is not enough and that the system still needs to be man-in-the-loop can not realize this prediction in the near future. When it comes to designing a new generation aircraft, we face with the most expected problem: the requirement of meeting infinite needs with limited resources. Analysis are needed to make efficient use of these constrained resources. The realities of operation that will participate in the analysis will form the basis of decision support. Currently, the 5th generation aircrafts are the whole of the limited budgets that combine the autonomy, technology and art of warfare. Limited budgets consist of limited energy, limited fuel, limited space, limited time and especially limited monetary budget. Furthermore, the operarational side of the analysis to allocate these constrained budgets has to be given the first priority. In this study, we have concentrated on the two main operational concepts of the 5th generation aircraft to be developed: survivability and lethality. We did operational analysis to find the most efficient mixture of this main concepts while not exceeding the budgets mentioned above.

2 - When is information sufficient for action? Search with unreliable yet informative intelligence

Moshe Kress

We analyze a variant of the whereabouts search problem, in which a searcher looks for a target hiding in one of n possible locations. Unlike in the classic version, our searcher does not pursue the target by actively moving from one location to the next. Instead, the searcher receives a stream of intelligence about the location of the target. At any time, the searcher can engage the location he thinks contains the target or wait for more intelligence. The searcher incurs costs when he engages the wrong location, based on insufficient intelligence, or waits too long in the hopes of gaining better situational awareness, which allows the target to either execute his plot or disappear. We formulate the searcher's decision as an optimal stopping problem and establish conditions for optimally executing this search-and-interdict mission. The search for, and capture of, Osama Bin-Laden motivated the model in this paper.

3 - Multi-criteria ABC inventory classification using AHP method

Makram Ben Jeddou

The classical ABC classification is set according to the criterion of value in stock. It can also be set according to other criteria but considering only one criterion at a time, which is a limitation. The need to consider simultaneously several criteria pushed us in this article, to provide a multidimensional ABC classification based on the AHP method presented by Thomas L. Saaty. This method determines the weights for each criterion. Then they will be used to calculate a score for each item. These scores will be used to divide articles into three classes ABC. This approach was applied to a family of one hundred ten articles belonging to a company selling vehicle spare parts. In fact, the inventory manager used the ABC classification according to the only criterion of annual use value. This approach remains not sufficient for a more efficient inventory tracking. Thus, four criteria were considered during the ABC multidimensional classification, namely: the annual use value, the margin profit, the annual number of orders related to the item and the number of customers who bought the item. Some articles which appeared in the class A, in a unique-criterion classification, were demoted in class B or even C. Thus, rises the need to apply different rules for managing inventory tracking. In contrast, some items have been promoted in the upper classes, hence the need to grant them better monitoring and control.

4 - Communities of interest and the districting problem

Miguel Martínez-Panero, Verónica Arredondo, Teresa Peña, Federica Ricca

Political districting consists of dividing a territory into small areas called districts (or constituencies) in order to elect political representatives. Such division is intended to be neutral, in the sense that the district map does not favor any political party. To solve the political districting problem many authors have suggested models mainly taking into account criteria of population balance, spatial contiguity and compactness. In addition to these considerations, the "Erice Decalog" (unanimously signed by relevant researchers in this area in 2005) established in its eighth point that: "A system using electoral districts should respect existing communities of interest". To this aim, this contribution is concerned with optimization models to solve the political districting problem with a particular attention to such collectives sharing some kind of bond. In particular, we are interested in margining regions and minority groups whose strong presence should be considered in districting approaches. In practical terms, we will focus on the mixed-member electoral system of Mexico. Concretely, we are interested in the state of Chiapas, with a high proportion of indigenous population. A new districting model taking into account this issue will be presented and tested on these data.

■ TB-21

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S303

Convex Optimization

Stream: Convex, Semi-Infinite and Semidefinite Optimization
Chair: *Agnieszka Prusińska*

1 - Copositive approach to adjustable robust optimization
Markus Gabl

Adjustable robust optimization aims at solving problems under uncertainty in a first stage; the second stage decisions can be adjusted after uncertainty is removed. Hence, the objective is to identify the best solution among those which in any case allow for feasible adjustment of the second stage variables. Obviously there is greater flexibility than in a general uncertainty setting and thus less conservative strategies are viable. However, the computational cost rises, also for problems where the constraint-coefficients of the second stage variables are affected by uncertainty as well (uncertain recourse). This talk reports on resarch efforts (in progress) to approach these issues by applying copositive optimization techniques.

2 - A new fuzzy programming approach to solve bi-level decentralized multi-objective linear fractional programming problem
Tunjo Perić, Tihomir Hunjak

This paper presents a new approach to solve bi-level decentralized multi-objective linear fractional programming problem. Investigation of the possibility to find a simple algorithm with the high confidence of the decision makers into the results that the methodology gives, was the main goal of this paper. First we separately solve all the linear fractional programming models on the given set of constraints. Then we linearize and normalize all the linear fractional objective functions and form fuzzy multi-objective linear programming model that is solved as linear goal programming problem by using simplex algorithm. The efficiency of the proposed algorithm is investigated using an economic example, and the obtained results are compared with the ones obtained by some existing methods.

3 - Separable cubic model for solving smooth large-scale unconstrained minimization problems
Carmo Bras, José Mario Martínez, Marcos Raydan

Trust-region methods based in Taylor series is a class of methods that presents second-order convergence properties and has been modified in the last years with the addition of a cubic regularization term that penalizes the cubic power of the step length. Recently, the replacement of the cubic regularization term by a separable cubic term, after a suitable change of variables defined by the spectral decomposition of the Hessian, has proven to converge quite frequently to lower-function-value local minimizers. In this work, we extend the separable cubic modeling strategies in optimization to solve large-scale problems. As the employment of Newton-type ideas is prohibitive when the number of variables is large, we propose and analyze a specialized trust region strategy to minimize the cubic model on a properly chosen low-dimensional subspace, which is built at each iteration using the Lanczos process. The convergence analysis to second-order stationary points is established. Some preliminary numerical results are presented to illustrate the performance of the proposed scheme when solving medium and large-scale problems.

4 - Implicit function and tangent cone theorems for singular inclusions. Applications to nonlinear programming
Agnieszka Prusińska, Ewa Bednarczuk, Alexey Tretyakov

The contribution is devoted to the implicit function theorem involving singular mappings. We also discuss the form of the tangent cone to the solution set of the generalized equations in singular case and give some applications to nonlinear programming problems and complementarity problems.

■ TB-22

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S304

Many-Objective Optimization

Stream: Multiobjective Optimization
Chair: *Joao Duro*
Chair: *Robin Purshouse*

1 - Extreme point guided PICEA-g for nadir point estimation in many-objective optimization
Rui Wang, Jianmai Shi

Nadir point which is constructed by the worst Pareto optimal objective values plays an important role in multi-objective optimization. For example, the nadir point is often a pre-requisite many multi-criterion decision making approaches. Along with the ideal point, the nadir point can be applied to normalize solutions so as to facilitate a comparison and agglomeration of the objectives. Moreover, nadir point is useful in visualization software catered for multi-objective optimization. However, the computation of nadir point is still a challenging and unsolved open question, particularly, for optimization and/or decision-making problems with many objectives. In this paper, we propose an extreme point guided PICEA-g (e-PICEA-g) to estimate the nadir point. As the name says, in the e-PICEA-g the fitness assignment scheme in PICEA-g is modified by further considering the impact of extreme points. Loosely speaking, the closer the individuals to the extreme points, the higher the fitness of the individuals. Experimental results on many-objective optimization benchmarks with up to 30 objectives demonstrate the efficiency and effectiveness of the e-PICEA-g.

2 - Machine learning analysis of solutions generated by many-objective Pareto local search
Andrzej Jaszkiewicz

Many-Objective Pareto Local Search (MPLS) is a relatively recently proposed extension of the standard Pareto Local Search (PLS) for problems with more than two objectives. The standard PLS proved to be very efficient tool for bi-objective combinatorial optimization. However, the standard PLS becomes very inefficient for a higher number of objectives because the size of Pareto archive composed of potentially Pareto-optimal solutions grows very fast with the growing number of objectives. MPLS overcomes the weak points of PLS with the use of three new mechanisms. The first mechanism is the use of a new ND-Tree data structure for an efficient update of even large Pareto archives. The second mechanism is the selection of promising solutions for neighborhood exploration based on randomly selected scalarizing functions. The third mechanisms is the partial exploration of the neighborhoods. In this piece of work we apply MPLS to a many objective routing problem in a real road network. We generate a set of potentially Pareto-optimal solutions and use machine learning techniques to explore some valuable knowledge about characteristic properties of such solutions.

3 - Multi-objective optimization for distributed design of complex systems
Joao Duro

Multidisciplinary design optimization problems with competing objectives that involve several interacting components, can be called complex systems. Nowadays it is common to partition the optimization problem of a complex system into smaller subsystems, each with a subproblem, in part because it is too difficult to deal with the problem all-at-once. Such an approach is suitable for large organisations where each subsystem can have its own specialised design team. However, this requires a design process that facilitates collaboration, and decision making, in an environment where teams may exchange limited information about their own designs, and also where the design teams work at different rates, have different time schedules, and are normally not co-located. Each design team is also expected to satisfy multiple design criteria. The existence of dependencies, relationships or interactions between the subsystems thus makes it difficult to predict the behaviour of the entire system. In addition, the design of such systems is frustrated by conflicting demands when attempts are made to satisfy the multiple criteria of all of the subsystems simultaneously. This talk discusses the concepts of Pareto-optimality for systems that have been decomposed into multiple subsystems, each with a multi-objective subproblem. The promise, pitfalls, and the applicability of the existing distributed multi-objective optimization approaches are discussed in scenarios where collaboration is critical.

4 - Toolkit for benchmarking multiobjective robust optimization algorithms
Shaul Salomon, Robin Purshouse

Nothing is certain in this world, except for death and taxes. Since this reality has not been changed since the days of Benjamin Franklin, optimization of real-world applications should not only consider peak performance at nominal conditions, but also the robustness to various uncertainties. Optimization problems that consider the stochastic nature of the objective and constraint functions are tackled in the field of robust optimization. Several algorithms exist for solving robust optimization problems, but a framework for benchmarking them still needs to be established. This study presents a novel toolkit for generating scalable, stochastic multiobjective optimization problems. It enables to transform a deterministic benchmark problem into a stochastic one by replacing the objective vector with a random vector. The distribution function is described parametrically in a radial coordinates system, allowing to control the level of uncertainty based on the proximity to the true Pareto front, and to change it at different regions across the Pareto front. This can be achieved regardless of the number of objectives. Additionally, the uncertainty can be changed according to specific variables and objectives. Through direct control over the stochastic features, in addition to the 'conventional' challenges determined by the deterministic problem, the toolkit can be used to analyse algorithms for robust optimization in order to match them to real-world applications.

■ TB-23

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S305

Simulation in Management Accounting and Control

Stream: Agent-Based Simulation in Business and Economics
Chair: *Stephan Leitner*

1 - Cooperative behavior of Q-learning agents in a repeated Cournot oligopoly game
Christian Mitsch

Q-learning is a reinforcement learning technique, which comes from the field of artificial intelligence. In this paper, the agents learn optimal strategies by Q-learning in a repeated Cournot oligopoly game. Based on an agent-based computer simulation, four different scenarios are evaluated for a possible cooperative behavior among the agents. The cognitive abilities of the agents differ severely in the four scenarios. In principle, agents have a memory of the played history and are non-myopic which indicates how far ahead in time the agents look for rewards.

The reward function in the Q-learning algorithm is the profit which results from the Cournot oligopoly model. The agents' memory is determined by the agents' played action as well as the competitors' actions in the previous period. The action space consists of integer values and the choice of an action is made according to the Boltzmann distribution. The probability of action choice is set in such a way that the agents have enough time to explore for good strategies, but also time for exploitation strategies. In addition, the agents can communicate with each other during the simulation and they may form coalitions to jointly seek a better strategy.

The simulation results suggest that Q-learning agents generally learn to cooperate in an infinite Cournot oligopoly game, but they do not learn to yield the highest feasible joint profit.

2 - Analyzing the supplier structure in a buyer-supplier model over time: an agent-based model
Kristian Strmenik

Besides selecting suitable suppliers, the allocation of buyer's procurement volumes is one of the key issues in supply chain management when following a multiple sourcing strategy. In order to allocate the procurement volume different parameters, like price, quality, on-time delivery, etc. are employed in research. In this model the emphasis is put on the parameters quality and price which are weighted by the buyer to allocate the procurement volume to the suppliers. Further the model captures a supplier quantity-quality trade-off, which reflects the responsiveness of quality to changes in volume.

When varying the quality-price weighting within the simulation study from a highly homogeneous to a highly heterogeneous quality supplier setting the question arises, what impacts this has on the supplier market structure in a pre-defined observation period.

To answer this research question an agent-based simulation is conducted, which is an appropriate approach to study systems of heterogeneous and interacting agents (e.g., buyer and suppliers, interactions between suppliers, mutual effects of parameters). The first research findings suggest, that the allocation of procurement volume reacts more sensitively when more emphasis is put on price and that quality leading suppliers might be able to identify situations, when it pays off to submit an offer.

3 - Utility maximization under model uncertainty
Ariel Neufeld

We present a tractable framework for model uncertainty, the so-called nonlinear Lévy processes, and use it to formulate and solve problems of robust utility maximization for an investor with logarithmic or power utility. The uncertainty is specified by a set of possible Lévy triplets; that is, possible instantaneous drift, volatility and jump characteristics of the price process. Thus, our setup describes uncertainty about drift, volatility and jumps over a class of fairly general models. We show that an optimal investment strategy exists and compute it in semi-closed form. Moreover, we provide a saddle point analysis describing a worst-case model.

This talk is based on joint works with Marcel Nutz.

4 - An agent-based variant of the hidden-action problem: on the economics of reciprocity
Stephan Leitner, Friederike Wall

We transfer the standard (one-period) hidden-action model into a multi-period agent-based model variant of the hidden-action problem. The principal and the agent are modeled to be self-interest seeking, and both parties are endowed with (limited) memory and learning capabilities. At the same time, we limit the principal's and the agent's information on exogenous factors as well as their information on the action-space, which contains the set of possible effort-levels. The principal as well as the agent are, however, modeled to learn the limited pieces of information over time. In each timestep, the principal is modeled to be able to adapt the configuration of the contract which is offered to the agent. We put special emphasis on the analysis of the distance between the configuration of the optimal contract derived from the standard hidden-action model and the contract 'discovered' by the principal as well as on the resulting incentive effect for the agent. We find that, even though we model the principal and the agent to be self-interest seeking, there is a relatively large proportion of exerted effort which is higher than what can be considered optimal from the agent's point of view. For an external observer, it might appear as if the agent behaves reciprocally - we, however, show that this type of behavior is not motivated by reciprocity but is driven by the principal's and the agent's information deficiencies.

■ TB-24

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S306

Optimal Control

Stream: Optimal Control
Chair: *Stefan Wrzaczek*

1 - Gradient methods on strongly convex feasible sets and optimal control of affine systems

Vladimir Veliov

The talk will be based on a joint paper with Phan Voung that presents new results about convergence of the gradient projection and the conditional gradient methods for abstract minimization problems on strongly convex sets. In particular, linear convergence is proved, although the objective functional does not need to be convex. Such problems arise, in particular, when a recently developed discretization technique is applied to optimal control problems which are affine with respect to the control. This discretization technique has the advantage to provide higher accuracy of discretization (compared with the known discretization schemes) and involves strongly convex constraints and possibly non-convex objective functional. The applicability of the abstract results is proved in the case of linear-quadratic affine optimal control problems, and error estimates are obtained. A numerical example is given, confirming the theoretical findings.

2 - A sequential decision process with stochastic action sets

Adam Narkiewicz

The article proposes a normative model of dynamic choice in which an agent must sequentially choose actions in order to maximize her performance. Unlike in traditional models, the action sets are random. That is, for a given state history, instead of a known action set, there is a known probability distribution over action sets. For example, given the asset prices and portfolio history up to n-th period, the specific distributions of returns for the assets in the n+1-th period are known only after the n-th period. I prove that an optimal decision policy requires and agent to follow the maximum expected performance principle and that an optimal decision policy can be expressed as a function over state space, whose expected value the agent ought to maximize. I find necessary conditions for optimality in the general case, in a Markovian environment, and in a stationary environment. I also prove existence, uniqueness, and sufficient conditions for optimality under certain circumstances. I then apply these results to solve three problems. The first is a portfolio allocation problem in which a future pensioner tries to maximize probability of having a certain portfolio value at the time of retirement or tries to obtain this value as quickly as possible. The second is an optimal-foraging problem. The third is a problem in which an artificial agent is trying to find the quickest route in a dynamically changing graph.

3 - Optimal control of a continuous-time W-configuration assemble-to-order system

Mohsen Elhafsi, Jianxin Fang, Herve Camus

We analyze a W-configuration assemble-to-order system with random lead times, random arrival of demand, and lost sales, in continuous time. Specifically, we assume exponentially distributed production and demand inter-arrival times. We formulate the problem as an infinite-horizon Markov decision process. We deviate from the standard approach by first characterizing a region (the recurrent region) of the state space where all properties of the cost function hold. We then characterize the optimal policy within this region. In particular, we show that within the recurrent region components are always produced. We also characterize the optimal component allocation policy which specifies whether an arriving product demand should be fulfilled. Our analysis reveals that the optimal allocation policy is counter-intuitive. For instance, even when one product dominates the other, in terms of lost sale cost and lost sale cost rate (i.e., demand rate times the lost sale cost), its demand may not have absolute priority over the other product's demand. We also show that the structure of the optimal policy remains the same for systems with batch production, Erlang distributed production times, and non-unitary product demand. Finally, we propose efficient heuristics that can be either used as an approximation to the optimal policy or can be used as a starting policy for the common algorithms that are used to obtain the optimal policy in an effort to reduce their computational time.

4 - Using vintage structure for a multi-stage optimal control model with random switching time

Stefan Wrzaczek, Ivan Frankovic, Michael Kuhn

The paper presents a transformation of a multi-stage optimal control model with random switching time to a vintage optimal control model. Following the mathematical transformation the advantages compared to a standard backward approach are discussed. The paper closes with a simple example on a climate shock. The model is used to highlight the advantages of the approach, which are numerical solution, analytical insights and illustration of variables.

■ TB-25

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S307

Districting Problems: Models and Applications

Stream: Combinatorial Optimization II
Chair: *Ozgur Ozpeynirci*

1 - Mathematical model and grasp for the districting problem in home health care services in a rapid-growing Colombian city

Juan G. Villegas, Sebastian Cortes Zapata, Elena Valentina Gutierrez Gutierrez, Juan D. Palacio

Home health care (HHC) comprises a range of medical services provided at patient's home, and it is a growing segment in the global healthcare industry. HHC implementation offers several benefits including increased coverage of health services, improved patient's recovery and reduced overall hospitalization costs. In the HHC context, districting problems (DPs) arise at the planning phase when service providers seek to group small geographic basic units-BUs (i.e., city quarters) into districts with balanced workloads. In this work, we present a mixed integer-programming model that uses a flow formulation to ensure the contiguity of the resulting districts. Using this formulation, we solve small DP instances with up to 44 BUs. To solve large-scale instances with more than 50 basic units, we propose a greedy randomized adaptive search procedure (GRASP). In this metaheuristic, the greedy randomized phase expands in parallel a set of districts initialized from random seed UBs. Whereas the improvement phase relies on a variable neighborhood descend with two neighborhoods. The first one removes BUs from the district with the maximum workload, whereas the second one adds BUs to the district with the smallest workload. Using the proposed GRASP we solve a large-scale DP instance with 484 BUs faced by a HHC provider in Medellín-Colombia.

The comparison of the GRASP solution with the districting currently used by the service provider revealed a 46% reduction in the workload imbalance

2 - Political districting in Turkey: a proposal for more fair representation
Ozgur Ozpeynirci, Hayri Onal, Enver Yakın

We present an optimization model for the political districting problem in Turkey to improve fairness of the regional political representation. In the current system, each of Turkey's 81 provinces serves a district which all together elect 550 representatives. The districting rules require that each province must elect a minimum number of representatives regardless of its size. This results in an unfair distribution of representation among districts where many small provinces are over-represented while several provinces, especially those including large metropolitan areas, are highly under-represented. We propose a new districting scheme using a lower administrative level with more than 900 geographical units. In the proposed scheme, unity of provinces is kept to the extent possible, but administrative units in some small provinces can be combined with units in adjacent provinces when configuring district boundaries. Each of the 550 districts is comprised by a compact and contiguous subset of the 900 units and elects one representative in such a way that the sum of discrepancies from the average voter population across all districts is minimized. We evaluate the current and proposed systems with respect to different performance metrics including the fairness of representation. Our computational results show that the proposed system provides a considerable improvement in representation fairness across regions.

3 - Mathematical model for a taxi-carsharing service
Aleksandra Panyukova, Valentina Dudareva

The phenomenon of uberisation is characterised by the elimination or quasi-elimination of middle man roles. Disruption is seen as a threat to businesses due to the emergence of unlikely competitors. Many businesses and enterprises fail, as they cannot keep up with evolving market demands that being better met by continuous technological disruptions. Uberisation leads to significant drop of the prices, thus even businesses that adopted to new operation scheme using service providers become almost unprofitable while operating legally. Trying to gain minimally profitable result leads to overuse of actor's and company's resources that leads to loose in quality and safety. Such systems work now on rotation of employees/partner organizations that works only on amount of people and not scaliable at all. Thus there's idea to make a profit for service executors not from end users, but from optimization of associate processes. For example, make being a taxi driver useless as a profession (moreover it will come true with autopilot integration), but the way to spend time or optimize expences, or to gain exclusive benefits. Make taxi pools a way for utilizing suppresses of car production. Make the idea of a man driving the car maximum reusable in city infrastructure. There's an attempt to make such optimization real as a taxi-carsharing service in Russia. This work contains testing of ideas that could be a part of this service or could lead to deployment of such a service.

■ TB-26

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S308

Recovery and Congestion in Public Transportation Systems

Stream: Public Transportation I
Chair: *Esteve Codina*

1 - A routes-based heuristic for real-time railway traffic management problem
Ricardo Garcia-Rodenas, Maria Luz Lopez, Luis Cadarso

The real-time Railway Traffic Management Problem (rtRTMP) faces the disruptions and incidents in railway networks. The unexpected events perturb railway operations and generate conflicts in tracks and deadlocks. The rtRTMP obtains a new working timetable through routing, ordering and timing decisions.

The rtRTMP is formulated as a mixed integer linear problem. The main difficulty to solve it is the real time context that imposes a maximum computation time in the solution process. The rtRTMP considers a set of feasible routes for each train and optimizes (in this set) the route and the departure time for each train. The number of routes grows exponentially with the size of the network, for this reason, the number of routes to be used is restricted.

In this work we explore a heuristic algorithm based on routes for the rtRTMP. The key issues of this algorithm are: i) in an off-line context, a pre-processing stage of the set of feasible routes and ii) after that, a greedy interchange heuristic to optimize the departure times and routing decisions. The heuristic simulates what happens in real-time traffic management. In this procedure, the routing and scheduling decisions are assessed in the temporal order and they are possibly modified if the actual traffic conditions change from the planned ones.

2 - Energy consumption and passenger compensation policy in disruption management from a microscopic point of view
Luis Cadarso, Ricardo Garcia-Rodenas

In a railway network, incidents may cause traffic to deviate from the planned operations making impossible to operate the schedule as it was planned. In such a situation the operator needs to adjust the schedule in order to get back to the original schedules.

A train operator may have the policy of economically compensating (e.g., refunding ticket fare) passengers when they incur in delays. Compensation levels usually depend in the amount of delay. Therefore, it is important to have a smart way of deciding whether to speed up trains in order to absorb delays, i.e., increasing energy consumption, or to compensate passengers.

In this paper a mathematical model which decides on the speed profile while considering passenger use is presented. The model decides on the optimal sequence of operating regimes and the switching points between them for a range of different circumstances and train types all while considering delays and passenger compensation policies applied by the train operator. The objective of this paper is to minimize both energy consumed and incurred compensation to passengers. Constraints on traction and braking forces, on train velocity, on forces caused by vertical and horizontal track profile, and on passenger compensation policy are considered.

Computational tests on realistic problem instances of the Spanish rail operator RENFE are reported. The proposed approach is able to find solutions with a very good balance between various managerial goals.

3 - Effects of introducing a control delay in real-time railway traffic management
Sofie Van Thielen, Francesco Corman, Pieter Vansteenwegen

Train timetables are built such that trains can drive without any delay. However, in real-time, unexpected events can cause conflicts, i.e. two trains requiring the same part of the infrastructure at the same time. Such conflicts are resolved by dispatchers that have to take the impact on the rest of the network into account. Conflict detection and prevention tools can help them in making informed decisions. Real-time railway traffic management seeks for good, feasible solutions after unexpected events have caused trains to deviate from their original schedule. It includes train movement prediction, conflict detection and prevention. Very advanced techniques are already implemented in a decision support system (DSS) to perform train movement prediction and conflict detection. Therefore, some fast conflict prevention techniques need to be introduced that can easily be integrated in a DSS. Previous research has already introduced a very fast heuristic for conflict prevention that is capable of delivering solutions in less than 30 seconds. However, due to the real-time application, the introduction of a control delay is required, accounting for the fact that all trains continue driving while the heuristic is calculating. This research focuses on the introduction of such control delay that should make conflict prevention measures feasible in real-time and give dispatchers time to make a decision based on the proposed prevention measures.

4 - A transit network planning model integrating reliability and recoverability aspects
Esteve Codina, Francisca Rosell, Luis Cadarso

A network design model (RRND) is proposed at the strategic level although interactions between recoverability aspects at the tactical level are taken into account. It is formulated under a stochastic programming approach which include disruption scenarios of various levels (from complete breakdowns or segment blockings to delays of some relevance). To this end, a submodel for estimating the capacities/delays is integrated in a lower level. The influence of the level of disruptions and the reliability of the service is taken into account as a factor of the modal choice by users of the railway system. As a support, modeling of possible disruption scenarios will be carried out and probability models associated with the disruptions developed in previous works of the authors will be used. Disruptions will be treated in the following cases: a) partial duration disruptions, including a simplified modeling of the propagation of delays in the network and b) disruptions that entail a blocking of part of the network (segments or stations). Both in the case of partial or complete disruptions it will be assumed that the basic infrastructure of the network already exists. In this sense, the models will take into account the cases of single or double track and a simplified modeling of the types of blocking that can be applied will be carried out.

■ TB-27

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S309

Capacity Planning

Stream: Production, Service and Supply Chain Management
Chair: *Justus Arne Schwarz*

1 - Optimal supply contract for new product development with risk consideration
Guoqing Zhang, Shiping Zhu

Automotive supply chain is complex due to the large number of parts assembled into an automobile, the multiple layers of suppliers to supply those parts, and the coordination of the material, information, and finance flows across the supply chains. As a common ex-ante strategy in risk management, supply chain contracts play an important role for auto supply chain members. This research is motivated by one real-world challenging problem from an auto manufacturer. The objective of this research is to design a supply contract when developing new product in order to reduce the risks and maximize their profits under uncertainty demands. Based on the newsvendor model and Stackelberg game theory, we develop a supply chain model consisting of a supplier and a manufacturer with demand uncertainty for a product development contract. The analytical solution for the situation the demand follows an uniform distribution is developed, and computational tests are also reported. The proposed solution provides an effective tool for supplier-manufacturer contracts when the manufacturer faces high uncertain demand.

2 - Combined effects of price, process flexibility and modularity for reducing supply-demand mismatch
Nishant K Verma

One of the fundamental goals of any manufacturing firm irrespective of the industry is to minimize the supply-demand mismatches (SDM). To control SDM and the associated cost, firms use both the demand side (DS) and the supply side (SS) strategies. Considering that many firms use flexible capacity (SS strategy) and dynamic pricing (DS strategy) together to tackle SDM, one of the recent works (Ceryan et al., 2013) studies the same. They find that under the presence of flexible capacity the difference between the optimal prices of the products (2 product setting) remain constant when both the products are critically understocked. The result is of important consideration from the marketing perspective. Product prices are often used as a signal mechanism by firms to differentiate two products (quality difference) in their product line. Therefore, maintaining constant price gap over time is of great importance. This paper examines the dynamic pricing in the presence of flexible capacity and product architecture (SS strategy for reducing SDM). Unlike Ceryan et al. (2013) where they consider products as integrated in nature, we consider the products to be modular in nature. We also incorporate the notion of partial production postponement to make our analysis closer to the real world. We prove that in the presence of modular product architecture the price difference between the products remains constant for a larger state space region as compared to integrated product architecture.

3 - An integrated production scheduling and workforce capacity planning model and analyses for maintenance repair operations in the airline industry
Fatma Sedanur Ozturk, Kadir Ertogral

Maintenance, repair, and overhaul (MRO) activities for the airline sector are generally subject to regulations to ensure the safety and continuity of flights and the strict deadlines constraint overhaul activities. Several systems on aircraft are of so-called rotable inventory type. These expensive rotable modules are overhauled and used again. MRO companies usually perform exchange programs with customer airlines regarding the expensive rotable inventories. When an airplane comes for an MRO service involving rotable module, a ready-to-use from the inventory of MRO company is exchanged with the rotable module extracted from the airplane so that the service time for the aircraft is minimized. The extracted module is overhauled in the MRO shop with a limited workforce capacity and the overhauled module is rotated back to the inventory for a future exchange. We tackle the overhaul and exchange scheduling problem together with the workforce planning in this setting with the expedited overhaul option. We propose a mixed integer programming as a finite horizon planning model where we assume that there are multiple type rotables handled by the MRO company and we minimize the sum of inventory holding and workforce-related costs. Both the problem and its model are new in the literature. We show that this planning problem is strongly NP-Hard. We carried our extensive numerical tests on randomly generated problems and proposed some managerial insights based on the results obtained.

4 - Analyzing the impact of finite capacity on sales and operations planning for product rollovers
Justus Arne Schwarz, Baris Tan

A product rollover takes place if a product generation is replaced by a successor version. This occurs frequently in industries which are characterized by short product life cycles such as semiconductor, consumer electronics, and fashion. We focus on the questions whether and how the presence of limited production capacities drives the selection of rollover strategies and the underlying optimal decisions on production, sales, and price. We propose a deterministic two-period model of a profit-maximizing company. A vertical demand model is used to capture assortment based substitution and stock-out based substitution. The problem is formalized as a non-linear integer program. We provide explicit solutions for the unlimited capacity case and closed-form solutions for given rollover strategies for the finite capacity case with customers that are unwilling to substitute in case of stock outs. Numerical results are obtained for the general setting. We show that the selected limited production capacity drives the firm to offer the old and new product generations simultaneously. Moreover, a decreasing willingness to substitute in case of stock-outs can cause the postponement of the introduction of the new products. Finally limited production capacity can lead to increased discounts for the older product, i.e., a lower price.

■ TB-28

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S310

Service systems

Stream: Service Operations Management
Chair: *Oualid Jouini*

1 - Simulation analytics for emergency medical services
Yong-Hong Kuo, Janny Leung, Colin Graham

In this talk, I will present our collaborative project with an emergency department in Hong Kong on analyzing their patient flows and system efficiency. A simulation model that captures all complicating factors in reality (e.g., time and category-dependent arrival rates of patients, multiple shift-times of doctors and re-entrant flows to the many "service stations" of the system) has been developed to examine possible solutions that could relieve the overcrowding situation. I will discuss the challenge that several key types of data were unavailable such that the stochastic components in the system could not be directly estimated. Computational results show that our simulation model can produce results consistent with the actual observations. I will also discuss some insights, derived from the simulation results, into managing ED operations.

2 - Early registration of patients: an empirical investigation of scheduling of emergency surgery rooms
Santamaria-Acevedo Gustavo, Oualid Jouini, Benjamin Legros, Zied Jemai

Hospitals all around the world are facing challenges due to the increasing amount of patients arriving to their emergencies departments (ED) and in need of surgery. This, coupled with inefficiencies in the different hospital processes, generates longer waiting times and higher levels of congestion in the surgery blocks. An empirical investigation of the impact of the delay of patient registration on the patient's average wait time to find an available surgery room was conducted in one of the largest hospitals in France. Using the patient-level data of the time of registration from over 25,000 surgeries performed between 2010 and 2017, we find that delaying the registration process of a patient reduces the probability of finding an idle surgery room and of performing the surgery within the desired timeframe. A simulation study is conducted and used to propose different scenarios of surgery block configuration and scheduling options.

3 - A hybrid approach based on MACTOR and 2-tuple fuzzy linguistic representation for the analysis of the energy service company market
Ozgur Yanmaz, Cigdem Kadaifci, Umut Asan

Energy efficiency attracts many industries due to climate change, scarce resources, price fluctuations of energy resources and increase in demand for renewable energy. It is possible for firms to decrease their waste, costs, and emission levels by implementing energy efficiency activities. The complexity and expertise involved in these activities make them inevitable to be managed by energy service companies (ESCOs), which provide an inclusive service package to firms to deal with various difficulties in planning, implementing and monitoring their energy efficiency projects. The ESCOs face certain difficulties hindering the development of the energy service market because of legal and institutional barriers.

In order to provide a strategic tool to analyze alternative policies against the barriers in the market as well as the critical role of actors in this respect, the MACTOR method is utilized. As a common method used in scenario planning, MACTOR systematically examines the relationships between actors and positions each actor in relation to the strategic objectives. Since these assessments are based on expert judgments, it inevitably involves uncertainty. To represent the uncertainty and to obtain more realistic and representative results, MACTOR method is integrated with 2-tuple fuzzy linguistic representation. The effectiveness and applicability of the proposed approach is demonstrated by a case study where the energy service contracting market in Turkey is examined.

4 - A simulation-based method for shift scheduling in multi-channel contact centers
Siqiao Li, Ger Koole, Oualid Jouini

We deal with the allocation of labour resources overtime in multi-channel contact centres, which have multiple types of calls, emails and chats. Multi-skill agents with different skill sets are considered. The introduction of emails and chats makes a major challenge for staffing and shift scheduling due to the different service processes of emails and chats comparing to calls. Specifically, emails often do not need to be handled within the interval arrived, leading to interval-based staffing invalid. Multiple chats can be handled at the same time by an agent. The system becomes more complex when we consider multiple queues blended to be served by a multi-skill agent. As a result, a simulation-based algorithm is proposed to optimize the staffing and shift scheduling problem together under given service level requirements. In Contact Centers, service level usually means the percent of jobs that are served within the accepted waiting times. There are three steps in our algorithm: rapidly generating an initial solution through a linear programming, looking for the optimal agent-shift configuration using simulation-based heuristics and further minimizing the costs by removing some agents if service level requirements remain being met. We involve a lot of practical details in our simulation model, such as different costs of agents and considering backlog emails, etc. Various real-life scenarios have been tested in our method, outputting quite satisfying results.

■ TB-29

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S311

Solutions in Cooperative Game Theory

Stream: Game Theory, Solutions and Structures
Chair: *Juan Vidal-Puga*

1 - Bankruptcy with a variable number of agents and priorities
Miguel Ginés-Vilar

Characterization of the priority augmented proportional solution in the bankruptcy problem in terms of merging and sppliting axions.

2 - Allocating the costs of cleaning a river: estimating responsibilities versus incentive compatibility
Gómez-Rúa María, Jorge Alcalde-Unzu, Elena Molis

We model a river as a segment divided into subsegments, each occupied by one region, from upstream to downstream. The waste is transferred from one region to the next at some rate t. Given that t may be unknown, Alcalde-Unzu et al. (2015) proposed the UR method to allocate the costs of cleaning a river in which each region pays the responsibility that it would have if t was its expected value. We prove in this paper that this allocation differs from the expected responsibility of each region and propose and characterize a new solution, the EUR, that assigns to each region precisely its expected responsibility. We also provide an axiomatic characterization of this solution. We show that although this new solution improves the estimation of responsibilities, there is a trade-off in terms of incentive compatibility: meanwhile with the EUR solution it is possible that a region can reduce the cost allocated to it by discharging more waste, this could not happen with the UR. Moreover, the UR solution is, between the ones that do not have this problem in a general family, the solution that minimizes the bias w.r.t. the EUR.

3 - A panting rule in minimum cost spanning tree problems with multiple sources
Adriana Navarro Ramos, Gustavo Bergantinos

We study situations when a group of agents is interested in some service which is provided by several suppliers, also called sources. The connections have associated a cost and agents do not care whether they are connected directly or indirectly to such sources, but they want to be connected to all of them. This situation is a generalization of the classical minimum cost spanning tree problem where there is a unique source. Given a cost spanning tree problem with multiple sources, the first issue to solve is to look for the least costly connection (a tree) that provides all the agents with the resource. Such tree can be obtained, in polynomial time, using the same algorithms as in the classical problem. These algorithms have been extensively studied in the operational research literature. The second question we must answer is how to allocate the cost of the obtained tree among the agents. To address this issue, we extend the painting rule, a cost distribution rule of connection problems involving a single source, to this context. We prove that this rule coincides with the generalized folk rule and provide a characterization of the rule based on meaningful properties.

4 - One-way and two-way cost allocation in hub network problems
Juan Vidal-Puga, Gustavo Bergantinos

We consider a cost allocation problem arising from a hub network problem design. Finding an optimal hub network is NP-hard, so we start with a hub network h that could be optimal or not. Our main objective is to divide the cost of such network h among the nodes. We consider two cases. In the one-way flow case, we assume that the cost paid by a set of nodes S depends only on the flow they send to other nodes (including nodes outside S), but not on the flow they receive from nodes outside S. In the two-way flow case, we assume that the cost paid by a set of nodes S depends on the flow they send to other nodes (including nodes outside S) and also on the flow they receive from nodes outside S. In both cases, we study the core and the Shapley value of the corresponding cost game.

■ TB-30

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S312

Operations Research Games II

Stream: Game Theory and Operations Management
Chair: *Ana Meca*

1 - On sequencing situations with exponential and logarithmic cost functions
Alejandro Saavedra-Nieves, Peter Borm, Jop Schouten

Sequencing problems describe those situations where several jobs have to be processed on a set of machines. It is assumed an initial order for the jobs and each of them (an agent) have an 0associated specific cost function depending on its completion time. Zhao and Tang (2010) and Rustogi and Strusevich (2012) are examples of works where general scheduling situations are studied.

Cooperation in this class of problems can be analysed. Curiel et al. (1989), Hamers et al. (1995) and Borm et al. (2002) illustrate several sequencing situations with a single machine according to different criterias for the costs. In order to analyze them one must deal with two common issues: (a) identify the optimal sequence for the jobs, and (b) distribute the corresponding cost savings with respect to the initial order among the agents. Issue (b) can be approached using cooperative game theory.

In this work, sequencing problems where the exponential and logarithmic function determine the costs of processing of each job are analyzed. Under these assumptions, we obtain some results about the optimal order and analyze the cooperation through the convexity of the associated saving games describing these situations.

2 - The effect of regulation and uncertainty on the investment incentives in the broadband market
Soumaya Amassaghrou

In this paper we investigate investment decisions in NGA (next generation access) where access ADSL and Fiber networks coexist and are substitutes each other. An incumbent firm competes with an entrant firm. It is assumed that the entrant has access to the local loop (copper infrastructure). Overall, it is found that the level of the access fee fixed by the regulatory authorities determines investment decisions. Moreover, the grade of substitution between the two networks also influence investment decisions by altering the effect of the access price on the investment incentives.It is also shown that the duplication of investment does not constitute a Nash equilibrium and the duopoly model only provides two possible asymmetric equilibrium.

3 - Dynamic pricing, local and national advertising decisions in a supply chain under different leadership roles
Anshuman Chutani, Suresh Sethi

We study dynamic pricing and advertising decisions in a one-manufacturer one-retailer supply chain. We consider two types of advertising efforts, a national advertising effort carried by the manufacturer, and a local advertising effort by the retailer since the retailer might be better aware of local advertising media and customer preferences. The sales at any time depends upon the retail price and both types of advertising. We model differential games with different supply chain leadership roles, such as: a Stackelberg game with manufacturer as the leader, Stackelberg game with retailer as the leader, and mixed leadership game where one player is leader in pricing decisions whereas the other player is the leader in advertising decisions. In addition to their respective advertising decisions, the manufacturer decides wholesale price and the retailer decides either the retail price or its retail margin depending upon the leadership structure. We obtain feedback equilibrium in all the games and obtain insights on the optimal policies of the two players under different supply chain leadership roles.

4 - Multiple corporation tax games: the role of dual and irreplaceable benefactors
Antonio José Mayor Serra, Ana Meca, Jose A. Garcia-martinez

We present here a new model of cooperation in corporate tax systems with multiple dual and irreplaceable benefactors. They are dual in the sense they reduce the costs of both beneficiaries and other benefactors. They are also irreplaceable benefactors because all the members of a coalition may see their cost increase if one of them leaves the group. The class of TU cooperative games corresponding to this model is called multiple corporation tax games. We prove the grand coalition is stable in the sense of the core of multiple corporation tax games. Then, we propose the Shapley value as an easily computable core-allocation that benefits all agents and, in particular, compensates the benefactors for their dual and irreplaceable role.

■ TB-31

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S313

Behavioural Impacts in OR Practice

Stream: Behavioural OR
Chair: *Judit Lienert*

1 - A diagnostic approach to improve the design and evaluation of decision support interventions
Lisa Scholten

A range of decision support interventions are claimed to aid managers in solving complex problems. Due to a lack of systematic evaluation, it is difficult to say whether and why a certain intervention works in a given context. Claimed benefits often cannot be substantiated, hindering their uptake and impeding learning for more targeted intervention design. Building on theories of persuasion, Rouwette et al (2003, 2009, 2011) developed and tested a framework to evaluate the performance of facilitated group model building. Although conditions for persuasion were given, the variable combinations could not predict the observed changes. I adapted the framework aiming to improve operationalization for problem structuring and MCDA interventions. I added variables to capture behavioral and social aspects known to affect group collaboration and decision outcomes. When testing the resulting pre-/post assessment in a problem structuring intervention with 13 Dutch sewer managers, a surprise happened. Despite their prior agreement, the intervention was met with resistance and social dynamics unfolded that hindered its completion. In hindsight, the pre-assessment revealed issues that if considered for designing rather than evaluating the intervention might have avoided failure. I will present the approach and the insights gained as well as how these might be adapted for better diagnosis of the situation to inform intervention design and evaluation.

2 - Effects of or applications and characteristics of or practitioners: an empirical study
Violeta Cvetkoska

Management as scientific discipline allows people to work together and accomplish something they could not do as individuals. Those who lead the organizations are responsible for the results they achieve today, but they are responsible for this in the long run as well. Good measurement allows for seeing the real situation about where the organization is in relation to what it wants to achieve, but here it is always necessary to ask the question of how it can work better. The discipline of OR, through the application of models and methods helps managers in making better decisions, but it is not only about models and methods, but also about the people - the OR actors. The aim of the study is to investigate the effects of the application of OR in organizations in Macedonia and to determine the characteristics that OR actors, i.e. practitioners should have in order to be engaged by the organizations' management in solving OR problems. The empirical research has been conducted by a questionnaire for the top managements of state and private organizations in Macedonia, and the obtained results are presented and interpreted.

3 - How does literacy, decision style and loss aversion influence end-users' choice of electricity dynamic tariffs in a smart grid context?
Marta Lopes, Inês Reis, Carlos Henggeler Antunes

End-users are acknowledged as a key agent in smart grids as energy co-providers, actively managing energy resources (appliances, storage, microgeneration) and participating in emerging markets (energy, capacity ancillary services). In this context, end-users face complex decisions such as choosing suppliers and electricity tariffs, continuously deciding to buy, sell, store and managing loads based on prices, comfort requirements and generation through renewable energy sources. Therefore, understanding how they make decisions about energy has become a key area of research. Although supported by automated enabling technologies and feedback systems, in this setting end-users are exposed to vast amounts of complex information provided by energy stakeholders. The way this information is presented and framed directly influences end-users' decision-making process and therefore behavioural failures and heuristic decision making must be considered. This work presents the preliminary results of an exploratory study performed in Portugal using BOR to explore the influence of end-users' literacy (energy, numeracy and graphical), decision style (intuitive, rational) and loss aversion on the choice of electricity dynamic tariffs. These results are paramount shape policy guidelines on how to communicate energy related information thus promoting better decisions contributing to a more efficient energy system in which end-users gain a proactive role.

4 - To aggregate or disaggregate? Experience from stakeholder interviews with two preference elicitation philosophies (SWING-weighting, UTA-GMS)
Judit Lienert, Jun Zheng

Often, to elicit preferences in Multi-Attribute Value Theory MAVT, an aggregation philosophy is chosen: preference parameters are elicited separately (eg. weights) and then included in MCDA models to get a global preference. The disaggregation philosophy (eg. UTA-GMS) elicits global preferences on some reference alternatives and then infers MAVT model parameters. Applications of both are found in the literature. Practitioners of MCDA in real decisions need to know which to choose. We aim at empirically learning about the pro's and con's of the two paradigms using a very complex, real, and typical environmental wastewater decision. We carried out two interview sets with the same ten stakeholders. We elicited weights (SMART/SWING-variant) and value functions. Later, we used an interactive UTA-GMS design with pairwise comparisons of hypothetical reference alternatives. We selected a limited number of questions and inferred preference parameters with linear programming. We discussed the process and outcomes of both methods with stakeholders. Similar best-performing alternatives indicate method convergence and demonstrate that UTA-GMS is applicable to a very complex decision. However, claims that UTA-GMS is cognitively less demanding were not fully supported. We present insights regarding the required effort and the perception of the two methods by respondents and analysts. We also found strong support for the constructive nature of preference formation.

■ TB-32

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S314

Multimodal Transportation

Stream: Routing, Logistics, Location and Transportation
Chair: *Kris Braekers*

1 - Dynamic multimodal freight routing using a co-simulation optimization approach
Maged Dessouky

One of the challenges for freight transport efficiency arises from the fact that both freight and passenger traffic share the same infrastructure for moving people in addition to freight goods which leads to non-homogeneous traffic. This non-homogeneity has a detrimental impact on urban transport performance because of the differences of vehicle sizes and dynamics between passenger and freight vehicles. Without efficient management of the freight transport, the whole transportation network will face severe capacity shortages, inefficiencies, and load imbalances. However, route decision-making in a dynamical and complex urban multi-modal transportation environment aims to minimize a certain objective cost relying on the accurate prediction of traffic network states and estimation of route costs that are not readily available. We introduce a hierarchical routing system to solve the formulated freight routing problem when hard vehicle availability and capacity constraints exist. The simulation layer provides the state and cost estimation and prediction for the upper optimization layer in which we use a COSMO (CO-Simulation Optimization) approach to solve the formulated freight routing problem based on iteratively rebalancing the freight loads. A simulation testbed consisting of a road traffic simulation model and a rail simulation model for the Los Angeles/Long Beach Port regional area has been developed and applied to demonstrate the efficiency of the proposed approach.

2 - Integrating local drayage and network flow planning in intermodal transport
Hilde Heggen, An Caris, Kris Braekers

Decisions with respect to the network flow planning for long-haul transport and routing trucks in a terminal service area are usually considered independently in intermodal transport. The integration of vehicle routing problems into the intermodal terminal selection and long-haul routing decision throughout the network may provide important cost savings and a better utilization of the available transport capacity. Within the context of intermodal transport, vehicle routing problems for drayage are often solved after long-haul decisions have been made. We introduce a new, integrated problem and investigate the advantages of simultaneously considering drayage (VRP) and long-haul rail planning (network flow planning) decisions. Pick-up and delivery locations of inbound and outbound load units at customer locations are known while containers can be flexibly routed throughout the rail network. The problem considers full-truckload orders, time windows at customers and intermodal terminals, and detailed operational capacity considerations for the available rail services. Both forward and backward flows are included between two large-volume regions, which implies that the truck routing in each region includes both pick-ups of containers at customers to deliver at terminals and deliveries of containers picked up at terminals to customer locations. The aim is to provide insights in how to best utilize the current intermodal network in order to reduce the total transport cost.

3 - Revenue-driven operational planning: sea-rail multimodal freight transportation vs road transportation

Aysun Mutlu, Yaşanur Kayıkçı, Bülent Çatay

Multimodal freight transport developed in the transportation sector as an alternative to unimodal transport faced with the challenges brought by the growing global demand for transporting goods. Sea-rail multimodal freight transportation is an environmentally sustainable transport chain against road transportation; however, this environmental impact should be considered together with economic aspects in order to make multimodality more competitive in the sector. This study first provides an extensive comparison between sea-rail multimodal transportation and unimodal road transportation in terms of their advantages and disadvantages with respect to capacity, time, CO2 emissions, monetary and external costs, reliability and governmental paperwork issues. Next, it proposes a dynamic pricing approach to increase revenue considering different type of pre-defined customer classes and booking system. We develop a time-space diagram and formulate the sea-rail multimodal freight transportation problem as a linear network flow model. We present a case study of operational planning from multimodal transport provider's perspective to provide managerial insights about the advantages of multimodality and dynamic pricing strategy.

4 - Intermodal terminal selection and its effect on pre- and end-haulage costs

Kris Braekers, Hilde Heggen, Noah Crauwels

Intermodal freight transportation consists of combining different modes to transport freight without handling the goods during transhipments at intermodal terminals. Typically, the main leg is performed by train or barge, while pre- and end-haulage are performed by truck.

At a tactical decision level, intermodal transportation companies are facing an intermodal terminal selection problem. In each region in which they wish to operate, they should carefully select the terminals from which to offer long haul connections. One the one hand, offering services from many terminals in a region will result in fragmented transport flows and less economies of scale on the main leg, and a need to reposition empty load units within the region. On the other hand, offering services from one or a few terminals may restrict the number of long haul connections that can be offered and will result in increased trucking costs as the distance between customer locations and terminals increases.

In this work, we focus on the effect of the terminal selection decision on the resulting pre- and end-haulage costs, i.e. the trucking costs for transporting load units between terminals and final customer locations. Two approaches are considered and compared: a straightforward analysis of direct distances, and a more complex vehicle routing approach. Both loaded as well as empty container repositioning movements are accounted for. Results of a real-life case study are presented.

■ TB-33

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S315

Data Mining and Statistics V

Stream: Data Mining and Statistics
Chair: *Emilio Carrizosa*

1 - Spatio-temporal clustering and sampling with continuous density-based distance weights

Antonia Gieschen, Jake Ansell, Belen Martin-Barragan, Raffaella Calabrese

Analysing data over both space and time is an issue in various areas of application including health, marketing and public services. Based on the spatio-temporal clustering algorithm ST-DBSCAN, we describe a method of clustering spatial time series while taking into account varying data point densities across space in a continuous manner via density-based distance weighting. The resulting clusters can not only inform decision-making through a deeper understanding of spatio-temporal data, but also be used for representative sampling of data and the generation of synthetic data sets. Our method is developed using data from National Health Service (NHS) Scotland Open Data on drug prescriptions. Possible applications reach further, e.g., for retailers and public services striving for an increased understanding of their customers while, at the same time, being concerned about retaining anonymity of identifiable single-person data. Our results demonstrate how, and offer a solution for, the necessity of methods adaptive to varying densities when performing spatio-temporal clustering of data points over large spatial areas. Further research is planned to develop an approach that allows for changes in the size of considered spatial areas ('zooming'), as well as for changes in cluster composition and memberships over time.

2 - Probabilistic inference and evidence-based decision making with incomplete data

Jian-Bo Yang, Dong-Ling Xu

In this paper, we introduce a new Maximum Likelihood Evidential Reasoning (MAKER) framework as an integrated process of statistical data analysis, probabilistic inference and decision making. Data routinely generated from different sources is incomplete in nature and is characterised by various types of uncertainty including randomness, ambiguity, inaccuracy and inconsistency. This paper is focused on the analysis of incomplete data and how to use extended probability distribution to model evidence acquired from incomplete data and ambiguous judgement with the various types of uncertainty. The main components of the MAKER framework will be discussed in detail, including its main concepts, key features, evidence space model, state space model, conjunctive evidence combination algorithm, qualitative and quantitative prediction, and decision making processes. The MAKER framework can be used to support probabilistic modelling of complex systems, maximum likelihood prediction via probabilistic or transparent machine learning and evidence based decision making under uncertainty. A numerical example in medical diagnosis is used to demonstrate the main components of the MAKER framework. A number of cases in the areas of healthcare and engineering system maintenance decision making will be discussed to show its wide potential applications.

3 - Pattern analysis methods based on sorting algorithms

Alexey Myachin

The methodology of research of heterogeneity of economic, educational and innovative systems is proposed on the methods of pattern analysis basing on a pair comparison of the parameters of the initial sample of objects. The algorithmic realization is given and the complexity of the proposed methods is studied. The main advantage of the approach under consideration is the possibility of dividing the objects under study into similar subsets at a chosen measure of proximity, regardless of the indicators order in initial selected sequence. As other advantages, we point out the possibility of determining such a partition without determining the number and composition of finite groups of objects, the consolidation of similar in internal structure, but different in absolute values of the objects indicators (for example, if you need to combine objects A (100; 200; 300) and B (10, 20, 30)), as well as a low complexity that allows to work with relatively large amounts of data. Three different indices are proposed that characterize the heterogeneity of the systems under study. Some of their properties have been studied. The calculations of the proposed indices are made using the Global Innovation Index data, as well as the Russian regional innovation index.

4 - Evidential reasoning rule for sequential machine learning - an application to fault detection
Dong-Ling Xu, Jian-Bo Yang

Many machine learning algorithms normally assume that data are collected independently and identically from a system. In practice, however, data may be collected in sequence and the outputs of the system may be related to patterns embedded in the sequence. For example, when a fault happens in a system, it may not disappear until it is repaired. How to utilise such information in the sequence to improve the accuracy of a fault detection classifier? This paper explores how to apply the Evidential Reasoning (ER) rule to combine evidence provided by both feature variables and the sequential patterns in data to improve classification accuracy. The sequential patters cannot be utilised by many popular machine learning methods such as neural network. Due to instrument inaccuracy and malfunction, process and measurement noise, and absence of prior distribution, traditional Bayes rule based approaches are not applicable either. The ER rule extends Bayes rule's capability in three ways. It can handle missing elements in data, process imperfect data which is not fully reliable and constitute a likelihood inference process independent of prior.A data set collected from a real world pipeline operation is used as an example to illustrate the application process and the performance of the ER rule in sequential machine learning and classification.False and missed alarm rates are compared with those in previous studies of the data set that do not consider the sequential patters of the data.

■ TB-34

Tuesday, 10:30-12:00 - SOUTH BUILDING UV S113

Advances in Sustainable Supply Chain Dynamics

Stream: Sustainable Supply Chains
Chair: *Uğurcan Özden*

1 - Cyber-physical system application for sustainable supply chain management
Valentas Gruzauskas, Edita Gimzauskienė

Sustainable supply chain management has gained even more attention for the past few decades due to rapidly growing world population, increasing urbanization level and social responsibility trend. These trends require new approaches to minimize the length of the supply chain in order to reduce lead-time and maintain high quality and minimal management costs. However, the current supply chain management approaches require making trade-offs while making business decisions. The conducted scientific literature analysis identified that sustainable supply chain can be achieved through integration of organizational dimension and technological approaches. However, empirical evidence identified that supply chain collaboration mainly fails due to lack of strategies and collaborative technologies. Moreover, the majority of research analysis supply chain as separate elements and not as a whole system. Therefore, the authors of this research proposed a sustainable supply chain framework, which can reduce the necessity to make trade-offs in supply chain management. The framework proposes a supply chain strategy, which suggests how to use cyber-physical systems for complete automation of tactical and operational levels, while the automation is controlled through strategic level. The understatement of the novel supply chain management approach has been grounded through complexity theory, more specifically computer simulations have been used to provide validity to the proposed framework.

2 - Government's optimal inter-temporal subsidy in the presence of uncertain cost reduction and strategic consumers
Weichun Chen, Benny Mantin, Bo Li

We study a two-period monopolistic setting where a manufacturer sells environmental-friendly products to strategic consumers under government's consumption subsidy provided for consumers. We model the interaction among government, manufacturer and consumers incorporating with uncertain production cost reduction. The goal of this paper is to investigate the government's two subsidy adjustment policies: (1) committing the subsidy adjustment beforehand (commitment policy); (2) dynamically announcing the subsidy policy before each period (dynamic policy). Then the manufacturer dynamically decides the corresponding optimal price in each period and strategic consumers choose when to purchase. Our results show that from the social welfare perspective, the dynamic policy is better-off. The manufacturer can be better-off or worse-off under the dynamic policy. If the variance of cost reduction is very small and the cost-learning effect is higher than a certain level, then the commitment policy is better for the manufacturer. Note that the expected effective sales price (original price minus subsidy) is the same under both policies. Thus, for the consumers, which policy is implemented makes no much difference. In addition, we further analyze the impacts of consumer's network effect and the government's sales target.

3 - Exploring pricing and incentivisation policies in the management of a closed loop supply chain
Brian Dangerfield

Interest in the creation of closed loop supply chains in manufacturing has grown considerably over the past decade. The notion that used products (particularly in consumer electronics) can be either cannibalised or remanufactured and re-sold, alongside equivalent new products, has been underpinned by elements of corporate social responsibility together with regulations imposed by national or super-national bodies. Many manufacturing companies have come to appreciate that, far from being a drain on their resources, introducing a closed loop supply chain policy can be beneficial financially. However, in managing such a process, certain issues, which link with consumer behaviour, need to be confronted. Examples here are, for instance, to decide on the price of the remanufactured product vis-à-vis the equivalent new product; and to explore incentives which induce users with a product they wish to replace to prefer to return it rather than dispose of it in an uncontrollable fashion. It is shown how the management of these (and other) policy issues can be assisted by use of a system dynamics model of a generic closed loop supply chain.

4 - A blockchain platform for raw material stock optimization
Uğurcan Özden, Y. Ilker Topcu

Blockchain technology is the most attracted topic nowadays,mainly the usage cases in finance sector.However, the real value lies in supply chain usage cases to create a sustainable, customer oriented and most importantly environment friendly business infrastructure.A global consumer goods company deals with 1327 types of raw material and aims to lower inventory levels supplied by 17 companies.A decision support system (DSS) is proposed to develop raw material stock optimization model and it is implemented on Microsoft Excel to minimize raw material inventory levels considering perishability probabilities and component commonality indexes.Upon introducing demand forecast, bill of materials, finished goods' customer service level, minimum order quantity and supplier lead times;the DSS calculates raw material safety,cycle stock levels and the related supplier service levels.By implementing this DSS, as a Blockchain platform, to all levels of multi-echelon supply chain; the excess inventory resulting from bullwhip effect can be minimized due to the fast flow of information,the fast approval process and the security obtained by distributed ledger.Impact of the order penetration point (OPP) determination using ANP can be observed in the reduction of production lead times.OPP makes it possible to assess the critical production process, which enables production method to change from make-to-stock to make-to-order.Simulated 2017 raw material inventory cost is 5 Million Dollars less.

■ TB-48

Tuesday, 10:30-12:00 - 4D UPV B.3

Post-Disaster Relief Problems

Stream: Humanitarian Operations
Chair: *Andréa Cynthia Santos*

1 - An overview of the supply chain logistics with a limited autonomy vehicle problem

Ana Flavia Macambira, Pedro Henrique González, Hugo Barbalho, Luidi Simonetti

Humanitarian aid has been increasingly decisive in disaster situations. Operational Research has a lot to contribute in order to improve logistic operations in humanitarian disasters, especially in dealing with very limited resources and finances. In this context, the Supply Chain Logistics with a Limited Autonomy Vehicle Problem (SCLAVP), which deals with the decentralization of operationalization of the distribution of supplies, is presented. This problem can be described as: a vehicle leaves a base of operations, visits distribution centers and returns to the point of origin. Each existent direct path connecting origin and distribution center or pair of distribution centers is associated to a distance and a cost. The limited autonomy of the vehicle is related to the maximum distance that it can travel. Possibly not all distribution centers are visited by the vehicle. In this case, the distribution centers are attended by the closest distribution centers in distance and supplies are spread among them. Between pairs of distribution centers there are attendance costs associated. Being that defined, the SCLAVP aims at minimizing the total costs, composed by the costs associated to the distance traveled by the vehicle and by the costs related to the attendance occurred among distribution centers. In this work we define this new problem, that can be classified in the disaster relief problem category and present a mathematical formulation and a branch and cut algorithm.

2 - Models and algorithms for emergency road accessibility after major earthquakes

Celso Satoshi Sakuraba, Andréa Cynthia Santos, Christian Prins

Road accessibility is very relevant after large-scale earthquakes, when support is provided by rescue teams departing from source points as airports and harbors to population gathering areas. Several roads are damaged or blocked, and finding the best available paths becomes a complex task. In this work, this issue was separated into two problems, for which mathematical models are presented: The Road Network Accessibility Problem, that is to find the fastest repairable path (or an available one) from any source point to all destination areas; and the Work-troops Scheduling Problem, which consists of planning the operation of road repairing teams to create shorter paths for rescue teams to reach the population. Whilst the former can be solved by shortest path (SP) algorithms, we proposed heuristics to deal with the latter, which were compared to optimal solutions for small simulated instances. Using as criteria the number of time periods necessary to make all gathering areas accessible from some source point, the Lexicographic Classification Heuristic (LCH) obtained optimal solutions for 78 of 80 instances. The models and algorithms can be applied to provide solutions for large-scale graphs of urban areas. In experiments using the graph of Port-au-Prince generated from satellite images after the 2010 earthquake, LCH was able to find a work-troop allocation that decreased the total distance of the weighted sum of the SP to one third of its initial value. *Research funded by CNPq

3 - Heuristics for last-mile distribution in case of large-scale earthquake

Andréa Cynthia Santos, Puca Huachi Penna, Christian Prins

The chaotic last-mile distribution after major earthquakes is studied here due to its scientific and practical relevance. The Last Mile Distribution Problem (LMDP) was modeled in collaboration with partners of the International Charter on Space and Major Disasters. LMDP is a multi-attribute vehicle routing problem, including heterogeneous fleet, multiple trips, multiple depots, accessibility constraints, a time window on the depots working time, fixed and variable costs, and service time. These attributes rely on the following needs raised in the real context: (i) small and medium size vehicles (heterogeneous fleet) are used instead of trucks to allow accessing strongly affected regions by different organisations (NGO, humanitarians, Government, etc); (ii) multi-trips and multi-depot are required since on emergencies, vehicles are used in rotation to ensure continuity of the service; (iii) accessibility contraints are focused due to the different levels of routes' blockages after a quake. LMDP consists in determining multi-trips for each vehicle such that vehicles capacity, time window on the depots and demands are satisfied, such that the total costs (fixed and variable) are minimized. A heuristic framework is proposed, tested over past earthquakes and compared to the best methods for VRP with multi-attributes found in the literature. High quality results were obtained and validated by humanitarians, providing several insights for LMDP in practice.

■ TB-49

Tuesday, 10:30-12:00 - 4D UPV B.4

OR in Agriculture III

Stream: OR in Agriculture, Forestry and Fisheries
Chair: *LluisM Pla*

1 - Improving harvesting operations in an oil palm plantation

Daniel Castillo-Gómez, Mariana Escallon, Jorge Leal, Andres Medaglia, Carlos Montenegro

Oil palm agricultural systems involve large extensions of land that need to be harvested at the right time to maximize oil production in latter stages of the value chain. When the crops are ripe, each field of palms must be visited every ten days. This short cycle time puts the oil plantation under a lot of stress. To optimize harvest operations, the operations manager must synchronize multiple activities through a careful schedule of tasks involving human and animal resources, machinery, and transportation systems (tractors and cableway). To tackle this problem, we propose an end-to-end analytics solution involving data collection, predictive, and prescriptive models (optimization and simulation) in this complex and uncertain agricultural system. We present a case study in a 2,000-hectare oil palm plantation in the Colombian Orinoquia.

2 - Postharvest quality characteristics according to harvest time of strawberry 'Seolhyang' grown in Korea

SaeJin Hong, YoungRog Yeoung, Seong-Jun Kim, Jeong Hee Choi

Strawberry 'Seolhyang', which is cultivated about 80% or more in Korea, has excellent characteristics such as taste, texture, color and shape, but its flesh firmness is very weak and this makes storage and distribution of strawberry very hard. In order to overcome this problem, an early harvesting with postharvest ripening has been applied. The purpose of this paper is to study postharvest quality of strawberry according to the harvesting time. In the study, the harvesting time is examined with three levels. We harvest strawberries at the 70%, 80%, and 90% maturing levels and, after the postharvest ripening treatment, measure their quality characteristics in which firmness, soluble solids content (SSC), and color are included. The firmness ranges from 2.2 to 2.5 N which are corresponding to 122% and 139% of the firmness of fully matured strawberries. SSC is distributed from 8.0 to 8.2 oBrix and there is no significant difference. The color of strawberries is measured by Hunter L, a, b, and hue angles. Among them, Hunter a values of postharvest ripening strawberry are from 32.4 to 33.8 which correspond to 91.2% and 96.3% of the fully matured one. Our experimental results suggest that the proposed postharvest technique can satisfy market standards well and thus increase the shelf life of strawberries. In future, as the postharvest quality varied with temperature, statistical modeling and optimization for harvesting time should be conducted further.

3 - Design of silicon pads in the forced-air cooling treatment for harvested strawberries
Seong-Jun Kim, SaeJin Hong, Jeong Hee Choi

Several postharvest treatments have been applied to maintain the quality of strawberries harvested at high temperature and to improve the shelf life. Among them, forced air cooling (FAC) is widespread in the field of postharvest quality control. Harvested strawberries are quick to be decayed and their tissues are very soft. FAC is a technique to dry skin by forcing both temperature and pressure lower and it is useful for increasing the firmness and lowering the respiration rate. The purpose of this paper is to develop a new floor pad for improving FAC performance as well as to verify its effect on the postharvest quality of strawberry. In our experiment, the pad is made of silicon and three pads having the properties of 40N, 50N, and 60N are considered respectively. Each pad is tested at 5-6oC for 4-10hr. The quality is measured by firmness, color, and soluble solids content (SSC). Experimental results show that 50N pad provides the most stable quality and the lowest epidermal tissue damage. Conducting FAC improves the firmness by 1.33 times. In particular, by the padding, the firmness is increased by 1.41 times. However, in terms of the color and SSC, the effect of FAC and padding is relatively insignificant. Interestingly, it is found that the treatment of silicon pads is helpful in uniformly drying the skin of strawberries. Statistical interactions between the padding and FAC parameters should be explored for future design.

4 - Supporting fresh fruit purchase and storage decisions through a system based on a mixed integer programming model
Wladimir E. Soto-Silva, Marcela C. Gonzalez-Araya, LluisM Pla

A decision support system (DSS) to optimize purchasing operations, cold storage selection and fresh fruit freight trips is proposed. The developed DSS incorporates a mixed integer programming model and it seeks to facilitate fresh fruit supply chain decisions. Currently, these decisions are carried out independently and are not automatized. For this reason, the proposed DSS aims to support tactical planning of a fresh fruit company during a processing season. This DSS was implemented in a real case, showing that it is possible to reduce approximately 10% in costs per season and to make decisions with less time and effort.

■ TB-50

Tuesday, 10:30-12:00 - 4D UPV 1.1

Modeling Tools for Energy and Sustainable Policy I

Stream: Long-term Planning in Energy, Environment and Climate
Chair: *Sandrine Selosse*

1 - In decarbonizing the European electric sector - the role of interconnections
Seyram Siggini, Jerôme Gutierrez, Sophie Demassey, Edi Assoumou

During the recent years, renewable energy clearly appeared as an effective way to decarbonize the European production mix and then increasing levels of penetration of renewables are expected. High share of renewable then raise many questions over the behavior of electric systems. The intermittent production of solar and wind capacities affects the flexibility of the system i.e. its ability to respond to changes in power demand and generation. This also brings more concern on the system's adequacy. Differentiate programs at countries level towards CO2 reduction in the electric system noticeably increase the disparity between the production mixes and therefore bring up concern to the electricity flows within the European system. In this context, interconnections facilitate integration and permits to build a spatial aggregation. They constitute the perfect outlet for the surplus of energy generated within a country (inversely the perfect way to satisfy a lacking generation) but a question is still pending on their usage and the required capacities in the future with regard to the upcoming renewable penetration.

The aim of our work is to provide, through prospective modelling up to 2050, comparisions between possible production mixes in Europe, their implication on energy exchanges between countries and therefore give elements for reflexions on the cost effective way to achieve energy transition at the European level.

2 - Benefits of energy storage and transmission switching in power systems with high renewable energy penetration
Meltem Peker, Ayse Selin Kocaman, Bahar Yetis Kara

Increasing the share of renewable energy sources in electricity generation helps address the concerns about global warming and dependence on fossil fuels. However, high penetration of renewable energy sources into the power systems may affect the power system reliability and stability. To use these clean sources without endangering the power system, various control mechanisms such as energy storage systems, demand side management, renewable energy curtailment and transmission switching are utilized. In this study, we analyze the effect of transmission switching on the total investment and operational costs, sizing and sitting decisions of energy storage systems, and changes in the load-shedding and renewable energy curtailment amounts. An extensive computational study on the IEEE 24-bus power system with wind and solar as available sources demonstrates that total cost and total storage capacity can be decreased up to 17% and 50%, respectively, when transmission switching is used in the system.

3 - An optimization model for carbon capture & storage/utilization vs. carbon trading and its application
Semra Agrali, F. Gorkem Uctug, Burcin Atilgan Turkmen

We consider fossil-fired power plants that operate in an environment where a cap and trade system is in operation. These plants need to choose between carbon capture and storage (CCS), carbon capture and utilization (CCU), or carbon trading in order to obey emissions limits enforced by the government. We develop a mixed-integer programming model that decides on the capacities of carbon capture units, the transportation network that needs to be built for transporting the carbon captured, and the locations of storage sites, if they are decided to be built. Main restrictions on the system are the minimum and maximum capacities of the different parts of the pipeline network, the amount of carbon that can be sold to companies for utilization, and the capacities on the storage sites. Under these restrictions, the model aims to minimize the net present value of the sum of the costs associated with installation and operation of the carbon capture unit and the transportation of carbon, the storage cost in case of CCS, the cost (or revenue) that results from the emissions trading system, and finally the negative revenue of selling the carbon to other entities for utilization. We implement the model by using data associated with two coal-fired power plants located in different regions of Turkey. We choose enhanced oil recovery (EOR) as the process for carbon utilization. The results show that CCU is preferable to CCS if there is sufficient demand in the EOR market.

4 - The influence of carbon storage and biomass potentials in the future development of bioenergy with carbone capture and storage
Sandrine Selosse

The challenges of climate change involve rethinking the world's energy system. In particular, carbon capture and storage technologies are still presented as a solution to reach ambitious decarbonization targets, and particularly when associated with bioenergy resources. However, avoiding the required Gt of CO2 emissions by investing in CCS technologies supposes the development of carbon storage capacities and, when associated with bioenergy, an adequate and sustainable potential of biomass resources. This analysis, conducted with the optimization model TIAM-FR (TIMES Integrated Assessment Model, a bottom-up, long-term and multiregional model), highlights the role of these elements in the future development of the BECCS option. More precisely, based, on the one hand, on a specific methodology of biomass potential assessment, and, on the other hand, detailed data on storage potential, including onshore and offshore classification, this study aims to discuss whether such potentials may be a limit to the development of (bioenergy with) carbon capture and storage technologies. And at what extend. We thus investigate various scenarios with different levels of potentials and different climate targets on the long-term.

■ TB-51

Tuesday, 10:30-12:00 - 4D UPV 1.2

Modelling Challenges in Energy Systems Analysis

Stream: Environmental Sustainability in Supply Chains
Chair: *Mel Devine*

1 - Solving problems with equilibrium constraints with an application to energy markets

Sauleh Siddiqui

We provide a new set of complementarity-based algorithms for solving mathematical programs with equilibrium constraints and extend them to solve equilibrium problems with equilibrium constraints. We apply these algorithms to provide insights into energy markets with hierarchical structures. We conclude with policy insights and recommendations on how this approach can be extended.

2 - An augmented Lagrangian approach for solving the optimal generator placement problem in a transmission grid with a high share of renewable energies

Viktor Slednev, Manuel Ruppert, Valentin Bertsch, Wolf Fichtner

With an increasing integration of fluctuating renewable generation into power grids, the challenge to ensuring the security of supply with controllable generators increases. In this context, the necessity to consider grid restrictions for the generator placement decision is gaining in importance. For an adequate decision support, models are needed which are able to provide an N-1 secure optimal placement of generators under different grid load situations. In large-scale power system models the solution of such a problem requires new approaches as time-coupling constraints imposed by power storages increase the size of an already hard to solve N-1 secure optimal power flow (OPF) problem with binary special ordered set type restrictions for the generator placement. Based on a hierarchical augmented Lagrangian approach we are able to decompose the time coupling restrictions and solve the generator placement problem for smaller subsets of coupled hours. We demonstrate our approach for the German transmission in 2030 based on a DC-approach for the dynamic OPF. The increasing importance of an integrated European electrical network for the security of supply is addressed by embedding the problem within a European transport problem. Our results indicate a high sensitivity of the optimal generator placement depending on the grid load scenario, while the lack of dominating solutions for the entire time horizon emphasis the need for an advanced time-coupled optimisation technique.

3 - Justification for the use of a dynamic gas flow formulation

Andreas Belderbos, Erik Delarue

To investigate increasingly volatile gas flows, a novel dynamic gas flow formulation is presented in the literature which is less computational intensive than transient flow calculations. This dynamic gas flow formulation combines elements from both transient and steady state flows. The aim of the current study is to justify the use of such dynamic flow formulation by verifying the physical feasibility of the results obtained with such model. The dynamic flow formulation allows the injection and off-take in a pipeline to be different, and to vary through time. However, to calculate the flow thourgh a pipeline resulting from a certain pressure difference between inlet and outlet, a steady state flow is assumed. Since inlet and outlet flow are allowed to be different, the pressure drop over the pipeline is linked to the average of inlet and outlet flow. Given an imposed, time varying, flow and pressure at inlet or outlet, the resulting flows and pressures from this dynamic flow formulation can be verified using a second detailed model which captures all transient effects. Using the transient model, it is shown that the dynamic flow formulation is able to accurately model the pressures in and flows through a give pipeline in most situations. Only when large instantaneous changes in injection or off-take flow occur, the dynamic model underestimates slightly the resulting pressure swings in the pipeline, with diviations up to 1% of the pressure calculated using a transient model

4 - Modelling the impact of demand response on different electricity markets: results and issues

Mel Devine, Valentin Bertsch

Energy systems based on renewables have an increasing demand for flexibility. In this work, we consider the role of demand response (DR) as a source of flexibility. The majority of research on DR to date has focussed on the operation of power systems in energy only markets, mostly using deterministic models. In contrast, we explore the impact of DR on generator investments and profits from different markets, on costs for different consumers from different markets, and on CO2 emissions whilst also considering the stochasticity associated with RES generation. We present a stochastic mixed complementarity problem that considers both operational and investment decisions and considers interactions between an energy market, a capacity market and a feed-in premium. We use a Benders decomposition algorithm to reduce the computational burden of the model and apply the model to the Irish power system. Both a perfect competition (PC) and an oligopoly with competitive fringe framework are considered. However, modelling the latter, in the presence of both an energy and capacity market, leads to modelling issues which we detail in this talk. Under a PC framework, we find that DR increases renewable generator profits. While DR may reduce consumer costs from the energy market, these savings may be (over)compensated by increasing costs from the capacity market and the feed-in premium. This result highlights the importance of considering such interactions between different markets.

■ TB-52

Tuesday, 10:30-12:00 - 4D UPV 1.3

Healthy Diets

Stream: OR for Health and Care I
Chair: *J.c. Gerdessen*

1 - A mathematical model to establish an optimal diet in Spain following Mediterranean standards

Monica Hernandez, Trinidad Gomez, Laura Delgado Antequera, Rafael Caballero

Latest data shows how the Spanish consumption habits are differing from the traditional Mediterranean diet, which is widely supported by different nutritional experts. So, this research proposes a model to design diets which fulfill the minimum nutritional requirements established by the WHO, and conform the Mediterranean standards, while considering a basic budget and, at the same time, staying as close as possible to the current Spanish consumption habits. In particular, an Extended Goal Programming model is developed, which is solved using MatLab software, obtaining different proposals. These proposals represent alternative food baskets corresponding to the daily intake that an adult in Spain should consume, obeying the nutritional recommendations and the Mediterranean patterns, with minimum changes on the food habits and an affordable budget. The used database has been obtained from Panel de Hogares, Spanish Ministry of Agriculture, Food and Environment.

2 - Diet optimization for vulnerable groups in Ecuador

Fernanda Salazar, Sandra Gutierrez

In this study, we consider the nutrition of two important vulnerable groups in Quito: elderly and children up to 3 years. Even though the concept of a good diet is clear, the process of getting such diet via optimization models is different for both groups. We have constructed linear integer models with the aim of generate diets of minimum cost that not only fulfill lower and upper bounds of nutrients but also ensure that the intake of nutrients is balanced and appropriate for each group. For the elderly, the daily nutritional requirements depend on the individual's basal metabolic rate and it's health condition. Since it is usual that they have several diseases at the same time and that, in turn, changes the nutritional recommendations, the parameters in the model vary for every patient. The health scenarios considered here are: No Diabetes, Only Diabetes, Diabetes and obesity and Diabetes and hypertension. Currently, the model is being used as a first approximation of the recommended diet for outpatients at an specialized hospital. For the second case, the study was carried out in the government day-care centers, in Quito. Conceptually, the model is the same as the previous one. Here, the nutritional recommendations are standard, however we consider no restrictions on the type of food that children can consume which makes the problem hard to solve. We have obtained an heuristic for the problem. We present computational results for both groups and conclusions.

3 - Recommending healthy meal plans using a many-objective optimization approach

Cumali Türkmenoğlu, A. Sima Etaner-Uyar, Berna Kiraz

In today's world, healthy eating is a very important issue affecting a large proportion of the population. In this study, we propose to extend the classical diet problem formulated by Stigler in 1945 and model it as a many-objective optimization problem. In our model, the objectives are inspired from the foraging behavior of animals and take into account user preferences as well as cost, while satisfying the recommended daily nutrient intake constraints for a user's gender and age group as defined by the USDA. Inspired by the animal foraging theory, the proposed many-objective diet problem has several objectives, such as: minimize cost, maximize user's liked foods, maximize availability of ingredients, minimize meal preparation times, maximize variety in meal plans. For making meal plan recommendations, a database containing complete recipes (like "cream of mushroom soup"), as opposed to individual food items (like mushroom), is used. Therefore, the recommendations become more realistic meal plans, which in turn make them more applicable by the users. As far as the authors know, this is the first study that models the diet problem as a many-objective and multi-constraint optimization problem and solves it using modern meta-heuristics such as many-objective evolutionary or ant-colony algorithms to make healthy meal recommendations. Thus, the study can have an academic impact as well as a social one by helping people stay healthy through eating healthy meals.

4 - Synergy between OR and nutrition research: decision-making in dietary assessment and advice

J.c. Gerdessen, G.D.H. (Frits) Claassen, Jack van der Vorst, Pieter van 't Veer

Unhealthy diets contribute substantially to the worldwide burden of non-communicable diseases, such as cardiovascular diseases, cancers, and diabetes. Globally, non-communicable diseases are the leading cause of death, and numbers are still rising, which makes healthy diets a global priority. In Nutrition Research, two fields are particularly relevant for formulating healthier diets: dietary assessment, which assesses food and nutrient intake in order to investigate the relation between diet and disease, and dietary advice, which translates food and nutrient recommendations into realistic food choices. Both fields face complex decision problems: which foods to include in dietary assessment or advice in order to pursue the multiple objectives of the researcher or fulfil the requirements of the consumer? We demonstrate the use of OR to improve decision-making for dietary assessment and advice, specifically for designing food frequency questionnaires and for modelling various ways in which multiple nutritional characteristics of a diet can be aggregated into an overall indicator for diet quality. We also show how the interaction with Nutrition Research contributes to model building and solving in OR. Considering the added value for Nutrition Research and the new models and solutions generated, we conclude that the combination of both fields has resulted in synergy between Nutrition Research and Operations Research.

■ TB-53

Tuesday, 10:30-12:00 - 4D UPV 1.4

Big Data, Social Media, and Personal Data

Stream: Operations/Marketing Interface
Chair: *José P. Garcia-Sabater*

1 - Big data vs small data: consumer profiling with data requirements

Jiahua Wu

We consider a model where a monopolist can profile consumers in order to price discriminate among them, and consumers can take costly actions to protect their identities and make the profiling technology less effective. A novel aspect of the model consists in the profiling technology: the signal that the monopolist gets about a consumer's willingness-to-pay can be made more accurate either by having more consumers revealing their identities, or by spending larger amounts of money on third-party complementary data or data analytics capabilities. We show that the optimal investment level of the monopolist is closely related to the flexibility of consumers to conceal their identities as well as to data requirements. In particular, a higher (lower) data requirement is an instance when more (less) consumers are required to achieve the same signal precision. For a given data requirement, we show that a smaller investment is required to achieve the same level of accuracy when it gets more difficult for consumers to conceal their identities, leading to a higher profit for the firm. Consumer surplus and social welfare are instead non-monotone in the ability of consumers to conceal their identities. Surprisingly, the firm's investment is not monotone in the level of data requirement, where investment is the greatest when data requirement is moderate. We also show that the monopolist has a tendency to invest excessively.

2 - Economics of free mobile applications: personal data

Vincent Lefrere

In the market for smartphone applications, the majority of apps are zero priced. To generate revenue, developers have to monetize theirs apps, however little is known about their monetization strategies. The theoretical literature underlines the importance of personal data for Internet companies' strategies but the importance of personal data in the smartphone applications market remains relatively unexplored. We provide empirical evidence of the monetization strategies related to free apps by studying how the collection of personal data is combined with more traditional revenue sources such as advertising and in-app purchase. We have unique data to measure how apps are monetized based on information related to 475,867 free applications available on the Google Play platform combined with data on applications' privacy-related behaviors provided by PrivacyGrade. Among the apps in our dataset, 9% collect personal data and use no other monetization strategy. Social networking and utility third parties are used largely by apps that rely on personal data as a monetization strategy. Apps with more than 1 million downloads rely more on personal data.

3 - STEM and teens: an algorithm bias on a social media

Clara Jean

We study whether online platforms might reproduce offline stereotypes of girls in the STEM disciplines. The article contributes to work that aims to shed light on the possible biases generated by algorithms. We estimate the effect of ad distribution via a field experiment. We set up a randomized online ad campaign on a popular social media platform on behalf of a French computer science engineering school. The treatment aims to estimate whether a message aimed at prompting girls is displayed to girls more than to boys. The ad campaign targeted students in high schools in France. Our results show that on average, girls saw 25 fewer impressions than boys; this difference in the number of impressions is not attributable to the less expensive cost for girls. The treatment ad which was aimed to display to more girls had a crowding-out effect, since overall, it was displayed less to both boys and girls.

4 - Distributed programming production planning with a shared capacity coordinated by a Lagrangian relaxation model on a rolling horizon
Gregorio Rius-sorolla, Julien Maheut, José P. Garcia-Sabater

A challenge of operations management is to align activities within their product or service value chain. Such a supply chain can include both inter-organizational and intra-organizational members and each member generally has its own objectives and limitations. Management must establish adequate coordination mechanisms, despite the asymmetry of information, so that the chain as a whole can be competitive in the face of possible market situations. In addition, in situations where its members may be competing in different supply chains and have available capabilities. This document analyzes the proposal of sharing a resource among these organizations in their behaviour in different situations of demand, uncertainty, product complexity, etc. It identifies a competitive improvement for all members, both in the use of excess capacity and in their production planning. For this, we have applied a distributed coordination mechanism for mathematical programming models with independent objectives, based on Lagrangian relaxation on a Generic Material and Operation Planning formulation on a rolling horizon which only share their available capacity, to a sufficiently broad repertoire of instances of multiple situations that allows the presentation of conclusions.

■ TB-54

Tuesday, 10:30-12:00 - 4D UPV 1.6

Sport Strategy Optimization

Stream: OR in Sports
Chair: *Susanne Hoffmeister*

1 - Optimizing a golfer's strategy with MDPs
Matthieu Guillot, Gautier Stauffer

The goal of a golfer is to put a ball in a hole in a minimum number of shots. Each time the golfer hits the ball, he has to decide upon which club to play and which target to aim at. As the player does not always play perfectly, the ball does not necessarily ends exactly where it was expected. Weather conditions and obstacles on the field can also disturb the theoretical trajectory of the ball. The golfer is facing a decision problem which can be modelled as a special type of total cost undiscounted MDP, called the stochastic shortest path problem. This is a natural extension of the deterministic shortest path problem whereby traversing an 'arc' may now lead to several destinations with different probabilities. In this setting, vertices are called states and arcs are called actions. The goal is to decide in each time step and each state which action to take in order to converge to a predefined target with probability one over an infinite time horizon. Taking an action has a cost and we wish to find a policy that minimizes the average cost over all possible realizations. We implement the standard algorithms to solve exactly the problem, and a new algorithm inspired by Dijkstra's algorithm from deterministic case of the problem. We ran tests on elite worldwide golfers by modeling their statistics with a database of shots they made in professional tournaments over the past thirty years. We compare the computational performances of our differents methods on these real datas.

2 - Optimizing strategic substitution in soccer
Jörg Rambau, Rónán Rian Carl Richter

Consider yourself as the coach of a soccer team. You are in the lead, and the final 15 minutes of the match are about to start. Should you take out a striker and send a fresh defensive player onto the field? In this talk, a two-scale Markov Decision Process model (2MDP) is presented that captures the most basic aspects of this strategic question. In contrast to pure statistical methods to validate the historic success of various decision rules, the 2MDP approach strives to provide a-priori decision support for a particular situation depending on the individual skills of the players involved. Such an approach was first applied to beach volleyball by Hoffmeister and Rambau. A formal generalization of the 2MDP concept is explained in the subseding talk by Hoffmeister in this session. In this talk on research in progress, based on Richter's Master's thesis, the first 2MDP modeling a strategic question in a team game with time-based duration is explained. Moreover, preliminary numerical results on artificial data are presented.

3 - Decision-making in sport's annual planning
Sarka Krizkova, Martin Gavalec

The domain of sports offers an excellent opportunity for studying decision making, for many reasons. Within the topical scope of sports decision-making, there are many different decision agents (coaches, players), tasks (training plan, in-game decisions) and contexts (during play or breaks). This provides the chance to examine a variety of interesting designs. Although there is no standard type of decision in sports and badminton is a great example because it is one of the most complex sport in the world. Based on investigations, this paper suggests the use of fuzzy theory to increase the impact of decision making. It is generally accepted that sports performance is governed by a complex interaction of variables, such a psychological fitness, psychological preparedness, physical development, biomechanical proficiency, and tactical awareness, amongst other (nutrition, genetics, general health and wellbeing, sociocultural factors, etc.). One of the most important problems the sportsman faces is the training plan. The purpose of a training plan is to identify the work to be carried out to achieve agreed objectives. Goal setting is a simple, yet often misused motivational technique that can provide some structure and give focus. This article provides benefits of using fuzzy theory while decision making within sports. Support of the Czech Science Foundation GAČR 18-01246S is gratefully acknowledged.

4 - Markov decision processes for sport strategy optimization
Susanne Hoffmeister, Jörg Rambau

We introduce a generalized framework of Markov Decision Processes suitable for sports games. The objective of these so called Sport-Strategy Optimization Markov Decision Processes (SSOMDPs) is to maximize the probability of winning a match. We investigate properties of SSOMDPs that help to determine an optimal strategy. However, there remains always the question on which level of detail a match should be modeled by an SSOMDP. We show how the same sports game can be modeled on different scales and how the advantages of different scales can be combined. This talk focuses on the generalized concept of the two scale approach and includes example models for the sport games Beachvolleyball and Tennis which were components of previous talks.

■ TB-55

Tuesday, 10:30-12:00 - 4D UPV 2.1

Lost in Translation

Stream: Making an Impact I
Chair: *Joaquim Gromicho*

1 - Lost in translation: expectations and misconceptions
Joaquim Gromicho

Probably we can all relate to this: while discussing we seem to agree, but we each have a slightly different thing in mind. This is fine if we are just having a cheerful chat at the bar; or even for a research endeavour: the starting vision may differ from the end results but all involved parties still be happy and proud of the achievements. But what if we are to deliver a product that is going to be used? What if the expectations lead to deceptions? If a deliverable is a physical device one can be sure about the way to interpret the specifications; and if one is delivering a well known type like a building, a bridge or a vehicle then there are many examples to relate to, so all parties probably expect the same outcome. However, OR consultancy shares the glory of being innovative with the curse of laying the first step. The chance that the involved parties share the same vision is much smaller.

To make things worse, the actors involved bring to the table different knowledge. Those involved in the business take rules for granted and those developing the solution produce models where rules are either present or not, they cannot be just assumed. We may therefore produce the optimal solution to the wrong model: neither feasible nor attractive to the customer.

This workshop aims at exchanging experiences and lessons learned to help each other manage expectations and avoid misconceptions. A good solution to the right problem seems much harder to find than we might expect!

■ TB-56

Tuesday, 10:30-12:00 - 4D UPV 2.2

Optimization in Renewable and Energy Systems I

Stream: Optimization in Renewable Energy Systems
Chair: *Ayşe Mutlu Derya*

1 - Cost effective electrical public transport network design

Jeroen Vester, Shadi Sharif Azadeh

Recent innovations in battery technology allow for public transport buses to be battery-driven and recharged at distinguished stops, rather than powered by catenaries. Various trial-projects have proven its feasibility for operation and its significant role in gas emission control in urban areas. Creating a network of electrical catenary free public transport system is very costly due to their battery usage and installing high tech charging stations. In recent years, several papers have addressed designing such networks from technological as well as operational aspects. For such systems, battery degradation is impacted by the operational decisions. Maximization of battery life is crucial. In this paper, we introduce a linearized battery degradation incorporated inside an MILP for such electrical public transport systems. Two commonly used approaches are applied for designing a Multicriteria Optimization Problem, weighted sum and epsilon-constraint. Charging and discharging show a non-linear behavior, but in current models are assumed to be linear. A more accurate representation of this behavior is proposed and incorporated in the model. A case study is carried out on semi-real data, based on real-life situations, to compare the impact of incorporating battery aging on the costs with results of a model without battery degradation minimization. Also the impact of a more accurate representation of (dis)charging behavior is evaluated.

2 - Common effluent treatment plants locations allocation modelling in an industrial cluster

Saurabh Chandra, Manish Sarkhel

Factories need to treat their effluent water before discharging out in the open, to minimize the level of environmental damage caused. Governments have regulations limiting the types and amount of effluents being discharged from any manufacturing or processing facility. Large firms may install expensive in-house effluent treatment facilities to treat their discharge water before release, although small and medium scale firms may prefer a common effluent treatment plant (CETP) to share the cost burden of water treatment. The paper describes a variant of multi-facility location allocation problem occurring in many industrial areas in India. The problem deals with designing a network of CETPs to serve a cluster of manufacturing facilities. The fixed cost of installation and maintenance and variable cost of running is shared by the members served, based on their individual usage levels. The aim is to minimize the fixed and variable cost of installation of CETPs among a subset of given locations, where the type of CETP, members connected, inter-CETP flows and level of treated water return to factories are to be determined. We propose a MILP model for the problem and present the solution results for a given case.

3 - Short-term wind speed prediction using multivariable dense data for optimum micro-grid operations

Tansu Filik, Ümmühan Başaran Filik

The amount of renewable energy sources in energy portfolio of developing countries are steadily increasing. In order to use these renewable energy sources reliably in the future's optimum economic power system operations (smart grid), it is critically important to accurately forecast the short-term power generation capacity. Recently, isolated micro grid systems and their optimal operations have become widespread. In this study, we investigate our experimental renewable energy plant in Anadolu University, which is a small micro grid system with a personal wind turbine (with 3 kW capacity), solar panels, batteries, weather station measurement sensors and controllable loads. In this study, a new multivariable autoregressive moving average (MARMA) model for short-term wind speed prediction for optimal grid operation is proposed. The proposed model uses very dense (5 seconds interval) wind speed, direction, temperature, pressure, solar radiation and the corresponding wind power generation values of the wind turbine. It is shown that the proposed multivariable mathematical model gives more accurate results when compared to other benchmark methods.

4 - Electromagnetic field optimization for Turkey's transportation energy demand estimation

Alkin Yurtkuran, Ilker Kucukoglu

Transportation energy consumption is on the rise especially in developing economies. Accurate estimation of transportation energy demand is essential to analyze the present demand, to improve future energy supplies and to develop energy policies effectively. In this study, linear, exponential, mix and quadratic models are analyzed to predict the transportation energy demand of Turkey. Electromagnetic field optimization (EFO) algorithm is employed to optimize the model parameters efficiently and effectively. EFO is a relatively new physics-inspired meta-heuristic algorithm, which simulates the behavior of electromagnets with different polarities. In the prediction models, different input parameters as population, gross domestic product, transportation modes statistics, e.g., air, vehicle, marine and rail were considered. The data from 1970 to 2015 were utilized to train and test the models. Models were compared using different prediction performance measures and the transportation energy demand of Turkey is estimated until 2030.

■ TB-57

Tuesday, 10:30-12:00 - 4D UPV 2.3

Software for Mixed-Integer Optimization I

Stream: Software for Optimization
Chair: *Gregor Hendel*

1 - On signed symmetries in MILP

Imre Polik, Philipp Christophel

Using signed permutations in detecting symmetry for MILP was suggested before, but in a somewhat limited way. In this talk we extend the previous concepts and investigate what we can gain by using signed row permutations and complemented variables in symmetry detection. Experiments are implemented using the SAS/OR MILP solver.

2 - How to fold a linear program
Timo Berthold, Qi Huangfu, Michael Perregaard

We present LP Folding which is a way to exploit symmetries in linear programming problems. It uses a structure called equitable partitions, which can be seen as a generalization of model symmetry in MIP solving. An equitable partition subdivides the problem such that for each block in the partitioned problem, all the bounds and costs are the same, and all row and column coefficients add up to the same value.

LP Folding can significantly reduce the size of the problem to be solved and thereby speed up the solution process. It can be used with all three major LP algorithms: primal simplex, dual simplex and barrier. We discuss the implementation of LP Folding within the FICO Xpress Optimizer and present computational results on public benchmarks.

3 - Gurobi 8.0 - what's new
Michael Winkler

We will give an overview on new features and improvements in the current Gurobi release. In particular, we focus on the new Cloud and Compute Server enhancements and present our newest performance improvements.

4 - More performance with the new generic callback in CPLEX 12.8
Xavier Nodet

Version 12.8 of IBM CPLEX Optimization Studio is available to customers, teachers and students since December 2017. Among other features, it offers a new callback framework in CPLEX, the Generic Callback. The CPLEX Generic Callback was designed from the ground up with a significant goal in mind: providing a simple framework that keeps all CPLEX performance. By making sure that callbacks don't introduce any change in the solution path, the Generic Callback allows users to monitor CPLEX behavior without interfering with it, and to drive CPLEX without incurring any undue cost. By not disabling Dynamic Search or any other feature, performance improves by 25% on difficult models. We will introduce this new feature and present some use cases to show how it can be used.

■ TB-58

Tuesday, 10:30-12:00 - 4D UPV 2.4

Topics on Education

Stream: OR Education
Chair: *Joao Miranda*

1 - Evaluating the potential trade-off between students' satisfaction and school performance using multiobjective programming
Sandra González Gallardo, Oscar David Marcenaro Gutierrez, Mariano Luque

In this article, we carry out a combined econometric and multiobjective analysis using data from a representative sample of Andalusian schools. In particular, four econometric models are estimated in which the students' academic performance (scores in math and reading, and percentage of students reaching a certain threshold in both subjects, respectively) are regressed against the satisfaction of students with different aspects of the teaching-learning process. From these estimates, four objective functions are defined which must simultaneously maximized. A set of constraints is obtained by analyzing dependencies between explanatory variables. This multiobjective programming model is intended to measure the students' academic performance as a function of the students' satisfaction. To solve the this problem, we use the reference point methodology together with the compromise programming, which allows generating several Pareto optimal solutions representative from the Pareto optimal front. In general, the results show the importance of promoting respect and closer interaction between students and teachers, as a way to increase the average performance of the students and the proportion above a certain threshold.

2 - Predicting job selection based on departmental courses by using clustering and adaptive regression methodologies
Ayşe Kuyrukçu, Fatma Yerlikaya Özkurt

Increasing variety of professions and rapid increase of alternatives that offer this diversity rendered the decision of job selection more difficult and more important. It seems that the course selections are highly influential on the choice of profession. Especially, for industrial engineer candidates, this decision is becoming more difficult as they have been educated with an interdisciplinary notion. Their curriculum has a wide range of courses in engineering and business fields; such as production, modeling and optimization, database, economics, project management, etc. In addition, industrial engineers do not have a specific job area definition as other engineers. These are the reasons of selecting industrial engineering students and graduates as a sample of this study.

In this research, the departmental courses (compulsory courses with IE code) and the grades of students of these courses are gathered. A group of graduated students working in different fields are selected as the sample set. The aim of this study is to obtain a relationship/model between the students' courses and their current jobs by using clustering and adaptive regression methodologies.

3 - Training schools and supply chain stakeholders for medicines shortages (cost action CA15105)
Joao Miranda, Sarah Ben Amor

The engagement of stakeholders, data management issues, decision making on conflicting framework, and researchers inclusiveness are crucial for the international cooperation programs, such as the COST actions. Namely, a pair of Training Schools focusing disruptions of pharmaceutical supply chains (SC) and drugs shortages was developed on behalf of the COST Action "Medicines Shortages" (CA15105), treating specific computational issues, integrating SC optimization, and experimenting data science tools within IBM Watson/Bluemix. Recent developments, a pilot-application and its updated functionalities, and the current situation on SC stakeholders are discussed, as well as other training actions and scientific missions for young researchers are outlined.

4 - Study on optimization of charge of quarters scheduling in military academy
Minsu Kim

The faculty members of the military academy are in a special position that serves as an officer of the military and a professor at the university. Because of that, each professor lectures for a fixed period of time, but also serves Charge of Quarters (CQ) as an officer. Usually, CQ service members are typically excused from duties the following day, except lectures. So that, faculty members are hopes that the next day of the CQ will not overlap with the lectures. In general, however, the schedule of the CQ is operated on an orderly basis. Therefore, each month after the schedule is announced, each faculty members are repeats replacing CQ schedule that are timely. In this research, I developed IP model for CQ scheduling and analyzed the efficacy of the model using real data. I also developed a heuristic model that can solve problems quickly. Through this study, it can be seen that effective CQ scheduling can be made for people in special positions of military academy professors

■ TB-59

Tuesday, 10:30-12:00 - 4D UPV 2.5

Integrating Renewable Energy Resources into Power Systems

Stream: Technical and Financial Aspects of Energy Problems
Chair: *Raquel García-Bertrand*

1 - Inertia changes in power systems with high wind power plant integration. An overview of frequency analysis challenges
Ana Fernandez-Guillamon, Angel Molina-Garcia, Antonio Vigueras-Rodriguez

Traditionally, inertia in power systems has been determined by considering the rotating masses directly connected to the grid. During the last decade, the integration of Renewable Energy Sources, mainly PV installations and wind power plants, has led to important generation rates from these sources, changing considerably the stability and reliability analysis of power systems. As an example of this relevance, renewables overtake coal and nuclear in EU for the first time during 2017. A new generation scenario for power systems thus emerges from the supply-side, replacing traditional generation by renewables and affecting parameters such as inertia and subsequently frequency regulation. Actually, renewable generation units are decoupled from the grid by electronic converters, decreasing the inertia of the grid and then becoming more vulnerable power systems. In this way, 'Hidden inertia', 'Synthetic inertia' or 'Virtual inertia' are terms currently under discussion. Alternative spinning reserves are then necessary to be provided in a new framework where the lack of rotating masses directly connected to the grid must be emulated by maintaining a suitable power system performance. With this aim, a detailed analysis to estimate the effect of low inertia parameter for frequency control purposes is discussed in detail. Different scenarios are simulated and analysed, taking into account high wind energy integration, demand variations and frequency oscillations.

2 - Spot market, futures and risk management in the integration of renewable resources
Carlos Ruiz, Paolo Falbo

This work aims to evaluate how the integration of distributed generation (prosumers) and demand response policies may impact the relationship between futures and spot electricity markets.

We consider a risk averse electricity producer that trades her energy in a two-stage setting: first in a futures market and then by participating in a spot market. In the first stage the producer aims to derive the optimal total sales in the futures accounting for uncertain spot market outcomes. In the second stage, when uncertainty is resolved, the producers decides the optimal total sales in the spot market together with the appropriate energy mix to supply the energy committed in both markets.

The model is formulated as a stochastic bilevel program. The upper-level problem represents a linear trade-off between producer's expected profit and conditional value at risk (CVaR). The lower-level problem reproduces the spot market clearing for a set of scenarios that differ in the availability of renewable sources (solar and wind), direct generation costs (gas and coal), and demand level. In particular, a copula method is used to generate demand and renewable generation scenarios at different levels of correlations. To easy its computational performance, the bilevel problem is reformulated into a single level MILP which can be solved with standard branch-and-cut solvers. Several numerical simulations are carried out to show the performance of the proposed model.

3 - Optimizing storage allocation and investment for transmission constrained networks considering losses and high renewable penetration
Sonja Wogrin, Diego Tejada, Dean Yacar

This work investigates the effects of transmission losses, constraints and increased renewable energy penetration on planning energy storage allocation and investment. By modifying a DC Optimal Power Flow model using a linearized approximation for ohmic losses we were able to understand which network characteristic or inhibitor drives the most change in expanding utility scale storage. Four different storage technologies were explored—Compressed Air Energy Storage, Pumped Hydro Storage, Lithium-Ion Battery and Fly Wheel—each having different charging, capacity and cost characteristics. The results of the storage allocation trials revealed that network congestion was a more influential network inhibitor than were line losses. Losses only had substantial effects on a free-flowing network but produced marginal changes in allocation in congested ones. The conclusion of the investment trials revealed two things: 1) Storage investment is not significantly affected by transmission constraints so long as renewable generation stays constant and relatively low; 2) More flexible technologies like Fly Wheels are favored at lower volumes of renewable penetration for their load balancing abilities while cheaper technologies are best as the volume of renewable power generated increase and become the majority of grid power.

4 - Robust transmission network expansion planning under correlated uncertainty
Raquel García-Bertrand, Cristina Roldán, Roberto Mínguez, José Manuel Arroyo

This paper addresses the transmission network expansion planning problem under uncertain demand and generation capacity. A two-stage adaptive robust optimization framework is adopted whereby the worst-case operating cost is accounted for under a given user-defined uncertainty set. This paper differs from previously reported robust solutions in two respects. First, the typically disregarded correlation of uncertainty sources is explicitly considered through an ellipsoidal uncertainty set relying on their variance-covariance matrix. In addition, we describe the analogy between the corresponding second-stage problem and a certain class of stochastic programs arising in structural reliability. This analogy gives rise to a relevant probabilistic interpretation of the second stage, thereby revealing the undisclosed relationship between stochastic programming and the worst-case setting characterizing robust optimization with ellipsoidal uncertainty sets. More importantly, a novel nested decomposition approach based on results from structural reliability is devised to solve the proposed robust counterpart, which is cast as an instance of mixed-integer trilevel programming. Numerical results from several case studies demonstrate that the effect of correlated uncertainty can be effectively captured by the proposed robust approach.

■ TB-60

Tuesday, 10:30-12:00 - 4D UPV B.5

EURO Excellence in Practice Award II

Stream: EURO Special Sessions
Chair: *Ulrich Dorndorf*

1 - The OR revolution in Vattenfall BA Wind
Martina Fischetti, Jesper Runge Kristoffersen, Michele Monaci, David Pisinger

Wind energy is a fast evolving field, that has attracted a lot of attention and investments in the last decades. Being an increasingly competitive market, it is very important to minimize establishment costs and to increase production profits already in the design phase of new wind parks. Our project uses state-of-the art Operational Research (OR) techniques in the design phase of a new offshore park. This work is based on 4 years of close collaboration between the academic world and Vattenfall, a leading wind energy developer and wind power operator. In particular, Vattenfall defined the problem, tested the models and nowadays routinely uses our software for turbine allocation and cable routing. Our project was the first (and very successful) attempt for Vattenfall to use OR in the wind farm sector. OR techniques are, indeed, not yet common in this new market. Our project proved that millions of Euros can be saved in practice, by a smarter use of resources (i.e., using sound optimization techniques) compared to the traditional and more manual approach.

2 - Blending systems thinking approaches for organisational analysis: reviewing child protection in England
David Lane, Eileen Munro, Elke Husemann

This work concerns the innovative use of a blend of systems thinking ideas in the 'Munro Review of Child Protection', a high-profile examination of child protection activities in England, conducted for the Department for Education of the UK Government. We present the legislative and organisational framing of child protection and discuss the inherent risk balance of 'child rescue' and 'family preservation'. We describe the environment from which the Munro Review emerged. We then show how a blend of different systems thinking approaches was used to consider public policy questions, concentrating on three specific contributions that systems thinking made to the Review. First, the systems-based analysis and visualisation of the 'compliance culture' that had grown up in the sector; we describe how this was created, what it revealed about the sector and what the response was to the diagnosis that it offered. Second, we describe the use of System Dynamics Modelling-based group model building to develop a large, complex systems map of current operations; this dealt with the intended and unintended consequences of previous policies and helped us to identify the drivers of the sector. Third, we describe how this OR work gave structure to the many concerns that the Review had to deal with and how it lead to a set of recommendations that aimed to be systemically coherent, thereby avoiding problems that were seen to have arisen as a result of previous policies. These recommendations were accepted by the UK Government and continue to be implemented via changes to a range of policy and inspection guidelines and changes to the laws of the country. We therefore close by outlining the main implementation steps taken so far to create a child protection system with the critically reflective properties of a learning organisation. We also touch on the broader consequences, both in the UK, and on how the findings of the Review have influenced child protection thinking and policy, and improved the lives of children in a range of countries internationally.

3 - An efficient algorithm for milk transport logistic optimization developed for the dairy industry enterprise Zott SE & Co. KG
Sascha Wörz, Michael Schmid, Heinz Bernhardt

Zott SE & Co. KG, an enterprise in dairy industry, has to process in a 48 h time and operation horizon about 2900 dairy farmers in at least 5 and at most 30 different milk draw areas. Up to now, the milk was collected and brought to the dairy by various process variants, whereby their applications planning was triggered manually with the major drawback that the overall milk transport logistic cost were more or less optimized. For this purpose, Zott SE & Co. KG ordered us to develop an ecient algorithm that finds an optimal solution with probability one, does not require any commercial optimization software as e.g. CPLEX and is anyway capable to reduce the overall milk transport logistic cost and to make savings between 5 and 15 percentage of the overall cost become reality.

Tuesday, 12:30-14:00

■ TC-01

Tuesday, 12:30-14:00 - UPV Nexus

MINLP and the cost of interpretability in Data Science

Stream: Keynotes
Chair: *Emilio Carrizosa*

1 - MINLP and the cost of interpretability in Data Science
Dolores Romero Morales

Data Science aims to develop models that extract knowledge from complex data and represent it to aid Data-Driven Decision Making. Mathematical Optimization has played a crucial role in the three main pillars of Data Science, namely Supervised Learning, Unsupervised Learning and Information Visualization. For instance, Quadratic Programming is used in Support Vector Machines, a Supervised Learning tool. Mixed-Integer Programming is used in Clustering, an Unsupervised Learning task. Global Optimization is used in MultiDimensional Scaling, an Information Visualization tool. Data Science models should strike a balance between accuracy and interpretability, enabling easy communication with the user who needs to interact with the models. In this lecture, we will navigate through several Mathematical-Optimization based models in Data Science that illustrate the important role of Mixed-Integer Nonlinear Programming in achieving such a balance.

■ TC-02

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S101

DEA in Education

Stream: DEA: Applications
Chair: *Nabil Amara*

1 - Assessing the education frontiers in Vietnam
Minh Hanh Le, Heinz Ahn

The education story in Vietnam remains a mystery when Vietnamese students obtain good academic achievements in spite of the country's low GDP per capita. Our study aims to assess the education frontiers of all 63 provinces in Vietnam using a DEA approach. The education frontiers are viewed with two loops. The first loop directly benchmarks the provinces based upon their investments in education and the outcome. The second loop is focused on the gap between frontiers of 7 groups of provinces and the national frontiers based upon high school national exam results of individual students in 2017. The findings show that (i) rural provinces are more technically efficient; (ii) many provinces, especially the most urbanized provinces are experiencing low scale efficiency level; (iii) the gap between provincial frontiers is critical. DEA approach is helpful in identifying the gap in performance frontiers.

2 - Benchmarking in higher education using data envelopment analysis and the Bologna process data
Kazim Baris Atici, Aydin Ulucan, Akin Ozkan

Quality Assurance is one of the core elements of the Bologna Process in European Higher Education and the Bologna Process data of the programs can serve as a rich resource for assessing program quality and benchmarking since the data follow a standardized framework for any program. Despite the standardized framework, the data of each program require an organization in order to come up with comprehensive measures so that such measures can become comparable between programs. This paper aims to propose an analytical approach for academic program quality assessment utilizing the Bologna declarations of the programs. First, we propose a methodology on data organization. Second, the organized data are used for assessments at program and subdivision levels via Data Envelopment Analysis. We illustrate our proposed methodology in an application to Business bachelor degree programs in Turkish universities. We discuss the implications to various stakeholders of higher education from policy makers to students.

3 - Measuring academic research efficiency: a comparison of results from parametric and nonparametric methods
Nabil Amara, Nizar Souiden, Mehdi Rhaiem

Using metrics on outputs from the Thompson ISI Web of Sciences, augmented by a survey data on factors explaining the productivity and impact performances of university researchers funded by the Natural Sciences and Engineering Research Council of Canada (NSERC), this article attempts to shed new light on the efficiency of academic research production as measured, at the researcher's level, by the peer-reviewed article counts. This is done by developing a formal conceptual framework to assess the academic production efficiency and by performing an empirical investigation of the determinants of researchers' efficiency using the Distance Frontier Production Function Approach and the Two-stage Bootstrap DEA Approach. Results reveal that there is substantial room for improvements of technical efficiency, both across the six fields considered in this study, and within each field. Furthermore, we obtained evidence showing that three determinants explain differences in academic efficiency across the six research fields considered in this study. These determinants were: university research size, experience and seniority. Moreover, social capital, and prestige and reputation of university of affiliation were found significant to explain the efficiency gap between researchers in four and three fields, respectively.

4 - Evaluation of disaster management system: a case study of earthquake performance in Turkey
Erdem Aksakal, Ufuk Altınsoy

Due to the technological and industrial developments, natural and human-sourced disasters have become riskier and hazardous for humans with the increase in population density. This makes people more sensitive to disasters and leads governments to design a disaster management system in order to prevent and mitigate possible disasters. As being an important part of the disaster management system, earthquake and the occurrence of an earthquake in a populated area threatened the countries with numerous casualties and injuries. Turkey's geographical location makes Turkey as a risky country. Turkey is exposed to various types of natural disasters such as earthquakes, floods, landslides which causes losses of life and property. In this study, three major earthquakes sampling considered to get an idea of the performance of disaster management system with using Data Envelopment Analysis. The purpose of the study is to elaborately analyze the performance of disaster management system and what kind of precautions are needed to be developed while faced up with an earthquake in Turkey.

■ TC-03

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S103

Facility Location and Sustainability

Stream: Location Analysis and Optimization
Chair: *Glaydston Ribeiro*

1 - Compromise programming for closed loop supply chain networks
Said Salhi, Chandra Irawan, Muhammad Abdulrahman

A sustainable closed loop supply chain (CLSC) network with two conflicting objectives, namely the minimisation of the total cost and the total amount of CO2 emission, is proposed. A Mixed Integer Linear Programming (MILP) model is developed to determine the location of distribution centres (DCs) and recycling centres (RCs), their respective numbers, the transportation mode (vehicle) assigned to each facility, and the flows of products within the CLSC network. An optimal method and a matheuristic using compromise programming are proposed. The latter incorporates an aggregation technique, an MILP model and a local search. A practical example using a UK map is given to demonstrate the usefulness of the compromise solutions. The performance of the proposed approaches is assessed using a newly constructed datasets. The computational experiments show that the proposed matheuristic outperforms the exact method while requiring a relatively smaller amount of computing time.

2 - Solving a bi-objective facility location problem in the presence of uncertainty
Najmesadat Nazemi, Sophie Parragh

To cope with uncertainty in optimization problems, many different approaches have been presented in the literature. The most widely used ones are stochastic optimization, including concepts such as expected value, chance constraints or risk measures, and robust optimization. However, the intersection of uncertainty and multi-objective optimization has not received as much attention. In this paper, we consider a bi-objective facility location model for designing last mile networks in a disaster relief setting, where the demand of beneficiaries is considered to be uncertain. We use two different approaches for dealing with uncertainty: (i) scenario based stochastic programming (optimizing the expected value) and (ii) the concept of minmax robustness (optimizing the worst case value). Both approaches are then integrated into two criterion space search methods, namely the well-known epsilon-constraint method and the more recently introduced balanced box method. Finally, we evaluate and compare the different approaches by applying them to data sets derived from a real world case study, in order to gain insights into structural differences of the obtained Pareto frontiers and the underlying solutions.

3 - Ambulance simulation package
Samuel Ridler, Andrew J Mason, Andrea Raith

Emergency medical services aim to provide timely medical care and transport of patients. The provision of these services requires many decisions to be made, such as where to locate ambulances and their stations, ambulance dispatching behaviour, dynamic redeployment, etc. We have developed an open source ambulance simulation package to allow for performance evaluation of such decisions. The package is implemented in Julia, a high-level programming language which executes quickly (comparable to C) and has the JuMP package for mathematical optimisation. Details of the simulation package will be presented, along with examples of how it may be used, such as for simulation based optimisation.

4 - Literature review of facility location and environmental issues
Vanessa de Almeida Guimarães, Glaydston Ribeiro

This paper presents a literature review of articles about facility location published in the Web of Science database until the year 2016. A scientometric analysis was performed to identify if the papers are dealing with the environmental issues in their mathematical models. Among almost 6,000 papers reported, 2% deal with environmental aspects and only 30 articles are directly related to some kind of facility location problem. Among these 30 papers, most investigate the closed-loop supply chain, aiming to identify the optimal location of (re)manufacture facilities and distribution centers. There is not a consensual approach to deal with the environmental impacts, but the most evaluated criterion is carbon emission. Some papers also apply life cycle assessment while others just consider emission polices especially carbon cap (limitation of the amount of carbon that firms can emit) and carbon trade (considering the possibility of buying and selling the carbon credit). Moreover, the mathematical formulation of the problems varies, since some papers consider the cost of carbon in the objective function (taxes related to the amount of carbon emitted or the value paid for additional carbon credits), others propose bi-objective models aiming to minimize the amount of carbon emitted, while other ones treat the environmental issue as a constraint of the main model. The results also showed that there are gaps to fulfill, especially models focusing in governmental strategic planning.

■ TC-04

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S104

Dynamic Asset allocation

Stream: New Challenges in Investment Strategies, Risk and Financial Modelling
Chair: *Roy Cerqueti*
Chair: *Mario Maggi*

1 - Networks and market-based measures of systemic risk: the global banking system in the aftermath of the financial crisis

Chiara Pederzoli, Gian Paolo Clemente, Rosanna Grassi

In this paper we investigate how the global banking system reacted to the financial crises occurred in the last decade, which highlighted the urgency of addressing systemic risk within financial regulation. Academics have proposed a wide range of different approaches to measure systemic risk. Broadly speaking, we refer to two different approaches, which have gained great relevance in the last years. One refers to market-based measures of systemic risk such as Marginal Expected Shortfall (MES) and CoVaR. The other approach deals with network analysis, which describes the architecture of the financial system by using either real financial flows among institutions or simulations in order to assess the resilience of the system to shocks. We follow alternatively both approaches to describe the evolution of systemic risk during the last few years, as a reaction to the financial crisis and to the regulatory innovations induced by the same. In particular, we study the network of the banking system using country-level data provided by the BIS on cross-border banking claims during 2005-2017. Besides this analysis, we apply MES and CoVaR at the aggregate level. In other words, we measure potential losses suffered by banks in any country when the banks in the other countries face difficulties. The two approaches are different in spirit but they share the common aim of measuring global systemic risk and therefore the comparison of the results can give deep insights into the issue.

2 - Optimal investment strategies with stochastic interest rate and minimum performance constraint

Daniele Marazzina

We consider the optimal strategy problem of a fund manager in the presence of a minimum guarantee. The manager, in fact, receives a fee which is proportional to the liquidation value of the portfolio, reduced through the application of a penalty if the liquidation value is below a specified-in-advance threshold (minimum guarantee). We deal with two different settings: a continuous time economy with constant instantaneous interest rate and the case where the short-term interest rate is described by the Vasicek model. Explicit formulas for the optimal investment are presented; moreover, we analyze the sensitivity of the optimal investment strategy with respect to the different model's parameters. We then compare our portfolio strategies with the Merton portfolio and with the Option Based Insurance strategy (El Karoui, 2005).

3 - Discounting of mean reverting cash flows

Henrik Andersson

If we believe in the dynamics of a competitive market economy, cash flows stemming from sales of standardised goods should be mean reverting. This is not congruent with the use of a constant risk-adjusted discount rate as the risk of a mean reverting cash flow is asymptotically constant. Nevertheless, option theory can handle mean revering price processes and be applied to indirectly determine an appropriate, but time dependent, risk-adjusted discount rate for calculating the present value of operations.

Our analysis is based on cash flows being mean reverting according to the exponential Ornstein-Uhlenbeck process. It shows that the risk premium changes from the standard form of being multiplied with the time to maturity to instead being multiplied with one minus an exponentially decaying function of time to maturity. In other words, the risk premium is a function of time but not a multiplication with time, and asymptotically constant as the risk is asymptotically constant. Mean reversion normally leads to an increase in value and differences are accentuated in a low interest rate environment even with a constant market risk premium simply because future payments are more worth. It is therefore even more important than historically to get the cash flow process and discounting right.

4 - A beta decomposition to set up a low beA asset allocation strategy

Mario Maggi, Antonio Amendola, Dennis Montagna

This paper presents the so called "Beta anomaly" regarding the risk-reward relationship in financial markets. There is evidence that a "Low Beta" strategies generate good performances. To use this fact in portfolio management, we decompose the beta formula into correlation and standard deviation, in order to assess the different drivers and contributions. We run an extensive analysis focusing on S&P500 Index and relative components, covering the last 10 years. We analyze the impact of the two components on the overall beta and we set up a portfolio strategy based on the betas and their components. We extend our research in different sectors and finally we develop a new proposal in order to show the beta evolution respect to the market and the reference sector, the "Walking Beta".

■ TC-05

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S105

Pickup and Delivery Problems

Stream: Vehicle Routing and Logistics Optimization I
Chair: *Cristiam Gil*

1 - An exact formulation for the one-to-one pickup and delivery problem with divisible split ups

Bolor Jargalsaikhan, Ward Romeijnders, Kees Jan Roodbergen

In vehicle routing problems, it is well known that splitting up the loads of a delivery may lead to significant cost benefits. We consider a pickup and delivery problem with divisible split-ups: In offshore helicopter routing problems, several teams may be located at the same platform and need to be transported to different platforms. Teams at the same origin platform with different destinations may split up. Such split-ups can be addressed in a mathematical model by duplicating the platforms into fictitious nodes for each arriving and leaving team. Then the extended network can be solved as if it is a standard pickup and delivery problem without split-ups. However, the number of nodes increases significantly and it becomes numerically inefficient. In this paper, we provide a linear integer programming formulation on the original graph of the platforms without any duplications.

2 - Order first cluster second algorithm for pick up and delivery problem

Tejas Ghorpade, Narayan Rangaraj

Freight carriers who face uncertain demand and travel times assign the vehicles dynamically and have no planned trips. When demands are known with some reasonable probability, defining fixed paths which can be modified using simple methods is desirable. We consider variation of the Pickup and Delivery Problem where the origin and destination of the load are specified by the customer and demand is in terms of the number of vehicles. This is an arc routing problem where demands need to be satisfied by multiple trips. Such situations arise during freight movement by rail or truck where the customer requests multiple vehicles to move the commodities. We solve the deterministic version of this problem using average demand by Order First Cluster Second method. A two-step algorithm is developed, where the first step generates a single path by determining the next location as the node having the maximum value, obtained from a greedy path from that node. In second step, we split this single path to form multiple paths around a particular node so as to form complete cycles. The proposed heuristic is compared with two methods, one where the initial path is obtained by ILP and splitting algorithm remains same and another ILP that gives an exact solution. Lastly, we develop an adaptive algorithm that modifies the cycles according to the difference between average and actual demand. We simulate such demands over a period of time to check the efficiency of this adaptive algorithm.

3 - A two-compartment single vehicle routing problem with simultaneous pickups and deliveries, stochastic demands and predefined customer order
Constantinos Karamatsoukis, Roza Zakar, Epaminondas Kyriakidis, Theodosis Dimitrakos

We consider the problem of finding the optimal routing of a vehicle with finite capacity that delivers new/fresh products and picks up old/expired items of the same product. The new/fresh products are stored in compartment 1 and the old/expired products are stored in compartment 2. The vehicle must deliver and pick up products according to a predefined customer order. For each customer the quantity of the products that is delivered and the quantity of the products that is collected are discrete random variables with known distributions. The actual demands for new/fresh products and for old/expired products are revealed upon the arrival to customer's site and cannot exceed the capacity of compartment 1 and 2, respectively. The vehicle is allowed to return to the depot to restock with new/fresh products and to unload the old/expired products. It is possible to find the optimal routing strategy by implementing a suitable dynamic programming algorithm. Numerical results are also presented for the problem we study.

4 - A column-generation based model to pickup and delivery problem with transfers
Cristiam Gil

Exact methods in the PDP-T literature were only employed for solving small instances with larges computational times: the best is no more than 75 requests and 4 transfer points running up to 1 CPU time hours (an imposed limit) with average gaps of 33.84% (Masson et al., 2014), showing an existing gap in real applications. Some recent promising works have improved gaps in reasonable computational times. Cortes et al. (2010) proved the computational benefits of implementing a branch-and-cut algorithm (based on Benders decomposition) to solve PDP-T problems. They reported savings of around 90% in CPU time when compared to standard MIP solvers. Ghilas et al. (2017) solves the PDPTW-T, through a Branch-and-Price methodology mainly consider for the PDPTW with scheduled lines, with up to 40 requests on the considered instances. Gschwind (2015) evidenced the effectiveness of column generation approaches for the PDP (with no transfer), solving 91% small and medium size instances and 66% of large size instances to optimality. It could be worth to explore this approach for the problem for the problem with transfers. Currently, we are developing of cutting-edge solution methods to PDP with transfers, specifically based in Column Generation. The purpose of this work is to show our ongoing progress in this problem: to propose a three and a two index formulations including precedence, route synchronization and capacity constraints, which present difficulties to deal.

■ TC-06
Tuesday, 12:30-14:00 - SOUTH BUILDING UV S106

Retail Distribution Planning II

Stream: Demand and Supply Management in Retail and Consumer Goods
Chair: *Thomas Archibald*

1 - Solving the integrated order picking and vehicle routing problem with order batching and delivery time windows
Daniel Schubert, Heinrich Kuhn, Andreas Holzapfel

Picking customer orders in the warehouse and scheduling the deliveries of those orders to the customers are commonly considered as two independent planning problems, i.e., order picking and vehicle routing. An integration of these problems yields significant advantages regarding costs and/or delivery reliability. These advantages are especially noticeable if independent customer orders are combined to one joint picking batch. Joint picking of customer orders reduces the total picking time of all orders in the warehouse. However, a favored order batch may be in conflict with a preferred delivery tour. Therefore, an integration of both problems is required. We present a model and a solution approach that integrate the order batching and a vehicle routing problem assuming delivery time windows with a hard lower and a soft upper bound in order to minimize the total tardiness of all orders. We compare the results of the integrated solution approach with those of a sequential one.

2 - Collaborative load plan design in the retail market: the pickup hub and delivery problem
Axel Grimault, Yun He, Fabien Lehuédé, Juliette Medina, Olivier Péton

In this paper, we present a service network design and routing problem that integrates long-haul and local transportation decisions. Consolidations between carriers with heterogeneous operating costs is important when fast and frequent deliveries are required in a dense network of retailers. A set of logistic hubs allows the consolidation of backlog orders between the inbound network (suppliers) and the outbound network (retailers). Direct deliveries are keys to reduce transfer operations and customer assignment to several hubs reduces transportation costs.

To solve the problem, we present a route based formulation that embed a large set of routing constraints. To tackle the variety of route costs and constraints, inbound network routes are enumerated based with a generator including specific carriers constraints. Generating outbound routes means solving a rich vehicle routing problem. This is performed by heuristic column generation. Once routes are generated, the master problem is solved with a MIP solver. Numerical experiments illustrate the leverage of consolidation on a real case.

3 - Integrating consumer preferences and shelf life data in urban e-grocery logistics planning
Christian Fikar, Andreas Mild, Martin Waitz

This work presents a decision support system to assist in the distribution of perishables in an urban e-grocery setting by incorporating product shelf life data and customer preferences in logistics planning procedures. An agent-based simulation estimates demand and further models customer perception of the delivered services over time based on results of a conjoint analysis surveying 432 urban consumers. The focus is set on the impact of varying remaining shelf lives at delivery of highly perishable fresh fruits and vegetables such as fresh berries. Incorporated food quality models and dynamic optimization procedures estimate shelf lives at delivery and optimize vehicle routes. Computational experiments investigate the impact of offering customers one or more competing service offers (e.g., varying time window widths, guaranteed product qualities at arrival or delivery fees). Therefore, store-based home deliveries of strawberries throughout Vienna, Austria, and a simulation horizon of four weeks are considered. Results highlight the importance of jointly investigating logistics performance and customer perception when designing service offers for e-grocery systems to facilitate efficient operations.

4 - Designing effective proactive transshipments in retail networks
Thomas Archibald, Kevin Glazebrook, Sandra Rauscher

Proactive transshipments are a means to redistribute inventory in a retail network in order to better meet future customer demand. Proactive transhipment is used when, for example, there are convenient times to redistribute inventory in the network or customers require immediate service. Planning proactive transshipments involves deciding when to redistribute inventory, which locations to involve in the transshipments and how much inventory to transship between the locations. This research proposes a model that can be used to plan proactive transshipments in a general setting. A heuristic transshipment policy is proposed that is shown to perform well compared to commonly used policies on a wide range of test problems.

■ TC-07

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S107

Timetabling under Capacity Constraints

Stream: Public Transportation II
Chair: *Nikola Besinovic*

1 - Integrated micro-macro railway timetable

Miguel Angel Ruiz Sanchez, Ángel Marín, Luis Cadarso, Esteve Codina

The railway timetable problem consists in selecting the optimal train routes and schedules to minimize the rail traffic time. The growth in the rail demand encourages infrastructure managers to improve the effective use of the infrastructure occupations, but keeping the passenger service quality (travel time). The design of effective timetables help to improve running times to use the infrastructure. The timetable problem is studied with two approaches, micro and macro. The macro approach simplifies the representation of the railway infrastructure considering railway segments linking consecutive control areas as a single network node. This approach is suitable for tackling problems from the passengers' point of view. The micro approach makes a detailed description of the railway infrastructure and allows taking into account the constraints on the conflict on the control areas. Both approaches micro-macro are integrated. Some computational tests have been studied with concrete rail applications. The macro model try to minimize the passenger travel time, considering the less generalized travel time, and delays at destination. The macro does not consider the conflicts at the control zones, so the solution will be not feasible considering the conflicts between trains at micro level. The micro model is defined in terms of track-circuits, they are track segments on which the presence of a train is automatically detected.

2 - Periodic timetabling with limited infrastructure capacity

Sebastian Albert, Soumya Dutta, Julius Pätzold, Narayan Rangaraj

The Periodic Event Scheduling Problem (PESP) has been widely researched and applied to the macroscopic planning of public transportation systems in order to find cyclic timetables. Optimisation traditionally focuses on the minimisation of rolling stock used or passengers' travel time, or both, while obeying several types of constraints. Some of these are soft in nature, such as equidistant spacing of parallel services within the cyclic time period, which can be relaxed in case of infeasibility. Other constraints are hard and cannot be changed due to physics, such as minimum driving times or the impossibility to use the same pieces of infrastructure simultaneously, especially in railway applications.

While the constraint of not driving along the same piece of track at the same time has been successfully modelled on the macroscopic level by minimum headway times, which can be expressed as standard PESP constraints, other situations are more intricate. Busy terminal stations may pose additional constraints on the number of concurrently present vehicles, and the interlocking around larger stations may restrict the simultaneous entrance and exit, often even depending on the platform allocation. If such constraints are numerous, especially in dense traffic on very limited infrastructure, even feasible solutions can become hard to find.

We formulate such additional capacity constraints on top of the PESP and employ Constraint Propagation to find feasible solutions.

3 - A mathematical model for timetabling problem in railway transportation

Fatih Bahar, Lale Ozbakir, Pınar Tapkan, Sinem Kulluk, M. Burak Telcioglu

In railway timetabling problem, the main issue is the determination of headways, the time between two consecutive train trips. This headway should meet the structural and operational constraints while satisfying the demand of passengers. Train timetabling problem is proven to be NP-hard. For this time consuming and complex problem, dispatchers must spend lots of time and effort. In this study a mathematical model is proposed to solve the timetabling problem of a real-world light railway public transportation system. In this study a cyclic timetable is optimized so as to determine the best headway in hourly time frames for satisfying the passenger demands without violating any constrains. Due to ease of usage and learning by the passengers, preferred headways are determined by the railway planners. Meeting the passenger demands is the most important factor that effecting the customer satisfaction. The ratio of passengers waiting at the station is taken into account while providing an efficient headway for the current time zone. By considering the comfort coefficient, train capacities can also be adjusted. The solution obtained by the proposed mathematical model is evaluated and compared with the current timetable. This study was supported by Research Fund of the TUBITAK 1011 (Project number: 117M590).

4 - A new flexible headway model for designing operationally feasible railway timetables

Nikola Besinovic

In this paper, we describe how minimum headway times in a periodic railway timetable can be modelled in a flexible way. Usually, timetabling models assume that the constraints for minimum headways are defined as fixed and are expected to hold for all train behaviours. Operational feasibility of a timetable is an ability to satisfy all microscopic constraints imposed by infrastructure layout, signalling and protection system, and rolling stock driving characteristics. We propose a new flexible headway time model for railway timetabling problems. The model is based on Periodic Event Scheduling Problem (PESP) formulation and integrates microscopic details to maintain operational feasibility of solutions. We define a functional relation between the minimum headway times and trains' running times. In particular, two variants of flexible headways are determined: a linear and piecewise linear. Flexible minimum headway times are introduced in a PESP-based mixed integer linear model for periodic timetabling. A flexible headway time model is tested on a part of the Dutch railway network and compared to an existing model with fixed minimum headways. The proposed model generates timetables with a significantly smaller number of conflicts and creates operationally feasible solutions for a number of instances. The proposed model contributes toward reducing time for designing railway timetables that are (almost) operationally feasible and can be implemented directly in operations.

■ TC-08

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S108

Applications in Industry and Services I

Stream: Combinatorial Optimization I
Chair: *José Fernando Oliveira*

1 - A dynamic IRP approach for the smart waste collection problem

Tania Ramos, Carolina Soares de Morais, Ana Barbosa-Povoa

Information and Communication Technologies' advances are today an important breakthrough for organizations allowing to deal with uncertainty and improving their operational decision-making process. This is the case of the waste management sector where the accumulation of municipal solid waste is difficult to forecast causing frequently an inefficient use of resources. The installation of sensors to transmit real-time information on the waste bins' fill-level can be explored to better plan and operate waste collection. The available real-time data should be used to optimize collection routes, where the amount of waste collected is maximized while transportation costs are minimized. A "smart collection" operation is explored as opposed to the traditional "blind collection" operation, in which all bins are visited through predefined and static routes. To guarantee a profit maximization for the entire planning horizon, Inventory Routing Problem (IRP) models are studied, coupled with dynamic solution approaches. This allows a continuous data updating, in contrast to traditional IRP models that only consider the use of real-time information in the first period of time and estimates for the days ahead. Additionally, the present work proposes a Rolling Horizon solution approach to solve the IRP dynamically, using every day the data transmitted by the sensors. The approach is applied to instances derived from real data provided by a Portuguese waste collection company.

2 - A heuristic approach to dispatch and conflict-free routing problem of capacitated vehicles for container transfers and relocations in a warehouse setting
Emmanouil Thanos, Tony Wauters, Greet Vanden Berghe

The present work proposes a heuristic approach for the integrated problem of scheduling container boxes' transportation with capacitated vehicles through conflict-free trajectories in a random warehouse setting. In addition to vehicles' dispatching, scheduling and routing decisions, the problem involves storage location selection for the boxes which must be relocated. The setting's traffic network is modeled as a graph including stacks of boxes. Single-type vehicles are incorporated alongside their loading, unloading and transfer operations, permitting split deliveries with Last-in-First-Out policy. Various real-world movement restrictions and conflict rules are considered. In the proposed Local Search (LS) framework, each LS solution indirectly represents a routing schedule. All assigned vehicles are gradually routed and waiting times are imposed to resolve conflicts and maintain safety distances, while satisfying all capacity and precedence restrictions. Numerous possible local moves are addressed for reducing the total makespan of an existing schedule, incorporated within both a Simulated Annealing and a Late Acceptance meta-heuristic. The integrated approach is applied to the real container yard layout and transport requests of a Belgian terminal and experimental evaluation shows that the proposed algorithm significantly reduces the operations' execution time for instances of different input sizes.

3 - Cruise itineraries optimal scheduling
Gianni Di Pillo, Stefano Lucidi, Renato Mari, Massimo Roma

A cruise company faces three decision problems: at a strategic level in which maritime area and in which season window to locate each ship of its fleet; at a tactical level, given a ship in a maritime area and in a season window, which cruises to offer, where a cruise is characterized by the embark and debark ports and the days length; at an operational level, to determine the day-by-day itinerary, in terms of transit ports, arrival and departure times and so on. This talk concerns the tactical level: more precisely to determine a scheduling of cruises with the objective to maximize the expected revenue provided by a ship in a maritime area and in a season window, taking into account a number of constraints: 1.for any port there is a minimum and a maximum number of visits 2.a port cannot be visited again unless a minimum number of days is elapsed 3.for any cruise length there is a minimum and a maximum number of cruises 4.some cruise must depart (arrive) in a given port in a given day of the season 5.charter cruises, specified by departure port and day - arrival port and day must be included. The problem is modelled as a MILP coded using AMPL and solved using GUROBI. The solution gives the sequence of cruises which satisfies all constraints and maximizes the expected revenue attained in the season window. As far as we are aware, this problem appears to be tackled for the first time, and no references on the subject seem to be available in the literature.

4 - Integrating capacity and pricing under uncertainty in the car rental business
José Fernando Oliveira, Beatriz Brito Oliveira, Maria Antónia Carravilla, Alysson Costa

The car rental business has interesting and different characteristics, such as the flexibility and the mobility of the fleet, associated with a competitive market, pushed by a price-sensitive and uncertain demand. These characteristics facilitate the integration of fleet- and revenue-oriented issues, traditionally tackled separately. Capacity decisions are made when a company is planning a selling season and must decide on the number (and type) of vehicles it will have to meet demand, which is uncertain and highly price-sensitive. Thus, the decisions regarding prices are connected with the capacity decisions. Throughout the season, the company must also decide on fleet deployment, by empty transfers or by rentals fulfilled, and on possibly leasing cars to face peeks of demand.

We model this problem as a two-stage stochastic program. The goal is to provide decision-makers with profitable solutions to the first stage decisions, describing their ability to deal with the different realizations of uncertainty, represented by scenarios.

The methodology developed is based on a co-evolutionary genetic algorithm, where parallel populations of solutions and scenarios co-evolve, depending on each other for the fitness evaluations. On the one hand, this method obtains a representative and diverse population of scenarios, in relation to the impact they have on solutions. On the other hand, solutions converge to well-performing decisions, based on different risk profiles.

■ TC-09

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S109

Matheuristics

Stream: Matheuristics
Chair: *Tony Wauters*

1 - A matheuristic improvement procedure for the Euclidean travelling salesman problem
Peter Greistorfer, Moritz Kettele, Rostislav Staněk

Given an edge-weighted graph, the travelling salesman problem (TSP) asks for the determination of a shortest Hamiltonian cycle. The TSP is an NP-hard important real-world and graph-theoretical problem and has been prominently treated in literature for many decades.

Exact algorithms usually employ integer linear programming (ILP), often utilizing a branch-and-bound- or branch-and-cut-scheme with cutting plane constraints. Besides, classical construction heuristics (e.g. nearest neighbour (NN) or farthest insertion (FI)), improvement methods (e.g. k-opt or Lin-Kernighan (LK) procedures) and metaheuristics play a meaningful role. Recently, with the rise of commercial solvers and the growing availability of more capable hardware, incomplete or partially exact linear optimization methods, so-called matheuristics, have been established. We propose such a matheuristic, an improvement procedure for the Euclidean TSP.

Our magnifying glass heuristic (MGH) removes sub-paths, defined by the current position of a magnifying glass, and rebuilds these destroyed regions by means of an ILP. This is iteratively repeated for the whole two-dimensional space of vertices, while usually improving the overall tour.

Starting with NN and FI, variants of MGH were tested on a set of DIMACS instances with sizes ranging up to several hundred thousand vertices. All results, compared to those of 2- and 3-opt and to LK, illustrate that MGH on average provides better results in shorter cpu-times.

2 - A matheuristic approach for forming, scheduling and routing field service teams with prioritized multi-skill tasks
Seray Çakırgil, Eda Yücel, Gultekin Kuyzu

This study focuses on the multi-skill workforce and routing problem arising in on-premises service operations. It is motivated by a real-life problem that an electricity distribution companies face on a daily basis. This problem entails assigning tasks at different geographical locations with different priorities and skill requirements to teams of centralized technicians having different skills. Our study aims to form the technician teams, to assign the tasks to the teams in accordance with the task skill requirements and to construct the daily routes of the teams. The primary objective is to complete high priority tasks earlier and the secondary objective is to minimize total operational costs. We first develop a mathematical formulation to address the problem. We propose a three-phase matheuristic as the computational effort grows for realistic problem instances. In the first phase, we divide the tasks into clusters based on similarity in their skill requirements, proximity in their locations and dissimilarity in their due dates. In the second phase; for each cluster, we solve two mathematical programs sequentially to form teams of technicians and assign the tasks to the teams. In the last phase, we use a neighborhood search heuristic to determine the routes of the teams. We analyze the effectiveness of the proposed solution approach on realistic problem instances and instances from the literature.

3 - Two decomposition strategies for a constructive matheuristic applied on shift minimization personnel task scheduling problem

Reshma Chirayil Chandrasekharan, Pieter Smet, Tony Wauters

The shift minimization personnel task scheduling problem (SMPTSP) is an NP-complete optimization problem that concerns the assignment of tasks to multi-skilled employees such that the total number of assigned employees is minimized. Recent literature on this problem indicates that hybrid methods that combine exact and heuristic techniques such as matheuristics prove to be efficient in generating high quality solutions for this problem. Matheuristics are methods those hybridize heuristic and mathematical programming techniques. The present work employs a constructive matheuristic (CMH); a decomposition based approach where the subproblems are solved to optimality using exact techniques. The optimal solutions of subproblems are subsequently utilized to construct a feasible solution to the entire problem. Generally multiple decomposition strategies are possible for the same problem and they lead to solutions that are substantially different in terms of the structure and solution quality. The goal of this work is to study how problem specific features can be utilized in choosing an appropriate decomposition strategy. Two decomposition strategies are implemented and their performance in terms of runtime and the final solution quality is compared. In addition, various algorithm design parameters are implemented and their effect is contrasted when aggregated with the different decomposition strategies.

4 - A math-heuristic approach for the bus driver scheduling problem for a company in Bogotá-Colombia

Juan Castillo

The bus driver scheduling problem (BDSP) is the problem of finding a covering by feasible workdays of the set of tasks assigned to a given bus company; a task is the minimum unit that the driver can perform. The BDSP is a relevant problem both in research and practice, given the complexity of its highly combinatorial decision space, and the large costs and implications it poses on the operating company and the overall urban system. The situation can be modelled by Column Generation as Desrochers and Soumis suggested in 1988. The subproblem of the Column Generation can be solved using the New Dynamic Programming introduced by Righini and Salani in 2007. In this document we describe the procedure that we used to solve the BDSP for a company that operates in Bogotá-Colombia, with 2339 tasks and 275 buses. The solution for the BDSP that we propose is capable of handling large-scale bus companies within a reasonable computational time for a weekly planning. As a pre-solve strategy we introduce a heuristic that reduces the complexity of the original problem, merging some tasks in order to reduce the number of tasks. We also suggest a systematic relaxation of the state space in the New Dynamic Programming. The proposed methodology allows to obtain solutions that match those provided by commercial software, while reducing computation time significantly.

■ TC-10

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S110

Decision Aiding Methods VII

Stream: Multiple Criteria Decision Aiding

Chair: *Salvatore Greco*

1 - On generating utility functions in stochastic multicriteria acceptability analysis (SMAA)

Luis C. Dias, Rudolf Vetschera

Stochastic Multicriteria Acceptability Analysis (SMAA) has become a popular Multi-Criteria Decision Aiding tool when some parameter values are uncertain or have not been set. SMAA methods use Monte-Carlo simulation of the uncertain values to obtain indicators that inform decision making. While there is considerable literature on sampling of uncertain probabilities or attribute weights, for example guaranteeing that sampled vectors are uniformly distributed over the unit simplex, the problem of generating utility values is addressed less frequently. In this work, we discuss several techniques for sampling utility functions, which may take into account various constraints on their shape. We review existing approaches, propose new approaches, and discuss what properties should be considered as desirable when generating utility functions. Then, we present a computational study to compare the different ways of generating random utilities, with regards to the desired properties.

2 - SURE: a method for decision-making under uncertainty

Richard Hodgett, Sajid Siraj

Managerial decision-making often involves the consideration of multiple criteria with high levels of uncertainty. Multi-attribute utility theory, a primary method proposed for decision-making under uncertainty, has been repeatedly shown to be difficult to use in practice. This talk presents a novel approach termed Simulated Uncertainty Range Evaluations (SURE) to aid decision makers in the presence of high levels of uncertainty. SURE has evolved from an existing method that has been applied extensively in the pharmaceutical and speciality chemical sectors involving uncertain decisions in whole process design. The new method utilises simulations based upon triangular distributions to create a plot which visualises the preferences and overlapping uncertainties of decision alternatives. It facilitates decision-makers to visualise the not-so-obvious uncertainties of decision alternatives. In a real-world case study for a large pharmaceutical company, SURE is compared to MARE, AHP and ELECTRE III and is shown to perform better than these existing methods.

3 - Multiple criteria hierarchy process and stochastic analysis for a nominal classification method based on similarity and dissimilarity

Ana Sara Costa, Salvatore Corrente, Salvatore Greco, José Rui Figueira, José Borbinha

With the purpose of dealing with nominal classification problems (no order among predefined categories), considering similarity and dissimilarity judgments, a multiple criteria decision aiding method was recently proposed, CAT-SD (CATegorization by Similarity Dissimilarity). A set of actions (or alternatives) are assessed on several criteria and categorized into at least one nominal category. To characterize each category, a set of reference actions needs to be defined. Interactions between criteria can be taken into account. Then, the assignment of an action to a given category depends on the comparison of such an action to the reference actions, based on a similarity degree. In complex nominal classification problems, considering criteria structured in a hierarchical way can be a useful approach. In this work, Multiple Criteria Hierarchy Process (MCHP) is adapted to the CAT-SD method. Moreover, an imprecise elicitation of criteria weights in MCHP is considered. Stochastic Multiobjective Acceptability Analysis (SMAA) is adopted to draw statistical conclusions on the assignment results by considering the sets of weights and interaction coefficients compatible with decision makers' preferences. Thus, a comprehensive method is proposed, namely SMAA-hCAT-SD, which allows the decision maker to analyse the assignment of the actions at different nodes of the criteria hierarchy. A numerical example is presented with the aim of illustrating the application of the proposed method.

4 - Robust ordinal regression and stochastic multicriteria acceptability analysis for the level dependent Choquet integral

Salvatore Greco, Sally Giuseppe Arcidiacono, Salvatore Corrente

We discuss a multiple criteria decision aiding methodology that adopts the level dependent Choquet integral to take into account importance and interaction of criteria which depend on the level of the evaluations attained by alternatives on the considered criteria. The level dependent Choquet integral is based on a level dependent capacity, which assigns a standard capacity to each level of evaluation for considered criteria. Since, in general, there is not only one but many level dependent capacities compatible with the preference information provided by the Decision Maker, we propose to take into account all of them by using the Robust Ordinal Regression (ROR) and the Stochastic Multicriteria Acceptability Analysis (SMAA). On one hand, ROR defines a necessary preference relation (if an alternative is at least as good as another for all compatible level dependent capacities), and a possible preference relation (if an alternative is at least as good as another for at least one compatible level dependent capacity). On the other hand, considering a random sampling of compatible level dependent capacities, SMAA gives information in terms of probability that each alternative reaches a certain position in the ranking of the alternatives as well as in terms of probability that an alternative is preferred to another. A didactic example will illustrate the proposed methodology

■ TC-11

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S111

Fraud Analytics

Stream: Business Analytics
Chair: *Cristian Bravo*

1 - Accounting fraud analytics for effective corporate regulation

Maria Jofre

Accounting Fraud is one of the most harmful financial crimes as it often results in massive corporate collapses, commonly silenced by powerful high-status executives and managers. Accounting fraud represents a significant threat to the financial system stability due to the resulting diminishing of the market confidence and trust of regulatory authorities. Its catastrophic consequences expose how vulnerable and unprotected the community is in regards to this matter, since most damage is inflicted to investors, employees, customers and government.

This study aims to identify signs of accounting fraud occurrence to be used to, first, identify corporations that are more likely to be manipulating financial statement reports, and second, assist the task of examination within the riskier firms by evaluating relevant financial red-flags. To achieve this, a thorough data analytic approach is proposed that includes all pertinent steps of a data-driven methodology, including the implementation of several machine learning methods for modelling fraudulent and non-fraudulent instances and further extraction of financial fraud-risk indicators.

2 - Including fine-grained features in customs fraud detection

Jellis Vanhoeyveld, David Martens, Bruno Peeters

The trade-off between ensuring trade facilitation and imposing regulatory control is a major concern for customs administrations worldwide. The growing levels of international trade and the limited resources of customs have led governments to invest in data mining techniques to target specifically the high risk cases. In this fraud detection application, we analyse a unique dataset of 9.624.124 records resulting from a collaboration with the Belgian customs administration. We focus on two gaps in the customs fraud detection literature: (1) the class imbalance problem is rarely addressed, yet this poses a major challenge for many classifiers. We propose a new implementation of the EasyEnsemble algorithm that integrates a confidence rated support vector machine in the boosting process to overcome the class skew problem. (2) Fine-grained features (e.g. supplier, importer, commodity codes, country of origin) are often neglected or included through creating artificial low-dimensional derived attributes. We show that such fine-grained information available at identifier level is very predictive for customs fraud detection (in terms of AUC and lift) and that applying imbalanced learning solutions provides significant improvements to the baseline. Our results have an immediate impact on the customs fraud detection domain through an improved retrieval of tax losses and an enhanced deterrence.

3 - From one-class to two-class classification by incorporating expert knowledge

Dieter Oosterlinck, Dries Benoit, Philippe Baecke

In certain business cases the aim is to identify observations that deviate from an identified normal behaviour. It is often the case that only instances of the normal class are known, whereas so called novelties are undiscovered. Novelty detection or anomaly detection approaches usually apply methods from the field of outlier detection. However, anomalies are not always outliers and outliers are not always anomalies. The standard one-class classification approaches therefore underperform in many real business cases. Drawing upon literature about incorporating expert knowledge, we come up with a new method that significantly improves the predictive performance of a one-class model. Combining the available data and expert knowledge about potential anomalies enables us to create synthetic novelties. The latter are incorporated into a standard two-class predictive model. Based on a telco dataset, we prove that our synthetic two-class model clearly outperforms a standard one-class model on the synthetic dataset. In a next step the model was applied to real data. Top identified novelties were manually checked by experts. The results indicate that incorporating expert knowledge to transform a one-class problem into a two-class problem is a valuable method.

4 - A text analytics-based decision support system for detecting fraudulent car insurance claims

Cristian Bravo, Andres Medina, Rodrigo Joannon, Richard Weber

Car insurance is a highly competitive business line in the insurance industry. Companies face a very large number of claims year-on-year and must decide carefully when to doubt a given claim, or when to simply cover the accident without question. In this presentation, we will show the results of a decision support system that ranks claims by their level of risk, suggesting which claims should be checked by an expert agent from the insurance agency. The decision support system analyses both common structured data, such as claim times and claimant information, and the report made by the claimant in free-text format. We show different strategies to deal with the text information, from using simple bag-of-words models, to much more complex embeddings using transforms such as Latent Semantic Analysis and fastText embeddings. Both sources of data, text-based and structured, are then used to create different predictive models estimating the probability that any given claim is fraudulent. Results indicate that there are clear gains in using more sophisticated models, but that data quality, specially having reliable fraud labels, might force the use of simpler models. We also will discuss how these models change business practices, by streamlining fraud detection as part of the day-to-day operation of insurance companies.

■ TC-12

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S112

Maritime Transportation

Stream: Maritime Transportation
Chair: *Yauheni Kisialiou*

1 - Integrating fleet deployment into liner shippingvessel repositioning
Kevin Tierney, Daniel Wetzel

Liner carriers must regularly adjust their shipping networks to respond to competitors and ever-changing customer demands. Ships must be selected and moved between routes to facilitate network changes. State-of-the-art approaches decompose this into two separate problems. Fleet deployment concerns the selection of a vessel or class of vessel for a particular route, while fleet repositioning deals with the minimal cost transit of a vessel from one route to another. We propose an integrated mathematical model for the liner shipping fleet deployment and repositioning problem (LSFDRP) that jointly optimizes the choice of vessels for routes and the cost of moving vessels to their assignments. We use real-world data to show that simultaneously optimizing deployment and repositioning can result in a cost reduction of up to 3.1 million USD over solving the problems independently. Furthermore, we evaluate our model on a number of different scenarios and configurations of charter vessels and route types to show when and where decision makers in the industry can expect gains from an integrated approach.

2 - The effects of the ultra large container ship on port choice and call size
Nemanja Milovanovic

Container liner shipping companies are currently undergoing heavy competition due to market overcapacity. This has pushed many companies to pursue economies of scales by ordering ever bigger container ships. In 2009, the biggest container ship could accommodate up to 14,000 TEU. Today, ships are ordered by MSC and CMA CGM to be completed in 2019 and 2020, which are estimated to carry at most 23,800 TEU: an increase of nearly 10,000 TEU in 10 years time. This increase in container ship size does not only bring about potential economies of scale for liner shipping companies, it also puts pressure on ports. In order for ports to be able to accommodate larger container ships, sizable investments in infrastructure need to be made. On top of that, it is envisaged that hub-and-spoke networks get more dominant. Thus, ports located in the same region need to compete for hub status, or specialize in other areas, for example in facilitating transshipments. In this study, we investigate primarily how container ship growth affects port choice and port call size. This is done by assuming that the liner shipper faces the Liner Shipping Network Design Problem, and considering a range of different scenarios to determine optimal network configurations. The main novelty of this approach (compared to existing literature in economies of scale in shipping) is the use of operations research and the inclusion of hinterland locations in the network optimization model.

3 - Contracting in ocean shipping market with empty container repositioning under asymmetric information
Mingzhu Yu, Ruina Yang, Chung-Yee Lee

We study a two-port system consisting of one carrier and two shippers, providing maritime transportation services between two container ports in the international trade. We model the contracting problem in a setting with one carrier and two shippers under asymmetric information as a two-stage game. Empty container repositioning of the carriers is considered. We explicitly analyze the two shippers' opportunity cost functions and the optimal contract strategy for the carrier. The impacts of the information asymmetry and the empty container transportation imbalance are investigated.

4 - Robust supply vessel planning under weather and demand uncertainty
Yauheni Kisialiou, Irina Gribkovskaia

In upstream offshore oil and gas logistics, supply vessel planning is important since it ensures the replenishment of offshore installations with the necessary materials and equipment on a regular basis from an onshore base. The periodic supply vessel planning problem involves the determination of the fleet composition and the repetitive vessel weekly schedule valid for a certain time horizon. Oil and gas operators require reliable and continuous vessel service since the downtime of an installation is too costly. The challenge is that the performance of the vessel schedule is affected by both uncertain weather conditions and uncertain and varying demands from installations. Uncertain weather conditions influence both sailing and service times leading to delays on vessel voyages. Uncertain demand may lead to inability to deliver all cargo according to schedule due to insufficient vessel capacity and insufficient number of scheduled departures from base. These uncertainties result not only in the reduced service level but as well in added costs of using more vessels. Planners aim to create vessel schedules with sufficient robustness against weather and demand uncertainty to avoid frequent schedule disruptions. In our study, we present an optimization-simulation method for construction of supply vessel schedules robust against uncertain demand and weather conditions. The method is based on the adaptive large neighborhood search algorithm and the discrete event simulation model.

■ TC-13

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S201

Financial Literacy and Investment Choices

Stream: Financial Modeling, Risk Management and Managerial Accounting
Chair: *Rosella Castellano*

1 - Money's importance from the religious perspective
Claudiu Herteliu, Ionel Jianu, Iulia Jianu, Catalin Vasile Bobb, Gurjeet Dhesi, Marcel Ausloos

Is there any difference among religious groups in regards to the money's importance? Different religions (and denominations) perceive the money's importance in various ways. Religion is an important factor which drives human believes and behavior. Previous studies signaled such interferences between economics/ money and religion. Therefore concepts like "money as a tool and as a drug" or "love of money scale" has been addressed before. Our dataset rely on a sample (n1=842) from Romanian adult population. In order to make statistical comparisons between groups eight small religious groups has been observed via additional interviews (n2=210). The direct interviews have been performed at the respondents' homes. A large (15 pages) questionnaire is used; the current research focus on nine questions (items) regarding individual perceptions about money. For each item a cross-tabulation is performed. The statistical significance of the differences is checked with a Chi Square test. A selection of control factors is used: (i) age; (ii) education; (iii) households' income; (iv) gender and (v) religious behavior. Usual limitations of data obtained via a random survey are applicable (e.g. partial or total non-responses). To our knowledge, this is the first research which puts together the battery of nine items focused on individual perceptions regarding money on a population segmented by self declared religious affiliation.

2 - Financial literacy: systematic literature review and future research agenda
Sebastian Ion Ceptureanu

Nowadays, individuals are increasingly facing challenges related to their financial decisions. But are they properly equipped, given the more complex financial instruments at their disposal and financial institutions practices in promoting these products? In the literature there is evidence that many individuals lacks the knowledge to make sound financial decisions. As such, this paper conducts a comprehensive literature review on Financial Literacy (FL) in order to identify current state of the art and research trends and to outline a future research agenda on this topic, given FL implications has on individuals, communities or society as a whole.

3 - The explanatory power of financial literacy on consumer financial behaviors: new evidences from Europe
Gianni Nicolini, *Marlene Haupt*

The development of the financial markets with sophisticated investment products, as well as the evolution of the welfare systems in several countries with a shift of responsibility to individuals about pension planning and retirement needs are two examples of the increased relevance of financial literacy in people life: the need to take a financial decision and the relevance of these decision on consumer financial wellbeing are today much more serious than just few years ago. If several studies tried to investigate the role of financial literacy in avoiding financial mistakes and finding a relationship with good financial practices, results about the key role of financial literacy in explaining consumer financial behaviors are not always clear. This study uses new data from a consumer research project collected in different European countries (Italy, Germany, Sweden, the UK) to investigate how alternative measures of financial literacy can help to explain the relationship between financial literacy and financial behaviors. Results seems to confirm the hypothesis that when financial literacy is assessed using items that are not limited to general financial principles and are related to specific areas of knowledge, the relevance of financial literacy on consumer financial decisions is more evident than previous studies.

4 - What if versus probabilistic financial investment scenarios: a behavioural and physiological investigation
Rosella Castellano, *Gaetano Tieri*, *Giorgia Ponsi*, *Marco Mancinelli*

In this paper we propose a study aimed at objectively measuring the impact of Probabilistic and What If scenarios related with financial decisions through a close look inside consumers' nervous system. In particular, we aim to investigate the behavioural and physiological indexes elicited in the decision-making process of consumers facing the two above mentioned types of scenario. The sample of investors will be stratified according to ISTAT data. The study will be conducted in laboratory and the tasks will be implemented by means of customized software. Participants will complete the tasks by using a standard PC monitor. In particular, they will be asked to (1) fulfill a financial education questionnaire and (2) to complete the financial investment task. The task comprises twenty-two trials including Probabilistic and What-If scenarios. Each trial consists of two financial products where one of them stochastically dominates the other. Participants will be asked to make 22 financial choices during which behavioural and physiological indexes will be recorded. In particular, the behavioural measures will include the (1) accuracy of the financial decision and the (2) reaction time (RT) associated to each decision (i.e. the time spent to make the decision). The physiological measures will include Galvanic Skin Responses (GSRs) and Heart Rate (HR), both considered as reliable indexes of stress level and cognitive load during the decision-making process.

■ TC-14
Tuesday, 12:30-14:00 - SOUTH BUILDING UV S202

Optimization Algorithms on Riemannian manifolds

Stream: Nonlinear Programming: Methods
Chair: *Orizon P Ferreira*
Chair: *Chong Li*

1 - A two-phase proximal-like algorithm in domains of positivity
Paulo Oliveira

This paper improves and extends a proximal-like algorithm, developed for computing minimums for convex functions within the framework of symmetric positive semidefinite matrices, to domains of positivity of reducible type, in a nonlinear sense and in a Riemannian setting.

2 - Some tools in geometric optimization
Genaro Lopez

In recent years considerable efforts have been done to extend concepts and results from the Euclidean/Hilbert context to settings with no vector space structure. We analyze the problems which appear when we consider some of these concepts, as the metric projection, the normal cone or the subdifferential, in the setting of geodesic spaces. Special attention is dedicated to Riemannian manifolds.

3 - Newton's method for semismooth vector field on Riemannian manifolds
Orizon P Ferreira, *Fabiana R. de Oliveira*

The goal of this paper is twofold. First, we generalize some results of nonsmooth analysis, from Euclidean context to the Riemannian setting. Next, we present Newton's method for finding a singularity of a locally Lipschitz continuous vector field and its convergence properties. Under the assumptions of semismoothness and regularity at the singularity we establish the well-definedness of generated sequence by the method in a neighborhood of this singularity. We also show that this sequence converge for the solution with superlinear or quadratic rate, under suitable conditions.

4 - Proximal point method for locally Lipschitz functions in multiobjective optimization on Hadamard manifolds
Glaydston Bento, *João Xavier da Cruz Neto*, *Lucas Vidal*

In this talk, will be presented a proximal point method for nonsmooth multiobjective program in the Riemannian context. In our approach it is explored an optimality condition, for multiobjective problems, which does not use scalarization and, consequently, allowed us to consider the method without any assumption of convexity over the constraint sets that determine the vectorial improvement steps. Our main result of convergence assures that each cluster point (if any) of any sequence generated from the method is a Pareto critical point. Moreover, when the problem is convex on Hadamard manifold it follows the full convergence of the method for a weak Pareto optimal.

■ TC-15
Tuesday, 12:30-14:00 - SOUTH BUILDING UV S203

Real-Life Vehicle Routing II

Stream: Vehicle Routing and Logistics Optimization II
Chair: *Ramin Raeesi*

1 - The 3L-VRPTW with advanced real-world loading constraints
Corinna Krebs, *Henriette Koch*, *Andreas Bortfeldt*

In the three-dimensional loading vehicle routing problem with time windows (3L-VRPTW), three-dimensional cuboid items have to be transported from a central depot to a given set of customers using a homogeneous fleet of vehicles. Each route must be provided with a feasible packing plan taking different packing constraints into account. In addition, time windows are considered here. The objective is to minimize the number of vehicles and the total routing costs.

This problem is a combination of two well-studied combinatorial problems: the vehicle routing problem and container loading problem. In the proposed hybrid approach, an Adaptive Large Neighborhood Search is used for solving the routing subproblem. The procedure is combined with a Deepest-Bottom-Left-Fill algorithm to ensure the feasibility of the obtained solutions with respect to the loading subproblem.

The focus of this paper is on the examination of loading constraints currently considered in the literature regarding their purpose and issues. As a result, new improved definitions and implementation variants such as of stacking and stability constraints are introduced in order to provide a more realistic formulation. Their impact on the objective function value is tested by using well-known instances.

2 - Integrated routing and scheduling of salt trucks with replenishment in urban areas

Sorour Zehtabiyan, Gultekin Kuyzu, Eda Yücel

Timely salting of roads before the snowfall is an important preventive activity for improving traffic safety and avoiding traffic congestions. We study the problem of routing and scheduling of salt trucks on a city road network. In this problem, the vehicle fleet consists of heterogeneous vehicles that differ in salt capacity and there are multiple salt replenishment points. At the beginning of the current planning horizon, given a set of salt needing roads with different urgency levels, the vehicles start from different points of the network (i.e., their final locations at the end of the former planning horizon) and should cover all salt needing roads with the objective of minimizing the total weighted completion time of salting operation of each service needing arc. Each service needing arc should be serviced by exactly one vehicle, however, can be traversed for deadheading by a vehicle as part of its route. Vehicles visit replenishment points when they run out of salt. We first develop a Mixed-Integer Programming model for the problem. Since the performance of the model degrades rapidly as the problem size increases, we propose a two-phase heuristic, which obtains an initial solution by a constructive heuristic in the first phase and then improves the solution by a neighborhood search algorithm. The efficiency of our solution approach is evaluated on randomly generated instances reflecting real-life road networks.

3 - An optimization model for the raw material pick-up process of a CGC through VRP

Lara Kasirga, Y. Ilker Topcu

Systematic vehicle routing usually remains unutilized by companies due to its puzzling structure as well as its complexity to be solved. The application of an advanced program to solve this puzzle would lead to higher profit and employee motivation. A well-known international consumer goods company deals with 1327 types of raw material and aims to lower transportation costs arising from the pick-up of raw materials from 17 suppliers across Turkey. Currently formed intuitively, the routes for the vehicles rented for the pick-up process are not sufficient both in terms of cost and time elapsed to form the routes. An integer programming model was developed and implemented on Microsoft Excel to obtain optimal (lowest cost) routes: an add-in called Open Solver was utilized. This user-friendly approach was made further flexible by the help of an interface created via VBA. Upon introducing current inventory levels, demand forecasts and vehicle capacities; the program calculates the raw material requirements, optimal vehicle routes and minimum number of vehicles needed for the pick-up process. The objective of automatically finding optimal solution in a short time was achieved by lowering the current manual computing time of 1 hour to about 9 seconds. The program achieved 250% reduction in number of vehicles to be rented, 150% reduction in distance travelled and 6500% improvement in the computation time.

4 - The robust multi-objective pollution routing problem on urban roadway networks

Ramin Raeesi, Konstantinos G. Zografos

In this study a robust multi-objective, time and load dependent, fleet size and mix Pollution Routing Problem (PRP) with multiple trips, time windows, and flexible departure times is formulated and solved on urban roadway networks. The proposed variant is robust against the inevitable inaccuracy in the estimation of the fuel consumption of trucks due to the lack of instantaneous truck acceleration data. Acknowledging the fact that for emissions minimisation in a time-dependent setting it is not possible to determine a priori a single road-path for travelling between each pair of customers, an exact Path Elimination Procedure (PEP) is proposed. A MILP based on the proposed PEP is developed and embedded within an efficient mathematical programming technique for the identification of the full set of the non-dominated solutions to the problem. We report results from the performance of the proposed PEP, and the comparison of the robust and the deterministic versions of the model on test networks.

■ TC-16

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S115

Green Logistics Applications

Stream: Green Logistics
Chair: *Panagiotis Angeloudis*

1 - Maritime vessels bunkering problem under the window time constraint

Mouna Aissaouislaoui, Mohamed Benslimane, Tarik Zouadi, Khalid El Yassini

The Bunkering is considered as a generic service that consists of supplying vessels with fuels necessary for propulsion. Indeed the problem of tankers management in ports is a critical issue that directly affects the efficiency and performance of any port, and directly influences the quality of services offered to vessels. The companies managing these activities must lean on very advanced planning tools to manage flows and ensure the quality required. This paper deals with the problem of bunker-refueling vessels assigning to meet the demands of their customers over a planning horizon. More specifically, we will address a problem of maritime routing with multi-compartments tankers ensuring refueling under time window constraints. The objective is to serve a set of customers using a set of multi-compartments tankers. It is assumed that tankers have a limited capacity and each compartment is dedicated to a product. An integer linear programming model is proposed that takes into account various scheduling and routing constraints, availability related constraint, location of vessels and tankers capacity constraints. In addition, time window constraints are integrated into the proposed model. The model applies penalties on vessels in the case they requires service out of the time window that they have advanced. The study proposes a hybrid resolution approach to solve the problem. The numerical results prove the quality of the proposed method in term of quality and execution time.

2 - Charging station placement in free-floating electric car sharing systems

Georg Brandstätter, Markus Leitner, Mario Ruthmair

Free-floating electric car sharing systems are a modern and environmentally-friendly mode of transportation that offers its customers much the same flexibility as owning a car while simultaneously reducing tailpipe emissions and improving operational efficiency. Since electric vehicles must be regularly recharged, a network of charging stations has to be built within the system's operational area where cars can occasionally be parked and recharged between rentals. We present a branch-and-price algorithm that solves the problem of finding optimal locations and sizes for charging stations within such systems. Our goal is to place them throughout the operational area in a way that covers as much of the expected customer demand as is possible with the given budget. The system's free-floating nature allows customers to use any car available nearby, as well as to end their trip anywhere within the system's operational area. Our model explicitly considers expected user behavior in that we assume customers will usually prefer closer vehicles and final parking spots. They are, however, incentivized by lower rental fees to return cars with low battery to a nearby charging station instead, which helps prevent vehicles from becoming stranded. We analyze the performance of our algorithm on a set of benchmark instances that is based on real-world data from Vienna.

3 - A competitive multiperiod supply chain network model with freight carriers and green technology investment option
Jose Cruz, Sara Saberi, Joseph Sarkis, Anna Nagurney

This paper presents a multiperiod supply chain with the freight carriers network model. In this model manufacturers, retailers, and carriers maximize the net present value (NPV) of their investments in ecologically friendly technology. Future production, inventory, transaction, and transportation costs savings are used to help fund investments. The environmental impact of production, inventory, transportation, and consumption of products in the supply chain network are all integrated. The tradeoff between the initial technology investment and its ecological footprint effect are considered for the supply chain planning period. We provide variational inequality formulations of the equilibrium conditions and then propose the modified projection method, along with conditions for convergence. Numerical examples are examined with an analysis of the effects of ecologically friendly technology investments on supply chain network production, transportation, and sales.

4 - Design of intermodal sustainable supply chains using inland waterways
Panagiotis Angeloudis, Pablo Achurra-Gonzalez

Freight transport in Latin America has been characterized for its high dependency on freight truck transport, which in return generates high levels of greenhouse gases (GHG), tailpipe emissions of nitrogen oxides (NOx) and particulate matter (PM) that negatively impact the health of the population. This reliance on road freight increases total logistic costs for exporting and importing goods while noxious emissions impact national health costs and increase mortality, which affects the productivity and competitiveness. We present a mathematical model for intermodal network design, developed and applied to case study in Colombia. The model designs a new intermodal network of zero-emission barges along the Magdalena River to reduce freight truck emissions and increase the logistics transport competitiveness. The proposed model seeks to address the disadvantages of the current facility location models by representing in a more holistic and realistic way the impact on society by splitting the costs paid by shippers, terminal operators and the community (represented by the negative impact of freight emissions and high logistics costs). In this way, the model has a bi-level structure with a network design on the upper level and a container assignment on the lower level. The lower level is based on a linear model that takes into consideration important logistical elements of the assignment of containers based on the recently cost-based maritime container assignment model.

■ TC-17
Tuesday, 12:30-14:00 - SOUTH BUILDING UV S205

Robust Optimization - Theory and Applications

Stream: Stochastic and Robust Optimization
Chair: *Chungmok Lee*

1 - Uniform distribution approach in chance constraint stochastic transportation problem
Shubham Singh, M.p. Biswal

This paper intends to give a general formulation of solid transportation problem where the parameters are uncertain. These uncertainties come in the transportation problem, because of weather condition or road condition or market mode, etc. There are several possibilities of the uncertain parameters. Sometimes these uncertainties characterized by random variables and sometimes these are given into bounded set. Here, we have considered that the parameter related to transportation cost is uncertain and which follows uniform random variables with known means and variances. To solve the problem efficiently, First, we have estimated the distance between the distribution of the sum of these independent uniform random variable and normal distribution. Obtained the deterministic form of the probabilistic constraints via Essen inequality. After obtaining the deterministic model, any standard mathematical programming technique is applied to solve the problem. Finally, a numerical example is presented to illustrate the model and methodology.

2 - Robust stochastic network flow interdiction
Joe Naoum-Sawaya

We present a decomposition approach for the Robust Stochastic Optimization of the Maximum Network Flow Interdiction Problem. The proposed approach considers fairly general uncertainty sets. Computational results are presented to compare the performance of the proposed approach over the solution of the full problem in standard optimization solvers.

3 - Robust scheduling with common due-date and interval processing times uncertainty
Maciej Drwal

We consider the robust version of scheduling problem on a single machine, where a set of jobs with uncertain processing times is given along with a common due-date. The objective is to sequence the jobs so that the total weight of on-time jobs is maximized. In order to hedge against interval uncertainty, the maximum regret of solutions is considered. The problem is related to the knapsack problem with uncertain item sizes. We present computational complexity results for weighted and unweighted variants of the problem, and present exact and heuristic solution algorithms. Mixed-integer programs are given for computing worst-case scenarios, and bilevel formulations are used to develop solution methods. The robust optimization algorithms are based on specialized branch and bound schemes. The solution methods are examined in a series of computational experiments on randomly generated data sets using different distributions of uncertain data. The results are compared with solutions obtained using mid-point scenario heuristic.

4 - A bi-label programming approach for robust transit-line planning problem
Chungmok Lee, Rahul Nair

The line-planning problem seeks to determine the set of fixed routes (or lines) a transit operator should run, along with associated operation frequencies. We propose an optimization algorithm for the transit-line-planning problem based on bi-level programming and a robust optimization approach that exploits the structure of the problem in conjunction with the range estimation of demands. The validity of the proposed algorithm is demonstrated by using real-world data derived from 2.5 billion call data records from Abidjan, Cote dIvoire.

■ TC-18
Tuesday, 12:30-14:00 - SOUTH BUILDING UV S206

Understanding the Practice of Problem Structuring Methods

Stream: Soft OR, Problem Structuring Methods
Chair: *Mike Yearworth*

1 - Applying a context and action framework to evaluate the interactions between the context, content, and process of problem structuring methods
Adrian Small, David Wainwright

Understanding the practice of problem structuring methods and multimethodology has been a persistent theme within the literature. Whilst approaches have been put forward, this question is still relevant and remains a key focal point within the debate. Due to the many problem structuring methods available and the many configurations that they have and which can be combined, it is not surprising the question persists. Studies that have applied problem structuring methods to practice usually apply some form of evaluation, but these evaluations primarily focus on the methods themselves, and how successful they have been in tackling the problem situation. This work draws on a management studies framework that looks at the context, content, and process of strategic change, and applies it to two case studies in order to understand the practice of using problem structuring methods. The framework is used to look at the domain holistically, as the problem structuring methods literature has identified that interventions are not sequential, orderly, or linear in nature as well as having to take stakeholders, socio-political, and organizational routines and norms into account. By drawing on this framework and tracing the interactions between the context, content, and process, it is proposed that a better understanding can be obtained of problem structuring methods in practice.

2 - Examining the case for the routine use of problem structuring methods as a stimulus for anticipatory organisational change

David Lowe, Karen Clark, Gerald Midgley, Mike Yearworth

The vast majority of organisational change is triggered in reaction to performance issues that threaten the viability of the organisation. The use of Problem Structuring Methods (PSMs) has proven to be very effective in guiding the interventions that follow by helping stakeholders to define the problem (problematisation) and to recognise that they will be affected by it and/or could have a role in resolving it (interessment). This reactionary use of PSMs is typically facilitated by external consultants operating under time pressures that limit their ability to fully access the organisation. This presentation examines the case for the routine internal use of PSMs to guide interventions in anticipation of performance issues. In particular it considers how PSMs could bring enhanced levels of 'mindful organising' through integration within existing business processes, with reference to a longitudinal case study drawn from the United Kingdom Ministry of Defence.

3 - Quantifying the value of problem structuring interventions?

Mike Yearworth, Patrick Tully, Leroy White, Katharina Burger

We review the current work on measuring and evaluating PSM interventions and return to the paradox of trying to determine a specific monetary value. In an attempt to resolve the paradox, we have borrowed freely from economic theory and constructed a scenario where the question of value can be investigated through the effect that a problem structuring intervention will have on information asymmetry in contract formation. This suggests an avenue of research where the value of problem structuring interventions can be investigated empirically. We discuss the difficulties of research design to investigate this question but also the potential benefits.

■ TC-19

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S207

Vector and Set-Valued Optimization VII

Stream: Vector- and Set-Valued Optimization

Chair: *Enrico Miglierina*

1 - Saddle point conditions for weak and proper efficiency in vector optimization

Giandomenico Mastroeni

We consider saddle point conditions for the generalized Lagrangian associated with a cone constrained nonconvex vector optimization problem. We establish a necessary and sufficient condition for the existence of a saddle point in case the multiplier vector related to the objective function belongs to the quasi interior of the polar of the ordering set. Moreover, exploiting suitable Slater-type constraints qualifications involving the notion of quasi-relative interior, we obtain several results concerning the existence of a saddle point, which allow us to obtain optimality conditions for a weak and a proper efficient solution of a vector optimizaton problem. Such results generalize to the nonconvex vector case existing conditions in the literature. Particular attention is devoted to bicriteria problems where optimality conditions are stated, both in a geometric form and by means of the level sets of the objective functions.

2 - On the existence of solutions to quasiequilibrium problems

Massimiliano Giuli

Several results concerning existence of solutions of a quasiequilibrium problem defined on a finite dimensional space are established. The proof of the first result, which holds when the feasible region is a compact set, is based on a Michael selection theorem for lower semicontinuous set-valued maps. Furthermore this result allows one to locate the position of a solution. Sufficient conditions, which are easier to verify, may be obtained by imposing restrictions either on the domain or on the bifunction. These facts make it possible to yield various existence results which reduce to the well known Ky Fan minimax inequality when the constraint map is constant and the quasiequilibrium problem coincides with an equilibrium problem. Lastly if the feasible region is not bounded, a coercivity condition is assumed for the bifunction.

3 - Stability of convex feasibility problem: the finite dimensional case

Enrico Miglierina, Carlo Alberto De Bernardi, Elena Molho

The convex feasibility problem is the classical problem of finding the intersection of a finite collection of closed and convex sets. Many concrete problems in applications can be formulated as a convex feasibility problem. As a typical example we mention the problem of image reconstruction. The aim of this talk is to investigate the stability properties of a 2-sets convex feasibility problem. In particular we consider two sequences of sets, each of them converging, with respect to a suitable notion of set convergence, to a given set. We present some assumptions on the original problems that are sufficient to ensure that the solutions of the perturbed problems converge to a solution of the original problem. In this talk we focus on the case of a convex feasibility problem settled in a finite dimensional normed space.

4 - Stability for the convex feasibility problem: the infinite-dimensional case

Carlo Alberto De Bernardi, Enrico Miglierina, Elena Molho

Given two closed convex sets A and B in a normed space, the convex feasibility problem asks to find a point in the intersection of A and B. More generally, we can consider the problem of finding (if possible) two points in A and B, respectively, which minimize the distance between A and B.

During the talk we present some results concerning stability properties of the convex feasibility problem in infinite-dimensional Banach spaces. Let us consider two sequences of sets converging to A and B, respectively (with respect to a suitable notion of set convergence). Easy examples show that, even in the case A and B are subsets of a Hilbert space and the intersection of A and B reduces to a point, the solutions of the perturbed problem do not converge, in general, to a solution of the problem for the sets A and B. In this context, we obtain stability results under an additional geometric assumption on the limit sets (namely, locally uniformly rotundity). We also provide some examples that point out the necessity of our assumption even in a Hilbert space framework.

■ TC-20

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S301

Multiattribute and Bayesian Methods in Decision Making and Negotiation

Stream: Decision Analysis and Decision Support Systems

Chair: *Ilkka Leppanen*

1 - On rationality conditions for multi-attribute choice behavior
Pekka Korhonen, Jyrki Wallenius, Tolga Genc, Peng Xu

This paper deals with rationality conditions for choice behavior. It bears similarity to Samuelson's Revealed Preference Theory, although it deviates from it in significant ways. However, like Samuelson, we are interested in rationality conditions for consumers (decision makers in general). We explore two different types of choice settings: (1) Win-Win setting, where consumers consider which goods they want to add to their basket, (2) Tradeoff setting, where consumers make pairwise choices between different (efficient) baskets, where they have to give up in some goods to gain in other goods. We study the decision-maker's rationality conditions in both settings. We do this by introducing conditions, which an outside observer can use to judge, whether the choices are rational or not. The basket is filled either with different or identical goods. The key underlying theoretical assumptions in our paper are increasing and concave single dimensional utility (value) functions with decreasing marginal values and the Kahneman-Tversky Prospect Theory model of choice with loss aversion. We use an empirical experiment to illustrate our considerations.

2 - A bilateral negotiation model using a Bayesian process of beliefs updating
María Jesús Rufo Bazaga, Jacinto Martín, Carlos Javier Pérez Sánchez

Because of huge competition in industrial and commercial issues, manufacturers are interested in offering products with suitable reliability characteristics such as the lifetime. This work presents a Bayesian sequential negotiation model between two agents (a manufacturer and a consumer) based on product lifetime. The main goal for the manufacturer is the sale of the product batch. In order to convince the consumer, a product sample for making life testing will be considered. A mediator's presence is not required. Thus, the manufacturer interacts with the consumer directly. In addition, the manufacturer does not have knowledge about the judgments of the consumer. The decision problem is solved under the manufacturer viewpoint. Then, a simulation-based approach is implemented. It allows to update the manufacturer's beliefs about the consumer's judgments and, thus, to obtain the optimal sample size that the manufacturer should offer the consumer. Finally, an application is presented and discussed in order to show that the proposed technique is easily applied in practice.

3 - Bayesian factorization machines for risk management and robust decision making
Pablo Angulo, Víctor Gallego, David Gómez-Ullate, Pablo Súarez-García

When considering different allocations of the marketing budget of a firm, some predictions, that correspond to scenarios similar to others observed in the past, can be made with more confidence than others, that correspond to more innovative strategies. Selecting a few relevant features of the predicted probability distribution leads to a multi-objective optimization problem, and the Pareto front contains the most interesting media plans. Using expected return and standard deviation we get the familiar two moment decision model, but other problem specific additional objectives can be incorporated. Factorization Machines, initially introduced for recommendation systems, but later used also for regression, are a good choice for incorporating interaction terms into the model, since they can effectively exploit the sparse nature of typical datasets found in econometrics.

4 - Decision support system for search engine advertising campaign management by determining negative keywords
Başak Tavşanoğlu, Kemal Kilic

Search engine advertisers need to determine the best keyword set for their campaigns. Every company has particular constraints and expectations from the Search Engine Advertising (SEA). In this research we developed a Decision Support System (DSS) that can be used in SEA campaign management. The DSS determines the negative keywords (which should be eliminated from the keyword set in order to improve the performance) based on the data obtained from the earlier campaigns. Current metrics used to determine the negative keywords are not sufficient/adequate, since they don't incorporate other important aspects such as bounce rate, quality score etc. which are often used by the advertisers in order to evaluate the traffic but rely mostly to conversion rate. In our research first we analyze the keywords at unigram level (similar to some of the existing approaches available in the literature) in order to identify the set of unigrams which are negatively and/or positively effecting the campaign by using various machine learning techniques (either as is or used the core concepts associated with them) such as Naïve Bayes, Decision Trees, Logistic Regression and Association Rule Mining. We also introduced novel metrics which incorporate more aspects used in real life SEA campaigns by the advertisers as part of this process. The performance of our approach is evaluated with an experimental analysis conducted on real life data obtained from a major FMCG producer.

■ TC-21

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S303

Games and Networks

Stream: Convex, Semi-Infinite and Semidefinite Optimization
Chair: *Laura Rosa Maria Scrimali*

1 - Myerson value and position value in network games
Ayşe Mutlu Derya

We provide an axiomatic characterization of the Myerson value with two axioms. Our first axiom considers a situation where there is a change of the value function at a network g and at each network containing g. It requires that at such a situation, this change must be divided equally between all the players in g that has at least one link at g. Our second axiom is a condition on the value function where the value of each network is zero. It requires that if the value is zero at each of the possible networks, then each player must get zero payoff at each network. By changing our first axiom slightly, we also give a characterization for the position value. A natural comparison of the two value operators arises by our results.

2 - Bridging effect, simple games, and an importance measure for edges
Jia-Ping Huang

A bridge of a network is an edge whose removal increases the number of components of the network. Though this concept captures the importance of edges through the effect of bridging, it is too restrictive as an importance measure function because of its binary value. We propose a new importance measure for edges capturing the bridging effect by focusing on cutsets, which are groups of edges whose removal together increases the number of components. We consider a random removal process of edges of a given network where in each step an edge is removed until there is no edges remained. Each realization of this process results in a series of growing cutsets. We define our measure as the probability that the edge under consideration becomes the one who completes the first (minimal) cutset in this process. We provide another equivalent definition by considering spanning subnetworks in a random reconstruction process of the original network. We then link our measure to the Shapley values of two simple games defined on the edge set of networks. Structural as well as game theoretical properties of the proposed measure are discovered, such as the normalization property, the bridge-get-the-most property, the auto-invariance property, etc. By utilizing the transfer property of the Shapley value of simple games, we also provide an alternative formulation of the proposed measure which in many cases leads to a great efficiency in evaluation.

3 - Types of nodes and centrality measures in networks
Vladimir Matveenko, Alexei Korolev

Equilibrium behaviors in games on network are often explained by centralities of players. We show that several centrality measures (CM) (degree, eigenvalue centrality; Katz-Bonacich centrality; diffusion centrality; alpha centrality) do characterize not just separate nodes but types of nodes. Networks of different size but the same typology have common properties in economic models,; in particular, game equilibria may be transplanted among them. The concept of typology is based on the fact that the nodes in any undirected graph may be colored in a minimal number of colors in such way that each node of a color is characterized by numbers of neighbors of different colors. A typology is described by a matrix T, which for any type shows numbers of neighbors of different types. For any typology, if i an j are nodes of the same type (may be even belonging different networks of the same typology), then (i)=c(j), where c is any of the abovementioned CM. For calculation of these CM, the matrix T may be used instead of the adjacency matrix. Bloch et al., 2017 formulate a problem: for which classes of networks each of a set of several CM defines the same order on the set of nodes of network? As such a class of networks, they find a class of trees - regular monotonous hierarchies. We show that such classes are not limited by trees: any network typology with two types of nodes has this property for the abovementioned CM set.

4 - Coalitional games in evolutionary supply chain networks
Laura Rosa Maria Scrimali

We present a supply chain network that consists of three layers of decision-makers, namely, suppliers, manufacturers and retailers, with prices and shipments that evolve in time. We focus on the vertical integration of the levels of the supply chain and propose that the retailer is the dominant player of the coalition. We give the equilibrium conditions governing the model and provide an equivalent evolutionary variational inequality formulation. Our research then applies results of infinite-dimensional duality theory to study the stability of coalitions.

■ TC-22

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S304

Multiobjective Integer and Mixed Integer Programming Problems: Methods and Applications I

Stream: Multiobjective Optimization
Chair: *Ozlem Karsu*
Chair: *Firdevs Ulus*

1 - A novel multi-objective approach for sustainable aggregate production planning: a case study
Seyyed Amir Babak Rasmi, Metin Turkay, Cem Kazan

Supply chain management is a concept that uses a wide range of tools to be improved. Aggregate production planning (APP) is one of the approaches that determines production rates, inventory levels, and workforce requirements for fulfilling customer demands in multiple periods of time. Traditional APP models focus on a single objective function to optimize monetary issues. However, we present a novel multi-objective APP model to consider economic, social, environmental, and cultural issues simultaneously. This multi-objective APP with mixed-integer variables is connected to the sustainability considerations. We approach this problem by an exact solution method for multi-objective mixed-integer linear programs to represent a large number of the non-dominated points which associate with different integer solutions. This approach provides a comprehensive analysis of the problem and trade-offs among four objective functions for decision makers. Finally, we analyze our models and their solutions with an industrial real case study.

2 - An algorithm for solving bi-objective integer programming problems
Firdevs Ulus, Ozlem Karsu, Saliha Ferda Dogan

We propose an objective-space based algorithm to solve bi-objective integer programming problems, where we assume that the set of all nondominated points are included within a bounded set. In each iteration of the algorithm a single Benson-type (weighted Chebyshev) scalarization is solved. The computational experiments demonstrate the satisfactory performance of the algorithm.

3 - Vector optimization models on combinatorial configuration sets and approaches to their solution
Liudmyla Koliechkina, Oksana Pichugina

Two models of real-world problems as vector optimization problems (VOP)over combinatorial configuration sets (CCS) are presented. They combine two aspects that make their solving complicated: a solution must be a feasible combinatorial configuration and satisfy a multi-objective criterion. The first problem is an unconstraint quadratic multi-objective problem over a composition image of the permutation and Boolean sets. The second is a multi-objective model with additional functional constraints over a vertex-located CCS. To solve them, structural properties of the CCS, their convex hulls, as well as Pareto optimal (efficient), strictly and weakly efficient solution sets are investigated. A super-criterion is built, and the VOP continuous reformulations are found based on applying the continuous representation method to the CCS. After a transformation into a mixed integer optimization, several standard optimization techniques become applicable to the problems, such as Branch and Bound, cutting methods, semidefinite and other relaxations, penalty algorithms, Lagrange multipliers, etc. Also, original methods are proposed to these problems and the whole VOP class over vertex- and spherically- located CCS such as the convex extension method that transforms VOP into convex Euclidean combinatorial optimization problems, the combinatorial-surface cutting method, the polyhedral-spherical method and the directed structuring method presenting SSC as a graph.

4 - Generating evenly distributed equitably efficient solutions in multi-objective optimization problems
Ozlem Karsu, Bashir A. Bashir

We consider multi-objective optimization problems (MOP) where the decision maker (DM) has equity concerns. We assume that the preference model of the DM satisfies properties related to inequity-aversion, hence we focus on finding nondominated solutions in line with the properties of inequity-averse preferences, namely the equitably efficient solutions. We discuss two algorithms for finding good subsets of equitably efficient solutions. In the first approach, we propose an algorithm that generates an evenly distributed subset of the set of equitably efficient solutions to be considered further by the DM. The second approach is an extension of an interactive approach developed for finding nondominated solutions in the rational dominance sense and finds equitably efficient solutions in the preferred region of the DM. We show the computational feasibility of the two algorithms on equitable multi-objective knapsack problems that fund projects in different categories subject to a limited budget. We perform experiments to show and discuss the performances of the algorithms for three and five criteria settings.

■ TC-23

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S305

Agent-Based Modeling and Simulation

Stream: Agent-Based Simulation in Business and Economics
Chair: *Loretta Mastroeni*

1 - Agent-based models for opinion dynamics: a survey
Maurizio Naldi, Loretta Mastroeni, Pierluigi Vellucci

Opinions in a group of individuals are influenced by the interactions between individuals and in many cases lead to a consensus about a given topic. The evolution of those opinions and the conditions under which aggregates of individuals with similar opinions exist are of interest in many fields. Agent-based models, where the behavior of individuals is described by a set of rules are an established approach to study such dynamics and have been investigated in a number of papers, with a fast growth in the past few years. In this paper we propose an exhaustive survey of the literature on the subject, considering the representation of opinions, the rules chosen for the agents, the classification of agents prior to and during their interaction, and the description of special relationships among them (e.g., trust, skill-based hierarchy, segregation).

2 - An agent-based methodology to quantify relations between security and efficiency in air transport systems
Stef Janssen, Alexei Sharpanskykh, Ricky Curran

Both security and efficiency are important performance areas of air transport systems. Several methods have been proposed in literature to assess security risks, like the risk of an Improvised Explosive Device (IED) attack, and estimate efficiency indicators, like average queuing time of passengers, independently. However, only few of these methods identify relationships between security risk sand efficiency indicators. We investigate the use of agent-based modelling to both identify and quantify these relationships between security and efficiency within air transport systems. To this end, a methodology is proposed that can be used to quantify these relationships using agent-based modelling. The first step of the methodology determines the scope of the analysis. Then, an agent-based model is defined to represent the standard operations in the selected scope as well as the operations under attack. In step three, efficiency indicators and security risks are estimated using Monte Carlo simulations. Finally, relationships are quantified using analytical approaches like uncertainty or causal analysis. The methodology is applied to two scenarios in the airport terminal. First, a case study that identifies relationships between security regarding an IED attack and different efficiency indicators in the aviation domain is discussed. Second, a case study that investigates the relationship between the processing speed and security performance of checkpoint employees is discussed.

3 - Analytic modelling of the dynamics of multi-agent systems
Stefania Monica, Federico Bergenti

Multi-agents systems have been introduced in the field of artificial intelligence to denote a set of entities which act and interact in intelligent ways. Even though the nomenclature derives from artificial intelligence, the application of results concerning multi-agent systems involves various disciplines, such as biology, sociology, finance, and economics.

In the literature, a large number of models have been proposed to describe the dynamics of multi-agent systems. Most of such models are based on simulations and, hence, their validity is related to considered scenarios and to the specific choice of parameters used to perform simulations. In order to derive more robust results, it is of interest to identify analytic approaches to study the dynamics of multi-agent systems.

In recent years, a framework inspired from mathematical kinetic theories has been investigated to obtain analytic results on the dynamics of multi-agent systems based on the description of the effects of single interactions among agents. The framework can incorporate different types of interactions, and it can be used to describe the dynamics of different features associated with multi-agent systems. The discussed research can be considered in the scope of new disciplines known as econophysics, which can be used to model wealth evolution, and sociophysics, which can be adopted to characterise opinion evolution.

4 - Agent-based models for personal finance decisions
Pierluigi Vellucci, Loretta Mastroeni, Maurizio Naldi

Decisions concerning personal finance are taken by individuals on the basis of a variety of factors.

Though classical wealth-maximization criteria are important to investors, the literature shows that investment decision process appears to incorporate a broader range of items than previously assumed. However, investors can benefit from financial advice to improve their investment process until the point of complete delegation on investment decisions. Researchers have shown that financial advice is potentially a correcting factor in investment decisions.

In all cases individual investors can be considered to follow an education process, starting from the initial stage as uninformed and unsophisticated traders. The idea is that, with proper financial education, one could exert a real bearing on his/her personal finance outcomes. The dynamics of the learning process are therefore relevant to understand how people take their choices and relate to fellow investors.

We consider the case in which the individual decisions in personal finance are taken not just on the basis of factual information but considering also the opinions of other individuals. A typical case of such an influence is the activity of financial forums on the Internet, where the influence exerted on the financial decisions taken by participants may be unrelated to the actual level of financial expertise of the people exerting that influence.

We explore these issues by proposing an agents-based model.

■ TC-24

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S306

Dynamical Models in Sustainable Development I

Stream: Dynamical Models in Sustainable Development
Chair: *Stein Ivar Steinshamn*
Chair: *Pierre Kunsch*

1 - Social efficiency of road transportation system in EU member states: a dynamic eco-inefficiency approach
Agnieszka Lejkowska, Seyedkeyvan Hosseini

The current evaluation research on sustainable transportation concentrate mainly on environmental and economic aspects, leaving behind the social dimension of sustainability. This study applies the eco-inefficiency model to estimate the road transport performance of 28 European Union (EU) member states in terms of social sustainability. The proposed dynamic version of the eco-inefficiency model, apart from incorporating both desirable and undesirable outputs, also provides a complete representation of reference technology over a period from 2005 to 2015. Due to the model properties, DMUs are allowed for a flexible choice of improvement directions, without necessity of weak or strong disposability assumption of undesirable outputs. The conducted empirical study suggests that the EU's older members (EU-15) averagely outperform newer entrants (EU-13) in social efficiency of road transportation system. However, the efficiency growth within the EU-13 cluster is higher than average in the sample, indicating dynamic changes in EU members admitted since 2004.

2 - The dynamic network DEA model with future performance for eco-efficiency analysis in OECD countries
Wendi Ouyang

Decision-making for selecting a set of sound sustainable policies has become a top issue. In the recent years, eco-efficiency analysis has been regarded as an important way to assist policymakers to address this issue. However, policymakers are no longer satisfied with only understanding the roughly sectional eco-efficiency of a region. The utility of policy is continuous, detail and dynamic, but existing eco-efficiency analysis only provides single static efficiency results. As such, policymakers are not supported to understand long-term policy effects and the detail of policy play, and this results in short-sighted decision-making. Such eco-efficiency analysis limits its original intention to be used as a tool for sustainable development. Introducing long-term perspectives and detail internal structure into eco-efficiency analysis is a requirement of policymakers. This study will consider future performance, detail internal structure, and time structure into eco-efficiency analysis to replace traditional static eco-efficiency analysis. The 35 OECD countries is employed in this research to show them eco-efficiency based on 10 years past data and 3 years future data. Each country has many economic sectors followed by traditional macroeconomic model. Data envelopment analysis (DEA) will be updated to a new dynamic network model for long term and complex structure eco-efficiency analysis to analysis above complex data situation.

3 - Solar farm land analysis using AHP technique

Inmacualada Guaita-Pradas, Inmaculada Marqués, Baldomero Segura

The rational and sustainable use of natural resources such as land make necessary the planned use of these resources in manner that is suitable their potential utility. Moreover, solar energy by grid-connected photo voltaic systems, is considered an important alternative electric energy sources, by it is a clean energy production system, easy installation, and low operating and maintenance costs. For these reasons it has achieved more popularity compared to other energy systems. Therefore, the strategic planning of renewable energy, and particularly solar energy planning, needs previous studies to identification of areas with high potential to build solar farms. Find optimal sites is a complex task with many criteria to consider that classic location models can't solve. It is necessary to change the problem approach and search new methodologies for location analysis. Multi criteria methods help to find satisfactory solutions. The AHPs method enables to determine the weights of the parameters in the solution of a multi-criteria problem. The aim of this study is determinate the parameters or criteria to be taken into consideration when assessing land use for solar farm, and by AHP determining the weights of the parameters by experts' opinions consulted. If we integrate these results in Geographical Information Systems (GIS) we can define potential areas to solar farm build, and can integrate into the decisions policies with the aimed to maximize the use of land

4 - Three species and three agents on a common ground: an optimization model with strategic and biological interaction

Stein Ivar Steinshamn, Nils-Arne Ekerhovd

In the North East Atlantic there are several straddling stocks, including herring, mackerel, and blue whiting, which are exploited both within coastal states' 200 nautical mile Exclusive Economic Zones (EEZ) and on the high seas. For several years, there has been an unsolved dispute between nations about the size of their respective quotas. Based on their importance and roles in the fisheries, we model the exploitation as consisting of three players, namely the EU, Norway, and Iceland. The optimization model takes into account biological interaction between the species and strategic interaction between the agents simultaneously. It is assumed that when the nations act as singletons, they behave myopically. When they are member of a coalition, they act in order to maximize the coalition's long-term discounted net revenue. The model is solved using DNLP (Nonlinear Programming with Discontinuous Derivatives), and shows that in most cases the biology (ecosystem) tends to approach a steady state even without this being imposed. Internal and external stability conditions, for all possible coalition structures in steady state, are analyzed in order to find out which coalition structures are most likely to occur, with and without side-payments. This is then compared with what we find in the real world, and political implications are discussed.

■ TC-25

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S307

Optimization in Safety and Security

Stream: Combinatorial Optimization II
Chair: *Karl Doerner*

1 - Path inconsistency: models and exact approaches

Philipp E.H. Salzmann, Michael Schilde, Karl Doerner

We discuss and solve multiple problems with relation to path inconsistency. Multiple branch-and-price approaches were tested as well as two set partitioning formulations. One is very similar to the classical periodic vehicle routing problem while the other uses problem specific characteristics to reduce symmetries. The exact procedure was enhanced with different concepts that were proposed in the literature for similar problems and common heuristic strategies. In addition to the exact procedure, we discuss the existing modelling concepts for path inconsistency with respect to their applicability in real world scenarios. We analyze their advantages and drawbacks in certain real-world scenarios. We tested the framework on capacitated vehicle routing instances, Solomon instances, and instances for the k-dissimilar and the m-peripatetic routing problem. The results show the impact of different enhancement methods to the solution time and the solution characteristics of different modelling concepts. The run times can be reduced easily by more than 75 percent with small changes to the classical labelling procedures. Even without cuts, we are able to solve a solid proportion of the classical as well as the problem specific instances. The strength of our framework is in its ability to solve instances with multiple periods for different inconsistency problems. For future discussion, we propose a set of new urban instances from Vienna.

2 - A comparison of different graph networks for the periodic vehicle routing problem with time spread constraints

Adria Soriano, Thibaut Vidal, Margaretha Gansterer, Karl Doerner

Regarding the transportation of valuables, also known as cash-in-transit (CIT) transportation, efficiency and security issues play a key role in the design of routes by companies. While efficiency relies on cost minimization, security is addressed by reduction of the risk of assault to a vehicle. This reduction can be achieved by designing unpredictable routes.The periodic vehicle routing problem with time spread constraints (PVRPTS) looks at a problem where a set of customers must be visited every day over a planning period, with the main restriction that there must be a minimum difference in the time of visit of a customer on each day. This generates unpredictable routing plans by spreading the arrival times to a customer, which also forces to use different sequences of visits and therefore different paths. This problem has received very little attention in literature. Besides, the problem has been only approached from a simple graph perspective. However, in real life many different paths exist between two points. Therefore, for a problem like the PVRPTS, is interesting to consider the possibility of a vehicle taking a detour to arrive to the next customer at a more suitable time. In our study, we evaluate the influence of considering more complex graph networks for the PVRPTS, by comparing them with the simple graph results. We develop an ALNS algorithm to tackle all possible graph considerations. We obtain results for existing and new sets of instances

3 - Metaheuristics for the multi-objective and periodic node edge, arc routing problem considering costs and route inconsistency

Georg Erwin Adrian Fröhlich, Michael Schilde, Karl Doerner

Security problems can take many different forms like cash in transit operations (e.g., collecting or delivering cash), guard duties (e.g., personal protection, patrolling areas, custody of buildings), or military operations (e.g., movement of troops, patrolling territory). The aspects, which are usually considered, are the costs and security of a solution. This research focusses on a multi-objective and periodic node, edge, arc routing problem (MO-P-NEARP). This covers a mix of patrolling streets with intermittent stationary guard duties. The two objectives that we study are costs and route inconsistency. Route inconsistency measures how often arcs or edges are used within given periods (not counting service), and whether the sequences, in which the services take place, have similar subsequences. Multi-directional local search (MDLS) with adaptive large neighborhood search (ALNS) as a local search component is used. This method is compared to an ϵ-constraint method (ϵ-CM) based on the same ALNS method. The solution representation we use includes only assignment and sequencing decisions. We solve the corresponding mode and path decisions optimally. Tests for single-objective version of the ALNS with respect to costs have been run on several benchmark sets (CBMix, BHW, MGGDB, DI-NEARP) and the results are close to optimal on many instances. Preliminary comparisons with two objectives on the MGGDB instances indicate that the ϵ-CM finds better non-dominated sets than MDLS.

4 - Fast and stochastic optimal resource planning for electric grids in emergencies
Sumanta Mukherjee, Krishnasuri Narayanam, Amith Singhee, Francisco Barahona, Joao Goncalves

Emergency preparedness and response is a common business process in power distribution utilities, and optimal resource position planning for uncertain damage scenarios is a key component of the process. In this paper, we propose a mathematical optimization model for very fast and optimal resource planning under multiple uncertain damage scenarios. The model employs a network flow representation of the resource positioning and transfer problem, at the granularity of operational shifts and service centers. The model lets the planner specify the resource constraints (e.g., maximum available and minimum required resources at a location, resource work hours per shift, task type to resource type mapping, resource organizations [internal, contractor, mutual assistance], resource deployment policies [e.g., use contractor resources only if all internal resources are used], etc.). It formulates the optimization problem as a mixed integer linear program (MILP), where stochastic scenarios are considered simultaneously to generate a single optimal resource positioning plan that achieves good restoration outcomes in any of the possible scenarios. The model uses an aggregate demand modeling technique to enable very fast generation of resource plan, allowing the planner to optimize multiple what-if scenarios in time critical situations to arrive at the best possible decision. We demonstrate the application of the model to real-world emergency scenarios from a large power distribution grid.

■ TC-26

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S308

Optimization in Public Transport and Shared Mobility

Stream: Public Transportation I
Chair: *M. Grazia Speranza*

1 - Integration methods for aircraft scheduling and trajectory optimization at a busy terminal manoeuvring area
Marcella Samà, Andrea DAriano, Konstantin Palagachev, Matthias Gerdts

This talk deals with the problem of efficiently scheduling take-off and landing operations at a busy Terminal Manoeuvring Area (TMA). This problem is particularly challenging, since the TMAs are becoming saturated due to the continuous growth of traffic demand and the limited available infrastructure capacity. The mathematical formulation of the problem requires taking into account several features simultaneously: the trajectory of each aircraft should be accurately predicted in each TMA resource, the safety rules between consecutive aircraft need to be modelled with high precision, the aircraft timing and ordering decisions have to be taken in a short time by optimizing performance indicators of practical interest, including the minimization of aircraft delays, travel times and fuel consumption. This work presents alternative approaches to integrate the various modeling features and to optimize the various performance indicators. The approaches are based on the resolution of mixed-integer linear programs via dedicated solvers. Computational experiments are performed on realistic data from Milano Malpensa in case of multiple delayed aircraft. The results obtained for the proposed approaches show different trade-off solutions when prioritizing different indicators.

2 - Optimal multi-line bus dispatching at terminals with electric charging scheduling constraints
Marco Rinaldi, Federico Parisi, Andrea D'Ariano, Francesco Viti, Georgios Laskaris

We consider the problem of optimally determining the sequence of electric and conventional internal combustion buses departing from a multi-line bus terminal, considering both service constraints (schedule adherence) and energy constraints (electric bus charging status, bus recharging scheduling in capacitated facilities). The problem is formulated as a Mixed Integer Linear Program, with the objective of minimizing the total operational cost for the bus lines in question. System dynamics are captured by twenty sets of constraints, ranging from scheduling adherence to discharge-recharge dynamics. Individual operational costs at the bus level (cost of running an electric / non electric bus per km, cost of recharging) and at the trip level (penalty due to failed schedule adherence) are fully parametrised, allowing for extensive sensitivity analysis. We investigate a real-life case study based in the city of Luxembourg, where two charging stations have been installed in the central station's bus terminal. Through the model we investigate: i) the minimum amount of electric buses necessary to perform a day's schedule for two currently partially electrified lines, without resorting to conventional internal combustion alternatives; ii) the impact of electrifying two additional lines, specifically considering the trade-offs related to either adding new buses or new charging stations at the bus terminal.

3 - Determining the most vulnearable components in transportation networks
Necati Aras, Hande Kucukaydin, Aylin Oncu

The glitches in the transportation networks in the big cities can cause serious problems. As an example of these problems, we can show the closure of a subway station and the lack of service between two stations on a tram line. These types of interventions can have two causes: human or nature-based random causes and human-induced intentional causes. Since the attacks in the second category are carried out by an intelligent agent, there is a potential to cause the most disruption. For this reason, when measuring the fragility of any transportation network, it is necessary to develop a model in which there is an intelligent attacker who wants to harm the infrastructure. The purpose of this work is to establish a bilevel mathematical programming model to identify the most vulnerable components (stations/stops or connections) in a transportation network. In this model, the leader of the so-called Stackelberg game is the intelligent virtual attacker who wants to cause the most disruption in the transportation network by minimizing the amount of the flow on the network. The follower is the system operator who is trying to rearrange the transportation network so that the maximum amount of flow on the network is attained given the leader's interdiction decisions. We develop two models which differ in the decision of the attacker: complete interdiction and partial interdiction. The solution method is based on reformulating the problem as a single-level optimization problem.

4 - The shared customer collaboration vehicle routing problem
M. Grazia Speranza, Elena Fernandez, Mireia Roca-Riu

This paper introduces a new vehicle routing problem that arises in an urban area where several carriers operate and some of their customers have demand of service for more than one carrier. The problem, called Shared Customer Collaboration Vehicle Routing Problem, aims at reducing the overall operational cost in a collaboration framework among the carriers for the service of the shared customers. Alternative mathematical programming formulations are proposed for the problem that are solved with a branch-and-cut algorithm. Computational experiments on dierent sets of benchmark instances are run to assess the efectiveness of the formulations. Moreover, in order to estimate the savings coming from the collaboration, the optimal solutions are compared with the solutions obtained when carriers work independently from each other.

■ TC-27

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S309

Inventory Models

Stream: Production, Service and Supply Chain Management
Chair: *Gholam Reza Nasiri*

1 - A simulation-based optimal inventory management model considering dynamic demand in IoT environment
Doo-hwan Kim, *Sangha Sung*, *Kangbae Lee*, *Hyeon Jo*

Under circumstances where customer demand changes rapidly and unpredictable situation continues, companies are making great efforts in internal and external cooperation and supply chain management in order to meet customers' dynamic demands. Inventory management is crucial in supply chain management to respond to dynamically changing demand and to provide the best logistics services while minimizing logistics costs. However, many companies have a structure to produce and sell products according to their own demand forecasts. In recent years, the Internet of Things (IoT) technology, which can connect a variety of devices, makes it possible to trace the location and status of the product from production to sales point. The aim of this study is to find out an optimal inventory management model in supply chain based on dynamic demand in IoT environment by using simulation optimization method. For the purpose, this study compares two inventory models - probabilistic and definite models and propose an optimal inventory management model considering dynamic demand in IoT environment.

2 - An inventory model with non-linear holding cost and return on investment maximization
Joaquin Sicilia-Rodriguez, *Valentín Pando-Fernández*, *Luis A. San-José-Nieto*

This work analyzes a deterministic inventory model with a stock-dependent demand pattern and non-linear holding cost. A new approach with the objective of maximization of the ratio profit/cost is considered. When resources are limited and the inventory manager can invest in different projects, it seems reasonable to select the one that provides a higher return on investment. Thus, the goal is to find the optimal inventory policy that gives a major return on investment. The solution for the maximum profit per unit time does not necessarily match with the maximum profit/cost index solution. It is proved that maximizing the profit/cost index is equivalent to minimizing the inventory cost per unit item, instead of minimizing the inventory cost per unit time. The optimal policy can be obtained in a closed form and the replacement should be done when the stock is depleted. Thus, the inventory manager does not need to process a new order while stock is available. This optimal solution is different from the other policies proposed for the problems of minimum cost or maximum profit per unit time. Finally, numerical examples are solved to illustrate the theoretical results and the solution methodology.

3 - Production smoothing and safety stock placement in supply networks
Kunal Kumar, *Tarik Aouam*

Our work presents a new model to integrate the decisions of production smoothing and safety stock placement in supply networks under the guaranteed-service approach. We first present a general smoothing policy and characterize related inventory and overtime costs for given inter-stage service times. Then, we focus on two special types of smoothing policies - equal-weighted moving average (EWMA) and exponential smoothing (ES) policies. An optimization model determines the optimal smoothing policy, its parameter and the service times such that networkwide costs of holding work in process, safety stocks, and of using overtime are minimized. Our analysis suggests that the ES policy is optimal for all cases when the outgoing service time minus the incoming service time at a stage is less than or equal to 1, while the EWMA policy is optimal for stages that do not hold safety stocks. Further, we show that a lower bound on optimal smoothing parameters also depend on service times. Taking these results into account, an effective dynamic program is proposed to solve the integrated problem. Numerical experiments highlight the value of optimizing the smoothing policy and the value of integration.

4 - An internal financing approach in the FMCG supply chain planning companies: a direct inventory improvement procedure with a case study
Gholam Reza Nasiri

Inventory management under stagflation economics environment is a widely investigated issue in supply chain management. Therefore, many different types of inventory policies have been developed to address tradeoff between two major situations including lower inventory levels and related stock out costs in comparing to excessive inventory levels to avoid the probability stock out costs. In this situation, considering inflation rate higher than the average and growth of good prices, the monetary costs are higher than the other economic conditions. Therefore, creating optimum/good position between various key components of an inventory system is one of the main concerns for decision makers. In this article an internal financing approach based on the inventory management principles, comprehensive review on executive procedures, and consequently better supply chain coordination between all parties have been developed. The real historical data of a leadership company in Iran is used for the purpose of illustration and the reliability of the suggested approaches and procedures. The results of inventory improvement and inventories turnover rate without significant side effect on sales volume, indicated that the benefit and effectiveness of the proposed conceptual model is very phenomenal and considerable.

■ TC-28

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S310

Dynamic Programming for Revenue Mangement, Pricing, and Control

Stream: Service Operations Management
Chair: *Dan Adelman*

1 - Dynamic lead-time quotation for substitutable products
Tuba Yilmaz Gozbasi, *Esma Gel*, *Pinar Keskinocak*

We study effective dynamic lead time quotation strategies for a firm that is able to offer substitute products or services to customers. This paper discusses the case with two substitutable products, where the firm has information on the preferences of each product's primary customer base. The objective is to maximize the long-run average expected profit per unit time, where profit from a customer order is defined as the revenues minus the expected lateness penalties incurred due to lead-time violations. We analyze the structure of the optimal profit and lead-time policies, and evaluate the value of substitution flexibility and dynamic lead time quotation strategy through an extensive numerical study. We observe that dynamic quotation and substitution have synergistic effects and that higher differences in revenues or arrival rates, higher traffic intensity, lead-time sensitivity or cross lead-time elasticity results in higher profit improvements by dynamic quotation and substitution.

2 - A price-responsive occupant-aware thermostat
Canan Uckun, *Dan Adelman*

Appliance manufacturers have been developing new lines of smart appliances with internet connectivity, and thus the potential to automatically adjust behavior in response to price signals. We formulate a dynamic programming model for an occupant-aware, price-responsive thermostat that takes the thermodynamic/heat transfer properties of the home into account in controlling the indoor temperature through time. We calibrate the parameters of the dynamic program using real-world data for occupancy, home energy characteristics, and thermal utility.

3 - Dynamic matching of workers to jobs with learning curves
Dan Adelman, Adam Mersereau

We consider the dynamic assignment of multiple workers to multiple classes of jobs. Workers are heterogeneous and become more effective at a job class with experience, and therefore the scheduler faces a tradeoff between matching workers with familiar jobs to minimize short-term cost versus matching workers with unfamiliar jobs to build expertise. A deterministic version of the problem has distinct structure that we leverage to derive price-directed approximations to stochastic versions featuring randomly arriving workers and jobs.

■ TC-29

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S311

Game Theory, Solutions and Structures II

Stream: Game Theory, Solutions and Structures
Chair: *Ignacio García-Jurado*

1 - The Coleman-Shapley-index: being decisive within the coalition of the interested
Frank Huettner, André Casajus

The Coleman Power of the Collectivity to Act (CPCA) is a popular measure of the agility of a committee. Applying the Shapley value to this measure, we derive a new power index that indicates each voter's contribution to the CPCA. This index is characterized by four axioms: anonymity, null voter, transfer property, and a new axiom which stipulates that sum of the voters' power equals the CPCA. Similar to the Shapley-Shubik index (SSI) and the Penrose-Banzhaf index (PBI), our new index emerges as the expectation of being a swing voter. Here, the coalitional formation model underlying the CPCA and the PBI is combined with the ordering approach underlying the SSI. In contrast to the SSI, the voters are not ordered according to their agreement with a potential bill but according to their vested interest in it. Among the most interested voters, the power is then measured in a similar way as with the PBI.

2 - Characterizing weighted prenucleoli without consistency
Peter Sudhölter, Pedro Calleja, Francesc Llerena

A solution on a set of transferable utility (TU) games satisfies "equal surplus division" (ESD) if adding equal shares of the additional worth of the grand coalition to any element of the solution applied to the original game yields an element of the solution applied to the new game. We show that the per capita nucleolus on balanced games is characterized by single-valuedness (SIVA), translation and scale covariance (COV), and equal "adjusted" surplus division (EASD), a property that is comparable but stronger than ESD. These properties together with ESD characterize the per capita prenucleolus on larger sets of TU games. EASD and ESD can be transformed to "independence of (adjusted) proportional shifting" and these properties may be generalized for arbitrary weight systems p to I(A)S(p). We show that the p-weighted prenucleolus on the set of balanced TU games is characterized by SIVA, COV, and IAS(p); and on larger sets by additionally requiring IS(p).

3 - Axiomatic foundations of a unifying concept of core for games in effectiveness form
Stéphane Gonzalez, Aymeric Lardon

This paper provides axiomatic characterizations of a concept of core for games in effectiveness form (Rosenthal, 1972) that unifies a wide variety of solution concepts prominent in the literature on social choice theory and game theory. Both of the main characterizations we propose use the standard non-emptiness axiom on the class of games with a non-empty core. Besides, the first characterization relies on coalitional unanimity and Maskin monotonicity properties together with a first independence principle with respect to leaving players. Alternatively, the second characterization invokes a strict dominant set property and a second independence principle with respect to irrelevant states. These results give new insights on characterization of well-known solution concepts such as the Condorcet winner or the Nash Equilibrium.

4 - Values, nullifiers and dummifiers
Ignacio García-Jurado, Julian Costa, José María Alonso-Meijide

In this lecture we provide new axiomatic characterizations of the Shapley and Banzhaf values for TU-games using properties involving nullifying players or dummifying players. These new characterizations prompt the introduction of two new values for TU-games: the e-Banzhaf value and the ie-Banzhaf value. Both are efficient variations of the Banzhaf value. Unlike the e-Banzhaf value, the ie-Banzhaf value is invariant to S-equivalence.

■ TC-30

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S312

Cooperative Games of Operations Management

Stream: Game Theory and Operations Management
Chair: *Ulas Ozen*

1 - Cooperation in urban consolidation centers
Behzad Hezarkhani

The rising number of private/public initiatives to establish and operate urban consolidation centers on one hand, and their low success rates on the other, signal the need for research into better mechanisms for managing cooperation in this context. Accordingly, in this talk we introduce dispatch consolidation games. We search for stable allocations and show that in case the truck capacities are not restrictive, the core is always non-empty. With restrictive truck capacities, however, core can be empty. We introduce a novel notion of stability, i.e., componentwise stability, and prove their non-emptiness in dispatch consolidation games.

2 - Maximal covering location games: an application for the coast guards
Loe Schlicher

In this talk, we focus on maximal covering location games. In these games, there are several players that each may or may not own a single resource. Players can cooperate by pooling these resources. It is assumed that a resource covers all players located within a certain radius from the resource. Coverage of a player by (at least) one resource results into a player-specific profit. Aim of the players is to position the resources in such a way that the joint profit (i.e., the sum of the profits of the covered players) is maximized. It is known that these games are superadditive, monotonic, and, under some conditions may have non-empty cores. We discuss a new sufficient condition for core non-emptiness of maximal covering location games, which also a has practical interpretation when dealing with a real-life application of our studied game, namely pooling of coast guard boats.

3 - Vaccine allocation: a cooperative game theoretic approach
Marieke Musegaas, Loe Schlicher, Evelot Duijzer

Vaccine allocation is the problem of allocating scarce resources, the vaccines, to fight outbreaks of infectious diseases. We consider the situation where every agent has its own initial set of vaccines. Moreover, there is a global decision maker who determines the optimal allocation of the total number of initial vaccines among the agents with respect to a given global objective function. As the global objective function is derived from the local objective functions of the different agents involved in the underlying system, additionally a cooperative problem has to be addressed. For example, in the optimal allocation, an agent might need to give away some of its initial set of vaccines. In order to make this transaction favorable for this agent, he would need to receive a fair compensation for it. An adequately defined associated cooperative game can help to analyze the problem of finding a fair compensation.

This cooperative problem can be addressed in several ways. One approach is by considering a cooperative game induced by a connectivity graph (which is based on the geographical location of the country). Another approach is by assuming that every country has its own S-shaped return function. We discuss both approaches and we relate it to the relevant literature in cooperative game theory (for example, Böhm-Bawerk horse market games and market games).

4 - On the core of m-attribute games
Ulas Ozen, Marco Slikker

In this paper, we study a special class of cooperative games with transferable utility, called m-attribute games, and their core. In this class, every player is endowed with a vector of m-attributes and every coalition is characterised by the vector that is the sum of the attribute vectors of its members. Moreover, the characteristic function is given by an m dimensional function of attribute vectors. We derive the sufficient and necessary conditions for every m-attribute game embedded in this function to have a non-empty Core (and hence, being totally balanced), and convex, separately. Afterwards, we present several sufficient conditions, which are easier to check, for m-attribute games to have non-empty cores. We demonstrate in several examples that how our results can be used to study the cores of OM-games that can be naturally formulated as m-attribute games.

■ TC-31

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S313

Behavioural Processes in OR practice

Stream: Behavioural OR
Chair: *L. Alberto Franco*

1 - In praise of the introverted: an extended use of soft systems methodology mode 2
Jose-Rodrigo Cordoba-Pachon, Sulafah Basahel

Recent developments and rediscovering of human aspects in operational research (Franco and Hamalainen, 2015) have highlighted the importance of studying psychological aspects of OR actors in conjunction with the use of OR methodologies. It becomes important to acknowledge that such conjunctions or relations could be built by considering different modes of systems methodology use, in particular soft systems methodology or SSM (Checkland and Scholes, 1990). The aim of this paper is to extend current understanding of methodology modes of use by considering their use by introvert facilitators or researchers (Cain, 2012). Introversion can be seen as a personality dimension that is not only influenced by character but also by cultural factors. We use a case vignette of online distance education in Saudi Arabia where one of us 'S', an introvert individual, had to deal with cultural and organisational issues of access. 'S' used SSM in mode two (Checkland and Scholes) as a way to learn and act in a context without having to explicitly use the SSM as a facilitation device. Insights prior to, during and after the intervention lead us to consider a number of ways in which SSM mode 2 could be enriched together with a more explicit inclusion of introvert features.

2 - Framing strategies and their impact on client/consultant meetings
Ashley Carreras, L. Alberto Franco

In this talk we examine the how the use of frames, and re-framing, influence the trajectory of client and consultant meetings. A conversation analytic approach is used to examine two audio recorded client-consultant meetings that took place in the interval between a series of facilitated workshops. The analysis draws upon an interactional understanding of framing where role, process, identities and issues are co-constructed. Registering divergences in frames, together with understanding the potential strategies for overcoming these divergences, are shown to be helpful in ensuring a more fruitful progression to successful outcomes to client/consultant interactions.

3 - Learning multi-criteria decision aiding workshop facilitation: experience from student case studies
Francis Marleau Donais, Irene Abi-Zeid

Group workshop settings are widely accepted and used in multi-criteria decision aiding (MCDA) to facilitate problem structuring and model building in a sharing preference procedure. Nonetheless, decision facilitation is more often referred to as an "art" rather than a "science"; it cannot be easily taught in a classic lecture course environment. In addition to acquiring knowledge regarding the facilitation process and the types of questions to ask, students must learn how to deal with group interactions such as conflicts and how to think proactively about ill-defined knowledge and elicited information during the workshops. Students must therefore get hands-on experience, which poses a challenge for teachers and students alike. At Laval University, Canada, we teach, every year, a graduate level course on the topic of MCDA where the final team project consists of finding and aiding a real-world multi-criteria decision with multiple decision makers. In order to support the students and to better understand their learning process, we attended and observed the workshops led by the different teams. These observations have allowed us to identify some of their good moves and their errors. We subsequently interviewed the students that acted as facilitators during the workshops to get their impressions and to gather suggestions on how to improve their in-class preparation. In this talk, we present and discuss our experience with this exercise that we plan to repeat on a yearly basis.

4 - Formulations in facilitation practice: an exploratory video-based investigation of their use in situ
L. Alberto Franco, Mie Nielsen

In this presentation we examine how the talk of the facilitator shapes group workshop interactions by using the conversational object 'formulation'. The data consist of video recordings of a corpus of four facilitated workshops held with management and development teams. By adopting an exploratory video-based investigation using conversational analysis to examine our data, we highlight the significance of three distinct set of formulations used by facilitators in workshops. Specifically, our findings show how formulations that encourage reflection or facilitate action, together with those collaboratively produced, enable sense making and the achievement of a temporal conversational order among participants. This research contributes to the study of facilitated workshops by offering a more nuanced approach to the understanding of the craftsmanship of doing facilitation, its effects on the workshop process and, ultimately, workshop outcomes.

■ TC-32

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S314

Order Batching and Picking

Stream: Routing, Logistics, Location and Transportation
Chair: *Utku Koc*

1 - Using flexible routing to improve the performance of a synchronized sequential zone-picking system
Shan-Nung Chu, Ying-Chin Ho

A traditional synchronized sequential zone-picking system is made up of several parallel sequential zone-picking lines. When an order enters the system, it may have to be divided into several sub-orders. A sub-order will have to visit the sequential zone-picking line containing the items it needs. In this traditional setting, a sub-order must follow a fixed sequence (i.e. a fixed route) to have its items picked and it cannot leave the sequential zone-picking line it is assigned to. This constraint often causes the workload imbalance between sequential zone-picking lines and as a result hinders the performance of the entire system. In this study, we propose a revised network system in which orders no longer have to follow fixed routes to have their items picked. In other words, orders will have the flexible routing capability to visit any zones in any lines. This is because the parallel sequential zone-picking lines are now connected into a zone-picking network. Also, orders no longer need to be divided into sub-orders in the revised system because orders are now allowed to travel anywhere. We conduct computer simulations to test whether the flexible routing capability provided by the proposed zone-picking network can have better performance results than the traditional synchronized sequential zone-picking system. It is hoped that the knowledge learned from this study can assist distribution centers in improving their synchronized sequential zone-picking systems.

2 - The cafeteria problem: order sequencing and picker routing in on-the-line picking systems
Stefan Fedtke, David Füßler, Nils Boysen

This paper is dedicated to the cafeteria problem: Given a single waiter operating multiple counters for different dishes arranged along a line and a set of customers with given subsets of dishes they desire, find a sequence of customers, which may not overtake each other, and a service schedule for the waiter, such that the makespan is minimized. This generic problem is shown to have different real-world applications in order picking with blocking restrictions. We present different heuristic and exact solution procedures for both problem parts, i.e., customer sequencing and waiter scheduling, and systematically compare these approaches. Our computational results reveal that the largest performance gains are enabled by not strictly processing order after order. Instead, the waiter should be allowed to flexibly swap between customers waiting along the line.

3 - Local search based strategies to solve the order batching problem
Çağla Cergibozan, A. Serdar Tasan

In warehouse management, order picking is a critical process among warehouse operations. Total operating cost of a warehouse depends on the efficiency of the operations inside; and an order picking process is commonly recognized to be the most cost intensive operation because of the time needed to collect the ordered items from their storage locations. The picking facility in manual order picking systems usually has a limited capacity, and picking of the ordered items is a time-consuming operation especially when a high number of different items are ordered. The order batching problem (OBP) is a combinatorial optimization problem that is encountered in order picking process. In the OBP, the aim is to find the groups of the orders and related picking tours to minimize the distance travelled by the order picker. The problem includes batching and routing decisions, therefore, finding an effective algorithm to solve the problem is significant to reduce the overall picking costs related with this process. In our study, we propose a local search based solution technique for the OBP. Proposed algorithm utilizes several permutation-based local search heuristics to explore the solution area. The computational study is implemented with different data sets and warehouse configurations. According to the results, algorithm finds effective solutions to the OBP in a reasonable time period.

4 - Integrated order acceptance, production planning and distribution problems
Utku Koc, Selçuk Gören

Transportation of finished goods to customers is an important logistics activity that must be planned along with production, inventory, and order acceptance decisions. In traditional supply chain literature and in practice, the planning activities focus on sales and production. Raw material procurement, inventory, and delivery decisions generally follow the production and sales plan. We study a manufacturer's multi-period production planning problem to produce and ship a subset of available orders from a given set, meeting due window constraints, with the maximum profit. Each potential order has a revenue, size, and a due window that the items can be delivered. The profit is calculated as the revenue minus the transportation and inventory holding costs. The manufacturer can use different type of vehicles varying in their price and availability for outbound transportation. We study the manufacturer's planning problem in this setting under three different delivery characteristics: 1) whether orders can be split or not, 2) whether they can be consolidated or not, and 3) whether their sizes are restricted to be in integer multiples of vehicle capacities or not.

■ TC-33

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S315

Data Mining, Statistics Theory and Its Applications

Stream: Data Mining and Statistics
Chair: *Carly Foster*

1 - Remaining useful life estimation based on deep learning approach
Youngji Yoo, Jun-Geol Baek

In recent years, interest in prognostics and health management has rapidly increased across the industry. Unexpected machine breakdown can cause production downtime, higher repair cost. Therefore, remaining useful lifetime (RUL) estimation is crucial to avoid sudden breakdowns and establish a maintenance strategy. During the manufacturing process, massive data, such as vibration signals and temperature, are collected in real time from sensors attached to the machine. In general, deep learning techniques are widely known to be effective in useful features extraction from the massive data. In addition, it is possible to compress the processes of feature extraction, selection and fusion, which are widely used in existing RUL prediction, by using a single deep learning architecture, and it is superior to capture high-quality degradation trends of the machine compared to the shallow architectures, such as support vector regression and linear discriminant analysis. In this study, we propose advanced health indicator based on deep learning approach for RUL prediction. Our method extracts features by considering characteristics of multi-sensory signals and inputs the extracted features into a deep learning architecture to monitor degradation trends of machine or parts and to predict RUL. The algorithm will be helpful to maximize machine availability and improve the reliability and safety of the manufacturing process.

2 - Analyzing business conditions by quantitative text analysis -time series analysis using appearance rate and principal component
Nariyasu Yamasawa

We present a procedure for analyzing the current business conditions and forecasting GDP growth rate by quantitative text analysis. We use text data of Japanese Economy Watcher Survey. Cabinet Office in Japan has been releasing this statistics since January 2000. We extract words from 190 thousands sentences and construct time series data by counting appearance rate every month. Our analyses consist of four parts. First, we draw several graphs of the appearance rate of words which shows real time business conditions. We try to draw graphs on "Sales", "Christmas", "Olympic", "Tax Reform", "Intense Heat", and so on. Second, we construct words lists which relate to business conditions by computing correlation coefficients. Words that correlate with business cycles are "Good", "Increase", "Favorable" and so on. We also construct business cycle indicators by calculating weighted average of appearance rate s of the words which correlate with business cycles. Third, we extract principal component from the most frequent 150 words. We see components and try to interpret. We find that the movement of the 1st principal component is similar to business cycle. The last, we forecast Japan's quarterly real GDP growth rate by text data. We find that forecast accuracy improved by adding the text data. It shows that text data has useful information for forecasting GDP.

3 - Data science techniques applied to analysis of incidents registered by the 1-1-2 Canary Islands emergency services

Carlos Perez Gonzalez, Marcos Colebrook, José Luis Roda-García, Carlos Rosa Remedios, Teno González Dos Santos

The study of alerts received in the emergency services is a very important issue in order to know different aspects of the time and spatial distribution of alerts in a given region. In particular, the Emergency and Security Coordinating Center (CECOES) 1-1-2 of the Government of the Canary Islands records detailed information about the incidents that are reported by the citizens through phone calls. Due to the high volume of information generated over the time in this process, it is needed to apply big data techniques to obtain statistical measures and results of interest. We have used the statistical software R and different libraries (Shiny, Highcharts, Highmaps) to present the data information in different interactive dashboards (time series charts to analyze the time evolution, tree classification of the sanitary emergencies, geospatial representations of incidents density distribution, etc.) and to propose several predictive and classification models. In this work, we illustrate some illustrative and valuable results in studying the incidents in the region during the last years.

4 - A realist evaluation of a learning analytics pilot project at Northumbria University, UK

Carly Foster

This is a realist evaluation of a Learning Analytics pilot implementation at a large UK University. Its purpose is to formatively assess the impact of the pilot in relation to the project's theory of change; that is it anticipates that the utilisation of Educational Data Mining (EDM) and Learning Analytics techniques will contribute to an improvement in the retention rate of students who would otherwise withdraw from their studies. Data collected includes qualitative interviews with stakeholders and survey data derived from academic staff as well as quantitative data to measure the impact on retention. Using these data sources and reflecting on the project's aims and objectives, the evaluation considers the outcomes and how they were influenced by contextual factors relating to the practice of Learning Analytics including the quality of the predictive model used to identify at risk students. The evaluation finds evidence to support the assertion that, firstly, a predictive model was built using EDM techniques, secondly, the application of the model promoted cross department collaboration to recommend and deliver data-informed interventions with high risk students and, thirdly, student outcomes did not improve compared to both previous years and the wider university because of issues highlighted in this paper. As per the realist tradition, care has been taken to isolate and discuss the contextual factors influencing success and the mechanism of Learning Analytics.

■ TC-34

Tuesday, 12:30-14:00 - SOUTH BUILDING UV S113

Stochastic Optimization with Application

Stream: Dynamical Systems and Mathematical Modelling in OR

Chair: *Yukihiro Maruyama*

1 - An adversarial risk analysis approach for differential games: a botnet defense model

Jorge Gonzalez-Ortega, David Rios, Antonio Gomez-Corral

We consider Differential Games (DGs) corresponding to conflict situations in which players choose strategies over time. In this context, typical applications include defense, counter-terrorism and finance. Attempts to solve DGs have focused mostly on game theoretical methods based on variants of Nash equilibria, but this is not satisfactory in many of the above applications since beliefs and preferences of adversaries will not be readily available, frequently violating game theoretical common knowledge assumptions. Adversarial Risk Analysis (ARA) provides a way forward by supporting one of the players (defender), minimising her subjective expected costs, treating the adversaries' (attackers') decisions as random variables. To do so, ARA models the attackers' decision-making problems and, under assumptions about their rationality, tries to assess their probabilities and utilities to predict their optimal actions, with the uncertainty in the assessments leading to probability distributions over them. Our approach is illustrated through a botnet defense example with an underlying SIS (Susceptible-Infectious-Susceptible) epidemic model, see Bensoussan et al. (2010), in which we compare both the game theoretical and ARA solutions.

2 - Multiple optimal decision rules and their applications in finance

Georgy Sofronov

In many applications data are sequentially collected over time, and it is necessary to make decisions based on already obtained information while future observations are not known yet. Formally speaking, we observe a sequence of random variables and have to decide when we must stop, given that there is no recall allowed, that is, a random variable once rejected cannot be chosen later on. Our decision to stop depends on the observations already made, but does not depend on the future which is not yet known. The objective is to find an optimal procedure that maximizes an expected gain. In this talk, we will consider problems when at least two stops are required, for example, a sequential problem of selling several identical assets over a finite time horizon.

3 - Optimal approximate dynamic programming strategies for online caching problem in wireless networks

Xinan Yang

Due to the increase in the number of wireless devices with network access, the mobile video traffic will reach 82% of the overall Internet traffic by 2021. This increases pressure on network operators infrastructure. Caching at Base Stations (BS) the popular contents, which exploits the spatial diversity of the data requests and makes required content closer to end users, can be an efficient solution.

Obviously, each Base Station can cache only a part of the entire content catalogue. The cache optimization problem can be mapped as a knapsack problem which is known to be NP-hard. In this work, we study the wireless edge cache optimization problem in a collaborative network. Unlike previous works, we propose a hybrid between offline and online schemes where the cache space is first optimized in off-peak hours and then is updated during the day according to the encountered content popularity dynamics. A rolling horizon approach is developed to capture the system dynamics, so as to allow decisions to be made proactively. To reduce the computational complexity of the problem, we make two simplifications to the problem: (a) we consider that the content can be cached in up to one SCBS and (b) we limit the number of allowed content replacements in the SCBS. These simplifications permit to maintain large gains over the comparison schemes and comparable performance to the offline scheme.

4 - On non-deterministic sequential decision processes and its applications

Yukihiro Maruyama

In this paper, the relation between a given non-deterministic discrete decision process (nd-ddp) and a subclass of non-deterministic monotone sequential decision process (nd-msdp) is made clear; the functional equation of non-deterministic dynamic programming is obtainable for the nd-msdp. The strong representation by the subclass of nd-msdp provides a necessary and sufficient condition for the existence of it with the same set of feasible policies and the same cost value for every feasible policy as the given process nd-ddp. Further, the strong representation is applied to some discrete non-deterministic optimization problems.

■ TC-48

Tuesday, 12:30-14:00 - 4D UPV B.3

Humanitarian Problems under Uncertain Parameters

Stream: Humanitarian Operations
Chair: *Christophe Duhamel*
Chair: *Andréa Cynthia Santos*

1 - Optimization of pre- and post-disaster decisions in infrastructure risk management
Camilo Gomez

A key problem in infrastructure risk management is that of evaluating the impact of pre-disaster decisions in relation to post-disaster consequences (e.g., human and economic losses, as well as repair costs), considering systems with many components and intricate interdependencies. Operations research tools have been increasingly adopted in these problems, particularly because of the potential of decomposition techniques and stochastic programming approaches for the combinatorial optimization problems that result from analyzing large-scale systems under many scenarios.

This research addresses the problem of pre-disaster investments in crew training, resource allocation, and physical protection, and evaluates their effect on post-disaster decisions regarding the period-by-period planning of recovery actions to provide immediate relief and restore basic services (e.g., water, electricity, gas). We propose a two-stage stochastic programming methodology, with allocation decisions on the first stage and a time-dependent MIP formulation for recovery on the second stage. Our methodology, as exposed in illustrative examples, enables decision makers to evaluate trade-offs between pre- and post-disaster investments, as well as account for the impact on different stakeholders.

2 - Inventory management of perishable items in long-term humanitarian operations using Markov decision processes
Guilherme Ferreira, Edilson Arruda

Humanitarian organizations often rely on donations of goods to keep their operations running for a long period. However, the donation of perishable goods, such as food and medicine, is a great challenge for logistic managers of such organizations, since deteriorated items may impose a threat to the population, if used incorrectly, and a huge cost for humanitarian operations, due the difficulties underlying their disposal policies. This paper aims at developing a decision making model for inventory management of perishable goods for long term humanitarian operations, using Markov Decision Process. Our model allows managers to ensure that the goods in the inventory are proper for consumption without necessarily keeping track of individual expiration dates for each item in the inventory. To illustrate the approach, we propose experiments to demonstrate how different shelf lives can affect the optimal ordering policies of critical perishable goods, such as blood packs or medicine, in humanitarian operations.

3 - Forecasting material requirements in ERP-based humanitarian logistics
Jose Gavidia

Recent failures in response to humanitarian crises highlight the need for an integrated and responsive humanitarian logistics system. The response to humanitarian crises is very complex and requires the coordination and collaboration of organizations with varied fields of expertise, such as logistics, establishing medical facilities, providing medical care, providing food and shelter, and so on. At the same time, business and non-profit organizations must respond to the demand for materials without warning. Inter-agency collaboration requires coordination and visibility. Enterprise Resource Planning (ERP) systems commonly used in multinational enterprises provide data integration; supply chain configuration and coordination, as well as tools for material forecasting and optimization of logistical resources. This paper explores the nature of material requirements in humanitarian crises within a global, integrated humanitarian enterprise system. Conclusions are drawn regarding alternative forecasting methods, and the use of material requirement forecasts in the optimization of the global humanitarian logistics system.

4 - Modeling the field hospitals location problem after natural disasters
Christophe Duhamel, Andréa Cynthia Santos

In the aftermath of disasters, like earthquakes, medical services quickly become saturate due to the sudden raise of inhabitants looking for help. Thus, installing field hospitals allows handling simpler medical cases in order to keep the hardest cases for hospitals. In the literature, most models for local emergencies (fire, floods, local accidents, etc.) rely on p facilities location: "p-medians" (minimize the total distance from demands to facilities), "p-center" (minimize the maximum distance from a demand point to its nearest facility), "covering" (minimize p while covering all demands), and "maximum covering" (cover the maximum number of demands points subject to limited resources). Another key element is the number of inhabitants needing assistance in each sector, both due to approximate need assessment and to population movement. Few works have investigated the impact of such uncertainties, especially on the location decisions for the field hospitals. Given a set of secured locations and a limited number of field hospitals, the location problem addressed here, consists in determining where to install field hospitals subject to uncertainties associated with the number of inhabitants requiring medical care. We model this problem and test our approach on real data from the Nepal 2015 earthquake.

■ TC-49

Tuesday, 12:30-14:00 - 4D UPV B.4

OR in Agriculture and Fisheries

Stream: OR in Agriculture, Forestry and Fisheries
Chair: *Pall Jensson*

1 - Multi-diet formulation model under activity-based costing for animal feed production
Adela Pages Bernaus, Virna Ortiz-araya, LluisM Pla, Jordi Mateo, Francesc Solsona, Dídac Florensa

Raw materials constitute the major cost in animal feed production. Due to price variation of the commodities used for feed production, the composition of the formulation changes frequently. Commercial software offers the possibility to formulate the least-cost diet while meeting a desired nutritive composition. The multi-diet formulation minimizes the cost of purchasing raw materials but disregards the changes that may bring in the production line, which may incur in higher cost due to, for example, a higher energy consumption in the grinding or the requirement of extra conditioning. We propose a mixed-integer programming model to solve the multi-diet formulation which takes into account the whole cost structure, from the raw materials adquisition to the complete feed-mill processing. In determining the cost, an Activity-Based Costing scheme is employed. The model is applied to different cases within the pig production sector.

2 - Determining the eco-efficiency of Chilean raspberry orchards through two LCA+DEA methods: an empirical comparison from an environmental and an operational point of view
Lidia Angulo Meza, Ricardo Rebolledo-Leiva, Marcela C. Gonzalez-Araya, Alfredo Iriarte

The environmental impacts of farming have been of increasing concern for producers as international markets are more concerned with sustainable practices. In recent years, an approach that uses both Life Cycle Assessment (LCI) and Data Envelopment Analysis (DEA), LCA+DEA, has been used to assess the eco-efficiency with the advantage of considering environmental and operational aspects. We use two methods, the four-step method (Rebolledo-Leiva et al, 2017) and the five-step method (Lozano et al., 2009, and Vázquez-Rowe et al., 2010) to assess the eco-efficiency of Chilean raspberry orchards. The main difference between both methods is that the four-step method includes environmental variables in the DEA model, whereas the five-step uses only operational variables in the DEA model, and the environmental variables are only used after the efficiency assessment to determine and compare emissions before and after the efficiency assessment. We analyse the effect of including or not the environmental variables within the DEA models. For inefficient orchards, targets for raspberry production and GHG emissions are determined using both methods. The eco-efficiency indexes as well as the targets for inefficient DMUs obtained using both methods are compared. We verify that the four-step methods rely more heavily on the eco-efficiency definition that seeks to produce more while reducing environmental impacts and its targets are more demanding.

3 - An extended approach allowing endogeneity in stochastic frontier models: an application to agricultural Brazilian municipal data
Geraldo Souza, Eliane Gomes

Market imperfections occur when farmers are subjected to different market conditions depending on their income. Relatively, large scale farmers access lower input prices and may sell their production at lower prices making competition harder for small farmers. Potential factors associated with market imperfections are related to infrastructure, environment control requirements and the presence of technical assistance. In this article, at municipal level and using Brazilian agricultural census data, we estimate the effects of these factors on production by maximum likelihood methods. We consider technical assistance as potentially endogenous and fit stochastic frontier models under this assumption. We generalize known approaches, allowing for nonlinear instrumental variable regressions. We explore the use of fractional regressions and the Murphy-Topel two-stage variance approach for maximum likelihood estimation. The best specification is a normal-half normal frontier model with variance effects. We conclude that technical assistance is not endogenous. All market imperfection covariates, with the exception of environment control, are statistically significant and show nonnegative rank correlation with technical efficiency.

4 - Linear optimization model for fish processing production planning
Pall Jensson

The fishing industry feature a fast paced and ever-changing environment wherein recent years' major developments of high-tech equipment's have occurred in the processing sector resulting in a wider range of product possibilities as well as increasing production capacity. This study attempts to show that optimization model and sensitivity analysis can be beneficial as a decision-making tool for production manager in this fast-paced environment. The paper proposes a linear optimization model that can be used as a decision aid for one-day production planning. The Net Profit Contribution is maximized subject to raw material requirements, machine time requirements, orders, and contracts. The model was tested and validated using real data from a typical processing day at a vertically integrated fishery in Iceland.

■ TC-50
Tuesday, 12:30-14:00 - 4D UPV 1.1

Modeling Tools for Energy and Sustainable Policy II

Stream: Long-term Planning in Energy, Environment and Climate
Chair: *Sandrine Selosse*

1 - EU and Norwegian policy analysis using CGE modelling
Gerardo Perez Valdes

Energy Policies in general are complex instruments with wide-ranging mechanisms and effects on the economic systems they impact. Using the flexible CGE model REMES, we have, over the last five years, analysed different aspects of the Norwegian and the European Energy System. Case studies performed with REMES address international oil prices, efficiency in the transport system, introduction of hydrogen, and deployment of energy-efficient building technologies. We present here short details of the implementation of these policy mechanisms.

2 - The Canadian contribution to limiting global warming below 2 degree C: an analysis with NATEM
Olivier Bahn, Kathleen Vaillancourt, Oskar Sigvaldason

Canada committed to reduce its greenhouse gas (GHG) emissions by 30% below 2005 levels, by 2030, and by 70% to 90% below 2005 levels, by 2050. These challenging commitments require special consideration of the energy sector in Canada. The main objective of this presentation is to identify different decarbonization pathways that would allow Canada to participate in global mitigation efforts to prevent climate changes. We analyse four GHG mitigation scenarios with increasing levels of mitigation efforts for 2050 using the NATEM regional optimization model. NATEM belongs to the TIMES family of models developed within the Energy Technology Systems Analysis Program of the International Energy Agency. It relies on the concept of a Reference Energy System that describes energy value chains from primary energy to useful energy. NATEM is cast as a dynamic linear programming model, where the objective is to minimize the net present worth cost of the energy system. The main transformations in the energy system include significant energy conservation and efficiency improvements, greater penetration of electricity in all end-use sectors (up to 64% of total consumption in 2050), as well as an important increased use of bioenergy in 2050. On the supply side, this translates into a rapid decarbonization of electricity production and a shift away from fossil fuel production and imports.

3 - Combining spatial analysis and choice experiments for the evaluation of sustainable neighbourhood strategies
Caterina Caprioli, Marta Bottero, Marina Bravi, Chiara D'Alpaos, Federico Dell'Anna, Giulio Mondini

Urban and territorial management processes must deal with new urgent questions, summarised into the meaning of urban regeneration. This term refers not only to the redevelopment of the existing buildings but also to other important issues, such as social hardship, inhabitants' quality of life and active involvement, tangible and intangible elements, cultural and natural resources, economic processes. The transition from the analysis of the single building to smart districts and sustainable neighbourhoods inevitably requires ad hoc tools and approaches for utilising urban data. The research examines an innovate hybrid model in which the systematic nature of the evaluation is combined with the spatial dimension for the management of urban transformations. Starting from a real case study in the city of Torino, the project investigates the use of a Choice Experiment model integrated with Geographic Information System (GIS) for exploring the Willingness To Pay for alternatives land-use strategies.

4 - Multi-objective multi-item fixed-charge solid transportation problem with green supply chain network in an intuitionistic fuzzy environment
Sankar Kumar Roy

The main objective of this paper is to analyze an innovative study of multi-objective multi-item fixed-charge solid transportation problem (MMFSTP) with green supply chain network in an intuitionistic fuzzy environment. Nowadays, it is the most controversial factor that greenhouse gas emission such as carbon dioxide, methane, etc., cause air pollution and global warming, which inspired me for designing the proposed study. In real-world practical situations, the parameters of MMFSTP with green supply chain network are usually of imprecise nature. Due to this reason, we include trapezoidal intuitionistic fuzzy number to deal with the imprecise parameters in the proposed study. Expected value operator is used to reduce intuitionistic fuzzy MMFSTP to deterministic MMFSTP. Then, we propose the methodologies for solving the deterministic MMFSTP by two programming, namely, weighted Tchebycheff metrics programming and min-max goal programming which give the Pareto-optimal solutions. Comparison study is presented between the optimal solutions, extracted from the considered programming. The procedure and efficiency of the study are shown by considering an application example which is closely related with real-life industrial problem. Finally, conclusions about the findings and future study are described.

■ TC-51

Tuesday, 12:30-14:00 - 4D UPV 1.2

Radiotherapy Optimization

Stream: OR for Health and Care II
Chair: *Matthias Ehrgott*

1 - Beam angle optimization in IMRT: are we really optimizing what matters?
Joana Matos Dias, Humberto Rocha, Tiago Ventura, Brígida da Costa Ferreira, Maria do Carmo Lopes

Intensity-modulated radiation therapy(IMRT)is a modern radiotherapy modality that enables the irradiation of the patient with non-uniform maps of radiation from a set of distinct beam irradiation directions. The aim of IMRT is to eradicate all cancerous cells by irradiating the tumor with a prescribed dose while simultaneously sparing, as much as possible, the neighboring tissues and organs. The optimal choice of beam irradiation directions - beam angle optimization (BAO) - can play an important role in IMRT treatment planning by improving organ sparing and tumor coverage, increasing the treatment plan quality. Typically, the BAO search is guided by the optimal value of the fluence map optimization (FMO) - the problem of obtaining the most appropriate radiation intensities for each beam direction. In this paper, a new score to guide the BAO search is introduced and embedded in a multistart derivative-free optimization framework that is detailed for the extremely challenging multi-modal BAO problem. For the set of ten clinical nasopharyngeal tumor cases considered, treatment plans obtained for optimized beam directions clearly outperform the benchmark treatment plans obtained considering equidistant beam directions typically used in clinical practice. Furthermore, treatment plans obtained considering the proposed score clearly improve the quality of the plans resulting from the use of the optimal value of the FMO problem to guide the BAO search.

2 - Targeted multi-criteria optimization in imrt planning using knowledge based model creation
Katrin Teichert, Philipp Süss

In radiotherapy treatment planning it often happens that an initial optimization model fails to generate expected trade-offs and a planner is thus forced to refine the model and repeat the calculations. This shortcoming stems from a drawback to conventional multi-criteria optimization that the optimization model cannot be changed once the Pareto front has been approximated. This implies that the planner has to guess an appropriate model a priori. However, only after the Pareto frontier is approximated can the planner assess the goodness of the model by exploring the inherent trade-offs. To counter this, we propose a local multi-criteria workflow (L-MCW) that enables local exploration around an initial, promising plan automatically inferred by a knowledge-based algorithm. The generation of Pareto-alternatives is done by varying the objective functions themselves, thus allowing the decision-maker to evaluate trade-offs in the most interesting region surrounding the initial plan. Clinical results of the combination of knowledge-based planning and L-MCW demonstrate substantially reduced planning time and improved organ-at-risk sparing compared to manual planning. The L-MCW provides an intuitive and flexible mechanism to adapt knowledge-based-planning models to similar, but not identical clinical situations and allows the practitioner to quickly determine and realize the most beneficial trade-offs in a treatment plan.

3 - Scheduling radiotherapy treatments considering stochastic appointment durations, patient unavailability and machine breakdowns
Petra Vogl, Roland Braune, Walter Gutjahr, Karl Doerner

The Radiotherapy Patient Scheduling Problem (RPSP) deals with the assignment of treatment appointments to patients suffering from various types of cancer. While photons are used to irradiate patients in classical radiotherapy, specialized centers all over the world use ion beam therapy in order to less harm healthy tissue surrounding the tumorous region. Due to the high demand and large costs of the accelerators used in these centers, optimizing radiotherapy appointments is crucial.

The described problem is highly stochastic: On the one hand actual appointment durations might deviate from the planned durations due to the patient's condition and mobility. On the other hand patients might feel too sick to be treated at the planned treatment time and need to be assigned a postponed appointment or machines might break down causing a serious delay.

In order to account for the stochasticity during the optimization process, we analyze real-world data on appointment durations from the past and use these data to develop individual probability distributions. We then develop an optimization approach for the RPSP that hopefully contains patient-specific buffer times. We apply a variant of a genetic algorithm approach that has proven to be successful in the deterministic version of the problem. The objective is to find a schedule that is as tight as possible while simultaneously minimizing patient waiting time.

4 - Evaluating the quality of radiotherapy treatment plans for prostate cancer
Emma Stubington, Matthias Ehrgott, Omid Nohadani

External beam radiation therapy is a common treatment method for cancer. Radiotherapy treatment is planned with the aim to achieve conflicting goals: while a sufficiently high dose of radiation is necessary for tumour control, a low dose of radiation is desirable to avoid complications in normal, healthy, tissue. Each hospital has a clinical protocol that defines a number of criteria that a plan must meet before it can be approved for delivery. If these targets are not met, the plan will be re-optimised using a trial and error process. To support the planning process, we seek plans that would benefit from re-optimisation by proposing a method to evaluate the quality of the treatment plans. First, the clinical protocol is translated into a set of measurable variables and Principal Component Analysis (PCA) is used for dimension reduction to select the most relevant variables. Data Envelopment Analysis (DEA) is then applied to assess the quality of individual treatment plans and simulation techniques are used to account for the uncertainty in the data. This allows us to make recommendations to the clinicians as to which plans we believe could potentially be improved. In this talk, we present a case study based on 51 prostate cancer treatment plans from the Royal Preston Hospital, UK. Clinicians at Preston then re-plan the identified plans and our findings are presented here.

■ TC-52

Tuesday, 12:30-14:00 - 4D UPV 1.3

Workforce Planning

Stream: OR for Health and Care I
Chair: *Inês Marques*

1 - Workforce planning for palliative care specialists in Nova Scotia: an operational research approach
Majid Taghavi, Grace Johnston, Robin Urquhart, David Henderson, Cheryl Tschupruk, Beth Tupala

Palliative care deals with patients with life-limiting diseases by helping them to achieve the best possible quality of life up to the end of life. Our population is ageing, and this means that an increasing number of adults will need a palliative approach at the end of their lives. In the past, palliative care was considered mainly for persons dying of cancer and very close to the end of life, but increasingly a palliative approach is being advised for persons with organ failure (congestive heart failure, chronic obstructive pulmonary disease, etc.) and frailty (dementia, etc.) earlier in the trajectory of their illness. There are specialist palliative care teams across Nova Scotia, but access to specialist palliative care teams varies and human resource planning is lacking. Our literature review showed that operations research has not been used for palliative care workforce planning so far. Therefore, in this research, we develop a linear programming model to plan for the number and distribution of specialist palliative care physicians, nurses, and social workers for Nova Scotia over next 20 years. This model enables comprehensive palliative care workforce planning and can be adapted for similar workforce planning problems in healthcare. Several Palliative care practitioners and health system managers reviewed and critiqued our mathematical model, and they were also consulted for estimating the parameters of the model.

2 - Improving shift schedule of non-urgent patient transportation ambulances while maximizing emergency coverage
Theresia van Essen, Pieter van den Berg

Many ambulance providers operate both advanced life support (ALS) and basic life support (BLS) ambulances. Typically, only an ALS ambulance can respond to an emergency call, whereas non-urgent patient transportation requests can either be served by an ALS or a BLS ambulance. The total capacity of BLS ambulances is usually not enough to fulfill all non-urgent transportation requests. The remaining transportation requests then have to be performed by ALS ambulances, which reduces the coverage for emergency calls. In a recent paper, we presented methods that determine the routes for BLS ambulances while maximizing the remaining coverage by ALS ambulances. However, this remaining coverage for emergency calls can be further improved by better fitting the shift schedule of BLS ambulances to the demand of transportation requests. In this presentation, we will present several (stochastic programming) methods to achieve this and test these methods on data of a Dutch ambulance provider.

3 - The big data newsvendor: practical insights from machine learning
Gah-Yi Ban, Cynthia Rudin

We investigate the data-driven newsvendor problem when one has n observations of p features related to the demand as well as historical demand data. Rather than a two-step process of first estimating a demand distribution then optimizing for the optimal order quantity, we propose solving the "Big Data" newsvendor problem via single step machine learning algorithms. Specifically, we propose algorithms based on the Empirical Risk Minimization (ERM) principle, with and without regularization, and an algorithm based on Kernel-weights Optimization (KO). We analytically justify the use of features by showing that their omission yields inconsistent decisions. We then derive finite-sample performance bounds on the out-of-sample costs of the feature-based algorithms, which quantify the effects of dimensionality and cost parameters. Our bounds, based on algorithmic stability theory, generalize known analyses for the newsvendor problem without feature information. Finally, we apply the feature-based algorithms for nurse staffing in a hospital emergency room using a data set from a large UK teaching hospital and find that (i) the best KO and ERM algorithms beat the best practice benchmark by 23% and 24% respectively in the out-of-sample cost, and (ii) the best KO algorithm is faster than the best ERM algorithm by three orders of magnitude and the best practice benchmark by two orders of magnitude.

■ TC-53

Tuesday, 12:30-14:00 - 4D UPV 1.4

International Aspects of OR I

Stream: International Aspects of OR
Chair: *Ulrike Reisach*

1 - Liberated social entrepreneur using business metrics: QZenobia refugee/migrant big data analytics startup
Berat Kjamili, Gerhard-Wilhelm Weber

LiBerated Social Entrepreneurship in Developing and Emerging Countries consists of a social entrepreneur using business metrics, to sustain social impact. We study differences between developing and developed countries, introducing a new OR approach to development. Commercial entrepreneurs are generally oriented to business metrics like profit, revenues and return. Instead, social entrepreneurs are non-profits or a blend with for-profit goals, generating Return to Society. In DCs, a social entrepreneurship has been uncommon. We introduce a mid-way as LiBerated Social Entrepreneur, where social businesses should be sustainable. We apply Game and Max-Flow - Min-Cut Theories, Schumpeter's creative destruction and Adam Smith's diversification model for our business plan. As a result, Berat started QZenobia: a mobile application that runs as a "refugee portal", supported by "Refugee Big-Data Analytics": refugees submit data to the application via "questionnaire" and search for opportunities, verified news privatized based on their answers.

Multivariate Adaptive Regression Splines (MARS), Conic MARS (CMARS) and its robust version RCMARS have shown their potential for Big-Data and, recently, Small-Data. With that toolbox, we aim to further support our project.

2 - Artificial intelligence and ethics - an international comparison of perceptions and policies
Ulrike Reisach

Artificial Intelligence (AI) uses unprecedented capabilities in the field of data collection, storage and analysis. The amounts of accessible personal data, combined with their analysis through AI, enable forecasting and profiling with greater accuracy than ever before. Private and public actors use the technology for their purposes, with more or less privacy protection and transparency. Legal regulations are under discussion in different political frameworks. The ethical legitimacy of different AI endeavors in their respective contexts needs to be discussed. The power concentration resulting from big data and AI has consequences for societies across borders. Tracking, facial recognition, mass personal profiling and targeted provision of information can be achieved, resulting in targeted but hidden influence, surveillance or social scoring models. They may be used for safety and crime prevention as well as for control of citizens and potential political opponents. Cultures and systems have diverging ethical standards and perceptions of the benefits and risks related with such types of AI. This presentation covers different perspectives and legitimation of the societal purposes and outcomes of AI. It compares different approaches regarding privacy, data ownership and sovereignty as well as potential governance measures to safeguard values such as cohesion, pluralism, mutual learning and cooperation within and among the different societies of this world.

■ TC-54

Tuesday, 12:30-14:00 - 4D UPV 1.6

Soccer Analytics

Stream: OR in Sports
Chair: *Nobuyoshi Hirotsu*

1 - The return to leadership: empirical evidence from football
Daniel Weimar, Joachim Prinz

Despite the high practical relevance of the effect of new team leaders on the overall outcome, there are only few existing studies analyzing the change in effort of the team leader and the production of the team. One potential drawback to investigate such relationships is the rare existence of adequate measurements of effort. For this reason, the running distance of football players as credible measurement of effort is utilized. As the main predictor the effort provi-sion and productivity of players right after becoming a team leader (captain) is plugged into the re-gression analysis. Therefore, we specifically look at "spontaneous" and unexpected in-season variation of captains. Such exogenous changes mainly occur when the actual captain misses some games (e.g. injuries, suspension). Constrained by the availability of running data, we use a dataset from the German Bundesliga covering four seasons 2011/2012 - 2014/2015 (N=47.000), containing 181 in-season captain changes). In contrast to the general expectation of motivation deriving from leaders and especially the assignment of new leaders,we found no significant relationship of being a captain/ becoming a new captain and the effort provision. Moreover, captain assignment had no effect on hiw own productivity (tackles, shots, touch-es, yellow card). We also found no impact for the new captain in the first five games. A new captain also did not affect the behavior of his teammates significantly.

2 - Regression based ratings for individual football players
Lars Magnus Hvattum

The last years have witnessed an increased focus on evaluating individual players in team sports. This work considers whether meaningful player ratings in football can be derived from data that only considers the observed goal differences when different players are on the pitch. To derive ratings, a multiple linear regression model is solved using ridge regression. By considering additional co-variates, effects of the home field advantage, red cards, and the age of players are identified.

3 - Serial correlation in DEA applied to soccer teams and interpretation of weights
Lucia Isabel Garcia-Cebrian

Data Envelopment Analysis has been often used as a tool for efficiency calculation in soccer teams context and the variety of focus in specialized literature is huge concerning sample, input and output variables. In its original version, DEA offers recommendations for inefficient DMUs assuming independence respect the other DMUs in the sample. Nevertheless, in a sport context and using sport result as output variable, this independence doesn't exist: if an inefficient team needs to add a win in order to become efficient, another team in the sample would worsen its sport result and, consequently, its efficiency ratio (Collier, Johnson and Ruggiero, 2011). From a more general and theoretical point of view, Førsund (2013) criticizes the imposition of restrictions in the input and output weights in DEA formulation because these weights enter in the formulation and right interpretation of shadow prices, marginal productivity of inputs, marginal rate of transformation between outputs and marginal rate of substitution between inputs, all of them well established concepts in organizations management. The aim of the present paper is to combine the ideas of both papers verifying if the new efficiency ratio proposed by Collier et al. (2011) for taking into account the serial correlation among soccer teams results in a championship maintains the interpretations provided by Førsund (2013). An application to Spanish soccer teams playing in the First Division will be presented.

4 - A Markov process approach for modeling a soccer game in the analysis of characteristics of teams
Nobuyoshi Hirotsu, Keita Inoue, Kenji Yamamoto

In this paper, we model a soccer game for analyzing characteristics of teams. We build Markov process models considering the location of the ball on the pitch, which will be useful to provide insights of characteristics of teams. According to different degrees of division of the pitch, we propose three models by dividing the pitch into up to 9 areas. Using the models we analyze their characteristics related to such factors as home advantage, offensive and defensive strength, in terms of goals and possession according to the location of the ball. Based on annual data from the J-League Division 1 in 2015, we select suitable models minimizing AIC for explaining the numbers of goals and transitions. We analyze the characteristics of the teams in ways that allow us to understand their offensive and defensive strength with respect to goals and possessions according to the location of the ball on the pitch, and discuss the effect of degrees of division of the pitch on the modeling of a soccer game.

■ TC-55

Tuesday, 12:30-14:00 - 4D UPV 2.1

Optimization R Us: Using R for Data-Driven Optimization

Stream: Making an Impact I
Chair: *Joaquim Gromicho*

1 - Optimization R Us: using R for data-driven optimization
Joaquim Gromicho

When it comes to modern and widely accessible programming languages two camps seem to attract comparable amounts of attention and collectively dominate: R and Python. R seems to be preferred by the statistic and data science communities, while Python seems to be the language of choice of the artificial intelligence and mathematical optimization communities. This classification is by no means limitative, since there are many other good choices such as Julia, Jump, Java, C, C++, C#, Matlab, Octave, etc. Nevertheless, the perception that R is not for optimization may interfere with the possibility to merge great libraries and tooling for (big) data analysis with optimization. This tutorial gives data scientists familiar with R a glimpse on how to use it for optimization and other scientists familiar with optimization a glimpse of the power of R. The tutorial includes examples of data driven optimization using R both as a platform to develop heuristic methods and as an interface to mathematical optimization solvers. To get the most from it, please bring your own laptop with an internet connection.

■ TC-56

Tuesday, 12:30-14:00 - 4D UPV 2.2

Optimization in Renewable and Energy Systems II

Stream: Optimization in Renewable Energy Systems
Chair: *Andreas Bley*

1 - Capacity payments, price cap, and the missing money problem
Irena Milstein, Asher Tishler

This paper analyzes the consequences of introducing capacity payments in competitive electricity markets. We develop and present a two-stage model with one type of electricity generation technology. Independent power producers (IPPs) choose capacity investment in the first stage and decide on their optimal outputs, via the Cournot model, in the second stage. We show analytically that the use of capacity payments can (a) dramatically reduce or fully eliminate outage costs due to price capping, (b) increase consumer surplus, and (c) increase or decrease IPP's profits. We use stylized data from Texas ERCOT to demonstrate our analytical results and show that capacity payments have little or no effect on social welfare (consumer surplus plus IPP's profits minus the cost of using capacity payments), and that the introduction of capacity payments reduces the electricity price and price volatility, and is likely to increases system reliability.

2 - Bilevel linear programming investment problems with lower-level primal and dual variables
Henrik Bylling, Steven Gabriel, Trine Krogh Boomsma

This paper examines bilevel linear programming investment problems in which the upper-level objective function depends on both the lower-level primal and dual variables. We show that the upper-level objective function is non-convex and even discontinuous but piece-wise linear with regard to the upper-level variables. We exploit this piece-wise linearity to design a global solution method based on parametric programming and with the advantage that it allows for decomposition of separable lower-level problems. If the upper-level objective function is a bilinear function of the lower-level primal and dual variables, we also provide an exact linearization method that produces a mixed-integer linear programming formulation of the bilevel problem. Numerical experiments demonstrate that our decomposed method has significant computational advantages for bilevel investment problems with a high number of lower-level market clearing problems. Furthermore, the parametric programming approach automatically allows for post-optimal sensitivity analysis of the bilevel programming problem.

3 - Electromagnetic field optimization algorithm for the photovoltaic solar cell parameter estimation problem
Ilker Kucukoglu, Alkin Yurtkuran

Recently, the researches on renewable energy have been increasing rapidly due to the considerable attention on environmental concerns. In this context, solar energy is one of the promising technology with its low maintenance cost and zero pollution. This study considers the parameter estimation problem of the photovoltaic cells to optimize the efficiency of the solar cell technology. The photovoltaic solar cell parameter estimation problem (PSCPEP) is described as extracting the electrical parameters of the photovoltaic cells from measured Current vs. Voltage curves with minimum prediction error. In order to obtain efficient results for the problem, a recent physics-inspired meta-heuristic algorithm, called Electromagnetic Field Optimization (EFO), is employed. The performance of the EFO is tested on a well-known benchmark problem set which is formed by real life experiments of a commercial silicon solar cell. Moreover, the proposed algorithm is compared with a set of powerful meta-heuristic algorithms. Results of the computational studies show that the EFO outperforms the other considered meta-heuristic algorithms by estimating the solar cell parameters with lower root mean square error values.

■ TC-57
Tuesday, 12:30-14:00 - 4D UPV 2.3

Software for Mixed-Integer Optimization II

Stream: Software for Optimization
Chair: *Timo Berthold*

1 - Benchmarks of commercial and noncommercial optimization software
Hans Mittelmann

Based on our benchmarking service we will provide an overview of the state-of-the-art in various areas of optimization.

2 - Adaptive algorithmic behavior for solving mixed integer programs using bandit algorithms
Gregor Hendel, Matthias Miltenberger, Jakob Witzig

State-of-the-art solvers for mixed integer programs (MIP) govern a variety of algorithmic components. Ideally, the solver adaptively learns to concentrate its computational budget on those components that perform well on a particular problem, especially if they are time consuming. In this work, we focus on three examples of such expensive algorithms, namely the classes of large neighborhood search and diving heuristics as well as the available pricing strategies to the Simplex algorithm for solving LP relaxations. Typically, only one algorithm is run and evaluated at a time to update the overall selection strategy. We review several common strategies for such a selection scenario under uncertainty, also known as Multi Armed Bandit Problem. In order to apply those bandit strategies, we carefully design deterministic reward functions to rank and compare each individual heuristic or pricing algorithm within its respective group. We use simulations on publicly available MIP problems to calibrate the bandit strategies and show their individual learning curves. Finally, we discuss the computational benefits of using the proposed adaptive selection within the MIP solver SCIP.

3 - Learning to tune parameters of NUOPT MILP solver
Koichi Fujii

MILP solvers implement branch and bound with several features such as presolving, cutting planes and primal heuristics to tackle difficult problems. Since changing parameters and configuring such features have a huge impact in solving times, it is an important task to find a best set for a specific problem or a certain class of problems. Recently many techniques are found in machine learning to learn an algorithm behavior or find a good set of parameters of an algorithm. In this talk, we will present how to use those techniques effectively to automate parameter tuning of a NUOPT MILP solver.

4 - To use or not to use an algebraic modeling language (such as OPL)?
Alex Fleischer

We discuss pros and cons of using an Algebraic Modeling Language (AML) for optimization, with examples from transport, finance and energy in the IBM CPLEX Optimization Studio OPL language. We show in particular how an AML helps do more with less, in relation to real-life resources as well as expert brain-power. With the same mental effort, the OR expert can take advantage of an AML to solve the same problem faster and to tackle harder problems.

Using an AML does add to the heterogeneity of the modeling environment, and can increase the time and memory overhead of model processing; additionally there is some risk for IP loss since the algebraic model is by design easily readable. However the advantages are many. Modeling gets fun; asking for help gets easy and prototyping is a game. Different lifecycles for models and applications reduce development cost. There's less need for OR and programming skills; instead one can focus on his/her expertise, and business users can have a say. Plus models tend to survive applications. Model inertia gets low and that is key when we remember that good modeling may be crucial to performance.

■ TC-58
Tuesday, 12:30-14:00 - 4D UPV 2.4

OR Promotion among Academia, Businesses, Governments

Stream: OR Education
Chair: *Gerhard-Wilhelm Weber*

1 - The contest approach for funding research in academic units
Baruch Keren, Yossi Hadad, Yizhaq Minchuk

This research presents a unique model that based on game theory. The model can help decision-makers in higher education (HE) institutions determine an optimal research budget, and then to decide how to allocate that budget among academic units (researchers/institutes/departments). The model considers the management of the institution as a contest organizer and the academic units as contestants that compete with each other to win the contest. The prize of this contest is a desired research budget. The proposed model includes a form of two contestants with different abilities, as well as a form with unlimited (N) contestants with the same abilities. The model enables decision-makers to determine the size of the prize (the optimal research budget) and the optimal distribution mechanism (a contest or a fair division) of that prize among the contestants. The study includes a real case study that demonstrates the model and its applicability.

2 - OR/MS education and international cooperation for employability
Joao Miranda, Ana Paula Teixeira

While international cooperation and societal challenges are framing the "knowledge triangle" education-research-innovation, the effectiveness and performance of higher education institutions are also appreciated from the impact of teaching/learning on the labor market, on career, on practice. In a recent work, the authors presented an overview of good practices in OR/MS Education and of EACEA projects, in a way to reinforce the insight on the OR/MS education trends. At now, additional experiments and data analysis are performed and preliminary results are presented, in particular, the enrolment of students and the transition of graduates onto the labor market are re-visited. These recent results are motivating further studies, namely, the comparative analysis between institutions or countries, the impact of new digital phenomena and the evolving ICT tools in OR/MS education, the graduates employability, being these topics discussed and next steps outlined.

3 - A system-dynamics approach to assess the factors which influence the quality of primary education in developing countries
Gerhard-Wilhelm Weber, Pedamallu Chandra Sekhar, Linet Ozdamar, Herman Mawengkang, Hanife Akar

System-dynamics approach is a holistic way of investigating and treating problems in real-time scenarios. It is a powerful methodology and computer simulation modeling technique for framing, analyzing, and discussing complex issues and challenges. System-dynamics modeling and simulation is often the background of a systemic thinking approach and has become a management and organizational development paradigm. In this presentation, we reflect our experiences and thoughts on developing system thinking models to understand the important factors such as Facilities (includes infrastructure), Local and national political stability, Family migration from rural to urban localities, and socio-economic status of the families on the quality of primary education system in developing nations. This study provides a refined view onto the factors which need to be addressed for providing sustainable education experience to children living in developing nations. In this talk, we discuss the situations in India, making an application of our method on data from the state of Gujarat, in Turkey and in Indonesia.

■ TC-59

Tuesday, 12:30-14:00 - 4D UPV 2.5

OR Models for the Operation and Planning of Integrated Energy Systems

Stream: Technical and Financial Aspects of Energy Problems
Chair: *Juan Miguel Morales*

1 - A three-stage stochastic optimization model for the design of smart energy districts under uncertainty
Matteo Zatti, Emanuele Martelli, Juan Miguel Morales

Multi-energy systems (MES) and district-energy systems (DES) have been identified as promising solutions to increase energy efficiency and to maximize the share of intermittent renewable sources in urban areas. A critical result of the analysis of MES and DES is that, when optimizing their design, the operation strategy and the part load behavior of the units must be considered. In addition, the key design data (i.e energy demand profiles, energy prices, weather conditions and intermittent renewable energy sources production) may be highly uncertain as they are results of forecasts. We formulate the optimal design of MES as a three-stage stochastic mixed integer linear programming model (SMILP) with integer recourse. The peculiarity of the model is to account for the uncertainty in the short-term weather and energy demand forecasts, the day-ahead electricity bidding, the day-ahead commitment of large power plants and the possibility of real-time scheduling adjustments of flexible generation units. Due to the large number of variables and constraints, the problem calls for the development of an efficient ad hoc decomposition approach. We propose a heuristic algorithm which solves a sequence of design (first and second stage) and operation (third stage) problems with progressively increasing integrality restrictions and number of scenarios.

2 - Operational detail in long-term energy-system planning models: assessment of the impact and moving forward
Kris Poncelet, Erik Delarue

To limit computational complexity, long-term energy-system planning models, such as TIMES models, typically use a low level of operational detail to model the power system. More specifically, these models have historically used a low level of temporal and technical detail to represent the operation of the power system, i.e., intra-annual variations in demand and renewable electricity generation are typically represented by 4-48 so-called time slices and the technical constraints faced by thermal power plants when changing their power output, starting up or shutting down are neglected. However, in the context of an increasing penetration of strongly fluctuating and limitedly predictable renewable energy sources such as wind turbines and solar photovoltaic panels, this low level of temporal and technical detail might not be sufficient to grasp the challenges related to integrating these intermittent renewable energy sources. In this context, this presentation addresses the following questions: (i) What is the impact of using such a low level of temporal and technical detail, and (ii) How can long-term energy-system planning models be improved without drastically increasing the computation time?

3 - Investments in merchant energy storage: trading-off between energy and reserve markets
Hrvoje Pandzic

Grid-scale energy storage (ES) units are regarded as an enabler of the renewable-dominant power systems. Currently available ES technologies are ubiquitous, but not equally suitable for providing different grid support services. For example, performing energy arbitrage requires ES units with high energy ratings and the ability to store energy during multiple operating intervals. On the other hand, performing reserve services requires ES units with high power ratings that can sustain quick changes in their net power input/output. Therefore, merchant ES investors need to ensure that their ES investments are well aligned with unique grid support needs and that the ES characteristics are suitable for the simultaneous provision of multiple services.

We will present a model to optimize merchant investments in ES units that can compete in the joint energy and reserve market. The proposed model uses the bilevel programming framework to maximize the expected lifetime profit and to ensure a desirable rate-of-return for the investor, while endogenously considering market clearing decisions over a set of characteristic days.

4 - Chronological time-period clustering for optimal capacity expansion planning with storage
Salvador Pineda Morente, Juan Miguel Morales

To reduce the computational burden of capacity expansion models, power system operations are commonly accounted for in these models using representative time periods of the planning horizon such as hours, days or weeks. However, the validity of these time-period aggregation approaches to determine the capacity expansion plan of future power systems is arguable, as they fail to capture properly the mid-terms dynamics of renewable power generation and to model accurately the operation of electricity storage. In this paper we propose a new time-period clustering method that overcomes the aforementioned drawbacks by maintaining the chronology of the input time series throughout the whole planning horizon. Thus, the proposed method can correctly assess the economic value of combining renewable power generation with interday storage devices. Numerical results from a test case based on the European electricity network show that our method provides more efficient capacity expansion plans than existing methods while requiring similar computational needs.

■ TC-60

Tuesday, 12:30-14:00 - 4D UPV B.5

Meet the editors EJDP

Stream: EURO Special Sessions
Chair: *Vincent Mousseau*

1 - EURO Journal on Decision Processes - Meet the Editors
Vincent Mousseau

The editors of EJDP will present the status of the journal and the priorities for the future. The editors will be available to discuss practical aspects of publishing in this journal. There will be opportunities for the panel to answer general questions from the audience.

Tuesday, 14:30-16:00

■ TD-01

Tuesday, 14:30-16:00 - UPV Nexus

Integrated Optimization in Public Transportation: Does it help?

Stream: Keynotes
Chair: *Daniele Vigo*

1 - Integrated Optimization in Public Transportation: Does it help?
Anita Schöbel

Attractive and efficient public transportation is needed for satisfying the increasing mobility demand in an environmental-friendly way. In view of growing emissions, research on optimizing public transport is more relevant than ever.

The classical approach in public transportation planning is the following: After the network design, the lines and their frequencies are planned. Based on these, the timetable is determined, and later on the vehicles' and drivers' schedules. In order to account for the passengers, their routes are estimated after each of these stages and then used as input for the next stage. These single planning stages are well understood and many of them can algorithmically be treated. However, following the above sketched sequential approach may be far away from finding an optimal solution for the whole system. This calls for integrated optimization.

In this talk we present approaches for integrated optimization in public transportation, apply them to benchmark examples and discuss how useful they are. While we focus on public transportation, many of the underlying ideas can also be used in other application areas.

Integrated versus sequential optimization. The sequential procedure sketched above can be regarded as a Greedy approach: in each planning stage one aims at the best one can do. This usually leads to suboptimal solutions. On the other hand, many of these single steps are already NP hard such that solving the integrated problem to optimality seems to be out of scope. Nevertheless, we show how improvements can be made using the Eigenmodel as a framework for (heuristic) integrated optimization. We furthermore introduce the price of sequentiality as a measure how much can be gained by integrated approaches.

Integrating passengers' routes. While many models in public transportation aim to minimize the traveling time of the passengers, the behavior of the passengers is not reflected realistically in most approaches. In many models, passengers are routed before the optimization. These routes are then fixed and are the basis for finding good line plans and timetables. We show that such a first routing has an immense impact on the resulting line plan, the timetable, the travel time and the costs. Better results are obtained if the routes of the passengers are variables which are determined within the optimization. However, these models are even harder to solve. We show two tricks to make such models tractable.

Finally, both aspects are combined, again in the framework of the Eigenmodel. We also show how more realistic models such as taking the vehicles' capacities into account, or using logit models can be heuristically treated within this framework. In an outlook, we also sketch questions and ideas which may be relevant for integrated public transportation in the future.

■ TD-02

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S101

DEA, Agriculture, Food

Stream: DEA: Applications
Chair: *Natalia Kuosmanen*

1 - The techical efficiency of Turkish crop production: a comparison of data envelopment analysis and stochastic frontier analysis
Bulent Cekic, Cem Menten, Kazim Baris Atici

The growing dependence on agricultural production, the concerns about this dependency and the growing consciousness between the manufacturing industry as well as the public and legislator have created the concept of sustainable agricultural production. The objective of sustainable agricultural production is to be able to process raw materials in balance with environmental, social and financial systems. In terms of geographical and climate indicators, Turkey is one of the countries suitable for growing a wide range of agricultural products. The purpose of this study is to investigate the country-level technical efficiency scores in the 2009-2015 year of crop production in the Turkish agricultural sector with utilising both Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). In both analysis, 61 agricultural products were selected as decision making units and the data covers the 6 years period. The agriculture sector has been selected as the field of application in terms of both the application of the DEA and SFA studies and the interpretability of the results to be obtained from the measurements. Given the strengths and weaknesses of these two approaches as DEA and SFA, efficiency measures and scale characteristics derived from these analysis are not always persuasive. In this study, we apply both approaches and compare the results obtained with using data from the balance tables of crop production at the Turkey-level technical efficiency scores.

2 - Designing healthier diets using data envelopment analysis
Argyris Kanellopoulos, Ante Ivancic, J.c. Gerdessen

Traditional diets are replaced by diets higher in refined sugars, fats, oils and meats which increase risks of chronic diseases. Designing healthier diets is a complex process which can have substantial public health benefits. The intake and requirements of important nutrients of different population groups must be taken into account. Moreover, the current dietary preferences of individuals should be also considered to increase acceptability. Diet models have been developed and used for designing such healthier and acceptable diets. The main objective of these models is to determine the optimal quantities of available food items that should be included in a diet to optimize a specific objective function (e.g. maximize a dietary quality index). Additional constraints are defined to improve the acceptability of the calculated diets. These constraints are either in the form of upper and lower limits to the intake of specific food-items or in the form of fixed combinations of food-items in meals. Defining such constraints is challenging and involves expert knowledge and a substantial degree of arbitrariness. To avoid defining such acceptability constraints we propose a DEA based diet model that benchmarks existing complete diets of a certain population and identify healthier alternatives. The method was applied successfully to benchmark alternative diets of a group of individuals in the Netherlands.

3 - The analysis of relative efficiency of small food and drink producers across selected EU countries using DEA
Zrinka Lukač, Margareta Gardijan

Lately, there has been an increasing awareness of healthy nutrition and increasing demand for home-grown and organic products. Small food and beverage producers, especially those in agro-industries, play an important role in the supply of such products. Given the important role that small food and drink producers have in socio-economic development of rural areas in many countries, the position of small producers should be recognized and supported on a country level. In this paper we concentrate on small producers in selected EU countries and estimate the relative efficiency of small food and drink producers across countries in terms of their operational and financial efficiency. Since there are multiple criteria that should be considered in determining efficiency, with unknown weights for each criteria, the relative efficiency is obtained using the data envelopment analysis (DEA). The empirical data for this research is obtained from the AMADEUS database for the period from 2011 to 2015. By applying DEA, we are able to detect countries that have relatively the highest percentage of efficient small producers as well as to recognize general strengths of efficient producers and detect areas of inefficiency of inefficient producers. The final purpose of this analysis is to provide policy makers valuable information for developing policies which could lessen the weaknesses and improve their strengths on a country level.

4 - How creative destruction of farms affects total factor productivity of Finnish agricultural sector?
Natalia Kuosmanen, Timo Kuosmanen

Total factor productivity figures of the Finnish agricultural sector, estimated at sector level and at farm level, reveal a large gap. To explain this gap, we develop a new decomposition technique of the sector productivity change, as an extension to Olley and Pakes (1996). Our decomposition brakes down total productivity change of a sector into following components: 1) growth effect, 2) entry and exit effect, and 3) product switching effect. Specifically, we use balanced and unbalance data of Finnish farms since 1995 to present. Product switching and exit of farms are identified as the main drivers of productivity growth of the sector.

■ TD-03

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S103

Location in the Public Sector and Humanitarian Logistics

Stream: Location Analysis and Optimization
Chair: *Carmela Piccolo*

1 - Optimal location of base hospitals for doctor-helicopters
Takamori Ukai, Ken-ichi Tanaka

In this presentation, we discuss location of base hospitals for air ambulance. Air ambulance is a transportation service to transport patients to and from a medical institute and accident scenes by using airplane or helicopter. It is expected to shorten the transportation time to a hospital, and to help start initial treatment by a doctor on site.

In order to evaluate locations of base hospitals for HEMS, we employ a variant of Maximum Covering Location Problem, and apply it to geographical data in Japan. As candidates for base stations, we choose 566 hospitals that play an important role in emergency medical in their individual region. For demand points, we set 178,411 points based on national census in 2015.

We assume that if the distance between a demand point and its closest candidate hospital is less than 7 km, ground transportation has advantage over air transportation. Thus, such demand points are excluded from target demands when calculating an objective function. We also assume that air transportation has a strong effect if the distance between a base hospital and a demand point is less than 50 km, and it has a moderate effect for less than 75 km. From these reasons, the objective function is defined to be the total covered demands weighted by the corresponding strong/moderate coverage values. Under the above settings, we obtain optimal deployments of 51 helicopters that is the same number as currently deployed in Japan.

2 - Reorganizing existing facilities network using multi-period model
Zati Aqmar Zaharudin, Andrea Genovese, Andrew Brint

In many countries, the financial pressure on government funding of services such as health care, waste collection, libraries, the fire and police services, is likely to continue for the foreseeable future. As consolidating services through reducing the number of locations or the number of hours they are open can often lead to significant cost savings, this is an approach that is frequently chosen to mitigate financial short falls. However, while many location-allocation studies can be found in the literature, there is a lack of studies developing congestion considerations in a scenario of supply reduction. To fill this gap, our study tackles the problem by developing a multi-period model for a multi-facility network, focusing on the possibility of having demand transfer across facilities with financial limitations in a congested environment. The model is able to identify possible users' flow and movement throughout the system. The risks from reorganisation can be highlighted and suitable decisions can be made. The model is tailored according to a real-world case (the optimisation of recycling centres in a large city in the UK). The results suggest that two of the facilities could be closed.

3 - Benefit maximizing network design in the public sector
Robert Aboolian, Oded Berman

Governments around the globe are actively involved in providing essential services, such as healthcare, transportation, education and utilities. Their mandate is to maximize the societal benefit by acting as agents of the public in contrast with the private firms' mission to maximize profit. Many models in this area focus on maximizing accessibility to public services. The idea is to (re-)design the public service so as to maximize the number of people who will benefit from the program given a limited budget. These models do not consider the marginal benefit (savings in costs to tax payers by adding an extra unit of service capacity) provided. In this work, we determine the optimal number, locations and capacities of a network of facilities so as to maximize the overall benefit to the public. The overall benefit here is the difference in savings for the public by participating in services and the cost of service capacity that are provided. We introduce exact and approximate methodologies and demonstrate that his problem can simply be extended to private sector as well.

4 - A multi-type facility location problem to support territorial re-organization decisions in non-competitive contexts
Giuseppe Bruno, Antonio Diglio, Carmela Piccolo

Facility Location Models have been widely applied in the context of both private and public sector, to decide the best configuration of new facilities to be located in a given area. In the last years, due to the general interest to reduce costs and improve efficiency, several works started to analyze problems aimed at modifying the territorial configuration of existing facilities, by closing, relocating, merging some of them and/or by downsizing or redistributing their operating capacities. In this work, we propose a new mathematical model to support territorial re-organization decisions in non-competitive contexts. Starting from a set of multi-type facilities (able to provide different kind of services), the model explores the possibility to improve the efficiency of the system by implementing different rationalization actions; i.e., facility closure, service closure, capacity reallocation among services at a given facility. The re-allocation of the demand after such rationalization decisions is performed according different rules (closest or probabilistic re-assignment). The model aims at finding a trade-off solution between the service efficiency and the need of ensuring a given accessibility level to users. The model has been tested on a set of randomly generated instances in order to show that a good range of problems can be solved to optimality through the use of a commercially available solver (CPLEX). Results are presented and direction for future research are drawn.

■ TD-04

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S104

Portfolio Modelling

Stream: New Challenges in Investment Strategies, Risk and Financial Modelling
Chair: *Francesco Cesarone*

1 - On the numerical stability of asset allocation models
Pierpaolo Uberti, Maria Laura Torrente

In this paper we analyze the numerical stability of classical asset allocation models. We discriminate two sources of numerical instability in asset selection models. The first source is well known in the literature and relates to the features of the input data and the inversion of the covariance matrix. We recognize and study a second source of instability that strictly depends on the mathematical structure of the optimization problem and its restrictions. The main result of the paper is the decomposition of the total numerical instability of the model in the two sources previously described. Moreover, we propose a theoretical approach in order to minimize the structural component of instability through an equivalent formulation of the original optimization problem. We also show, both theoretically and empirically, that the proposed formulation of the optimization problem is numerically stable. The results, obtained for the classical mean-variance model developed by Markowitz, are general and apply to a wide class of portfolio selection models.

2 - The l1-regularization for dynamic-portfolio selection
Stefania Corsaro, Valentina De Simone, Zelda Marino, Francesca Perla

In this work we focus on dynamic portfolio selection problem. This problem arises in medium- and long-term investments, in which one allows decisions to change over time by the end of the investment, taking into account the time evolution of available information. We introduce a dynamic model, based on a separable expected conditional mapping, obtained by summing single-period terms in which the variance is taken as risk measure; we fix a final target expected wealth. We introduce l1-regularization techniques to stabilize the solution process, which is typically ill-conditioned because of assets correlation. This also promotes sparsity in the solution; since solutions establish the amount of capital to be invested in each available security, sparsity means that money are invested in a few securities. This allows investor to reduce both the number of positions to be monitored and the transaction costs. We develop iterative algorithms based on Bregman iteration method, that converts the constrained problem into a short sequence of unconstrained ones. The presence of the l1-term makes the solution of the involved optimization sub-problem not trivial, thus we apply ad hoc methods to deal with non-smoothness.

3 - On the stability of portfolio selection models
Francesco Cesarone, Fabio Tardella, Carlo Mottura, Mustafa Cagri Gurbuz, Jacopo Maria Ricci

One of the main issues in portfolio selection models consists in assessing the effect of the estimation errors of the parameters required by the models on the quality of the selected portfolios. Several studies have been devoted to this topic for the minimum variance and for several others minimum risk models. However, no sensitivity analysis seems to have been reported for the recent popular Risk Parity diversification approach, nor for other portfolio selection models requiring maximum gain-risk ratios. Based on a simulation approach, we provide here empirical evidence showing that the Risk Parity model is always the most stable one in all the cases analyzed. Furthermore, the minimum risk models are typically more stable than the maximum gain-risk models, with the minimum variance model being often the preferable one.

4 - Robustness via noncooperative games
Giancarlo Bigi, Simone Sagratella

One way to deal with uncertainty in optimization problems relies on the introduction of uncertainty sets for the data. This allows considering solutions that are feasible for any realization of the data while taking into account the worst-case for the objective as well. A problem of production planning under price uncertainty is exploited to address how to formulate robust counterparts of optimization problems as semi-infinite programs (shortly SIPs), i.e., optimization problems with infinitely many constraints. In turn, SIPs share some similarities with Generalized Nash games (shortly GNEPs) that lead to meaningful connections. Indeed, SIPs can be reformulated as GNEPs with a peculiar structure under some mild assumptions. Pairing this structure with a suitable partial penalization scheme for GNEPs leads to a class of solution methods for SIPs that are based on a sequence of saddlepoint problems. Any converging algorithm for the saddlepoint problem provides the basic iterations to perform the penalty updating scheme. In particular, a projected subgradient method for nonsmooth optimization and a subgradient method for saddlepoints are adapted to our framework and the convergence of the resulting algorithms is shown. A comparison between the two algorithms is outlined as well.

■ TD-05

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S105

Routing Problems with Drones

Stream: Vehicle Routing and Logistics Optimization I
Chair: *Ahmad Hemmati*

1 - Formulations and algorithms for multi-trip drone routing problem with time windows
Yossiri Adulyasak, Chun Cheng, Louis-Martin Rousseau

This study focuses on a multi-trip drone routing problem with time windows, where drones' energy consumption is influenced by payload and travel distance. To tackle the nonlinear energy function, we propose two types of cuts to calculate it exactly. Two formulations are presented and branch-and-cut algorithms are proposed. Computational experiments are used to evaluate the effectiveness of the valid inequalities and user cuts, compare the performance of the two formulations as well as the solutions generated by the exact and approximate methods for energy calculation.

2 - Traveling salesman problem with multi-drone
Emine Es Yurek, H. Cenk Özmutlu

A new delivery problem has recently been introduced as a new variant of classical TSP. In this problem, which is commonly referred as traveling salesman problem with drone (TSP-D), a specially designed truck and a drone simultaneously serve customers. These two vehicles have complementary features. The classical delivery truck is relatively slow but has huge load capacity whereas the drone is faster but has a load capacity of exactly one. Also, the life of the drone battery is limited. These restrictions force the drone to change its battery with a full one and load the next customer's package after each customer visit. To achieve these, the drone is assumed to return to the truck after each flight. Since the truck is modified in order to carry the drone on its top, the vehicles are allowed to travel both individually and in tandem. Therefore, in this new delivery problem, a customer package can be delivered by either the drone, the truck alone or the truck carrying the drone on its top. This study investigates TSP-mD (traveling salesman problem with multi-drone) in which the truck is allowed to carry multiple drones. We propose a two-stage iterative solution approach. In the first stage, we determine the truck route. Then, in the second stage, we optimally determine the drone tours by solving a mixed integer linear programming formulation. A computational study is conducted to analyze the impact of employing multiple drones in truck and drone coordinated delivery system.

3 - Vehicle routing problem with drones: a computational study
Daniel Schermer, Mahdi Moeini, Oliver Wendt

Drones have started to play an increasing role in logistic systems in both, academic research and practical context. In particular, drones have already been successfully applied in related industries including energy, agriculture, and emergency response. Recently, the Vehicle Routing Problem with Drones (VRPD) has been introduced as a variant of the Vehicle Routing Problem. In the case of the VRPD, a fleet of trucks, each truck equipped with a set of drones, is tasked with delivering parcels to customers. The objective is to find a feasible routing that minimizes the time required to complete the mission. The drones may be launched from and recovered by the truck at the depot or any customer location, and move at a velocity that might differ from the truck's speed. Furthermore, drones possess a limited flight endurance and carrying capacity. The VRPD can be formulated as a Mixed Integer Linear Program (MILP) and, consequently, be solved by any standard MILP solver, e.g., Gurobi. Due to limited performance of the solvers in solving large-scale VRPD instances, we propose an algorithm based on the well-known Variable Neighborhood Search. In order to evaluate the performance of the proposed algorithm as well as the MILP solver, we carried out extensive computational experiments. According to the numerical results, our algorithm provides high-quality solutions in short computation time. Furthermore, we observe that the use of drones can significantly reduce the mission time.

4 - A multi-modal truck and drone delivery system
Ahmad Hemmati, Mohammad Moshref-Javadi, Matthias Winkenbach

The last mile delivery is one of the major and costly parts of supply chain, which consider the delivery of products to their final destinations. The planning of last mile delivery is significantly challenging with respect to the dimensions of the problem with deliveries of hundreds of packages to demand locations per day considering all the fleet limitations, customer constraints and preferences, traffic and road constraints, and several other transportation issues. This study addresses a multi-modal truck and drone delivery system in which multiple drones are scheduled to deliver packages to the customers from a single truck with the objective of minimizing the total waiting time at demand locations. The multi-modal truck and drone delivery systems assume that drones pick packages up from the truck, dispatched to the customers, delivering one package in each trip, and return to the truck. While the truck serves as a moving hub for the drones, it can also deliver packages to the customers. It is assumed that the truck and drones can move simultaneously, serving customers concurrently to achieve the minimum waiting time of the system. We propose a mathematical formulation of the problem with extensive numerical computation on small-scale problem instances. An efficient heuristic is also designed to solve the larger problem instances adopted from the literature. Finally, a case study is presented and analyzed to illustrate the use of this system in the real world.

■ TD-06

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S106

Stochastic Modeling and Simulation in Engineering, Management and Science I

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Chair: *Christopher Kirkbride*

1 - Analysis of lot priority rules in semiconductor production systems by queuing networks
Bernhard Oberegger, Boualem Rabta, Gerald Reiner

Production processes in the semiconductor industry (e.g., wafer production) are very complex. They are characterized by high product variety, low-volume production, high cycle time variability and diversity in lot priorities. Low prices and low profit margins lead to huge competitive pressure and manufacturers in the semiconductor sector must introduce their products to the market with short leadtimes according to their contractual agreements. In order to satisfy customer demand in terms of quantity, cost and leadtime, high priority lots are pushed through the factory as quickly as possible. This prioritization of certain lots has an influence on other lots in the line. This leads to longer cycle times for the other lots and may require additional setup procedures. We build a queuing network model for the semiconductor plant under study and develop hybrid decomposition method to analyse lot priority rules. We explore diverse configurations of the system under different contractual agreements regarding leadtimes/penalty costs.

2 - Determination of important disease spread characteristics using Markov chain models
Zeynep Gökçe İşlier, Wolfgang Hörmann, Refik Gullu

There are a number of different approaches to analyze stochastic disease spread models. In the literature, Markov chain modeling approach became quite popular recently as it allows predicting the behavior of stochastic disease spread explicitly using a set of equations. In our study, we deal with continuous time Markov chain modeling of SIS and SIR disease spread models with constant population size to find important properties for SIS and SIR models. The important properties we calculate explicitly using Markov models includes the expected time to extinction, the maximum number of infected individuals during disease and the probability distribution of final size of an epidemic. Moreover, one drawback of Markov disease spread models is the exponential disease duration assumption which is not realistic. Therefore, we extend our study by assuming gamma distributed disease duration and recalculating the important properties explicitly.

3 - An integrated inventory replenishment, lateral transshipments, and routing problem

Hussein Naseraldin, Shiry Varem, Aharon Ben-Tal

Inventory control is an essential part in operations management. We consider a system comprised of retailers facing uncertain demand. In each period, replenishments are made, endogenously, and order-up-to quantities are set. Lateral transshipments are performed after demand is realized but not materialized, in order to minimize predicted excess and shortage of inventory costs at the retailers. However, since transshipments have a non-negligible cost, an important decision on routing costs arises. Lateral transshipments literature provides recommendations on what quantities to deliver directly between retailers. Finding the optimal route to perform the transshipments is different from finding an optimal route for supplying goods (Traveling Salesman Problem) or from pick-up and delivery problems. Another important aspect at hand is the need to deal with uncertainty in the demand. While typically stochastic optimization is the approach, here we address the case where no distribution is given or can be deduced, which is the case when there aren't any or enough or reliable or on-time past demand data or it cannot be attributed to a known distribution thus, we utilize Robust Optimization. We studied the integrated problem of inventory replenishment, lateral transshipments, and routing in a setting in which the demand is uncertain.

4 - Effective heuristic policies for time-critical intelligence gathering operations

Christopher Kirkbride

We consider a multi-source intelligence-gathering problem where, over a finite horizon, an analyst is required to retain a subset of the sampled intelligence items with highest value (or reward) to allocate (or claim) for further processing. In each period, the analyst decides which one of the available information sources to sample from, guided by the posterior distribution of each source. Given the constraint that a small sample of intelligence items are to be collected, the analyst must further decide whether to claim a sampled reward or pass it over for potentially higher value rewards later in the horizon. Formulating the optimization problem as a Multi-Armed Bandit Allocation model, the objective is to determine a joint source selection and reward allocation policy to maximise the expected total reward claimed. Classical solution methods are impractical for problems of realistic size, hence, the requirement is to develop effective heuristic polices for the problem. We approach this through the application of a Lagrangian relaxation to the problem, the solution of which allows for the development a class of index heuristics with source specific indices. We utilise an approximative method for index generation, employing ideas from the Knowledge Gradient approach. The resulting index heuristic, in comparison to other approaches from the literature including Thompson Sampling and KL-UCB, is shown to have consistently strong performance.

■ TD-07

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S107

Recent Advances in Line Planning, Timetabling and Crew Scheduling

Stream: Public Transportation II

Chair: *Valentina Cacchiani*

1 - Combined line planning and train timetabling for strongly heterogeneous railway lines

Fei Yan, Rob Goverde

Rail systems have been developing rapidly in recent years aiming at satisfying the growing passenger demand and shortening passenger travel time. The line planning problem (LPP) and train timetabling problem (TTP) are two key issues at the strategic level and tactical level, laying the foundation of a high-level service quality for railway operation. In this paper, a multi-frequency LPP (MF-LPP) model and a multi-periodic TTP (MP-TTP) model are introduced, with consideration of both periodic and aperiodic nature to meet strongly heterogeneous passenger patterns and reduce the capacity loss of train operating companies. A combined LPP and TTP method is designed considering timetable robustness, timetable regularity, and passenger travel time. For a given line pool, a multi-objective mixed integer linear programming model of MF-LPP is formulated to obtain a line plan with multiple line frequencies by minimizing travel time, empty-seat-hour and the number of lines. Using the acquired line plan from the previous step, an MP-TTP is proposed to achieve minimal travel time, maximal timetable robustness and minimal number of overtakings. The two models work iteratively with designed feedback constraints to find a better plan for the rail transport system. Numerical experiments are applied to verify the performance of the proposed model and solution approach.

2 - Robust train timetabling and stop planning with uncertain passenger demand

Jianguo Qi, Valentina Cacchiani, Lixing Yang

The integrated Train Timetabling and Stop Planning (TTSP) problem calls for determining the optimal timetables for a given set of trains, while choosing, for each train, the subset of stations where it will stop. Both the timetable and the stop plan are determined based on the passenger demand, i.e. on the number of passengers travelling between an origin and a destination stations. In this work, we study the Robust TTSP (RTTSP), where passenger demand is considered to be uncertain, as it is often the case in real practice. We propose an Integer Linear Programming (ILP) model for RTTSP based on Light Robustness, an effective technique introduced by Fischetti and Monaci (2009). We test the proposed ILP model on real-world data of the Wuhan-Guangzhou high-speed railway corridor under different demand scenarios.

3 - Column generation approach: a case study for light railway public transportation system

Sinem Kulluk, Lale Ozbakir, M. Burak Telcioglu, Pınar Tapkan, Fatih Bahar

Crew scheduling (CS) is a difficult and challenging problem faced within railway public transportation systems. The objective of the CS is to form crew schedules or duties in accordance with specific working policies and operational constraints in the railway system where timetable is specified. The CS is a complex problem due to the multiple constraints related to the duties and size of the problems. Generally it is modeled as a set covering problem in the literature. The objective of the model is the minimization of the total cost so that every trip is covered at (least) once. Due to the set covering problem is a NP-hard problem, column generation approach is used in this study to solve crew scheduling problem. In column generation approach, master problem is modeled as a set covering problem while the subproblem is modeled as a shortest path problem and these models are solved iteratively. The approach is applied to a real life light railway system which is operated by Kayseri Ulaşım Inc. The optimal crew schedules are obtained and compared with the current schedules of the railway system. This study was supported by Research Fund of the TUBITAK 1011 (Project number: 117M590).

4 - Line planning and train timetabling using passenger demand data
Valentina Cacchiani, Gert-Jaap Polinder, Marie Schmidt, Dennis Huisman

Line planning and train timetabling are typically solved in sequence. In a first phase, line planning determines the optimal train lines, with the corresponding stopping pattern and frequency, by taking into account passenger demand data. In a second phase, train timetabling starts from the given line plan and determines the optimal train timetables, while satisfying railway infrastructure constraints (e.g. headway constraints). This sequential approach can lead to timetables that are not satisfactory from the passengers point of view, since railway infrastructure constraints may require to significantly change the line plan. In this work, we propose an iterative framework to determine timetables that are good from a passenger perspective. In particular, we iteratively combine two modules: the first one consists of a PESP-based timetabling model that minimizes the weighted sum of waiting time at the departure station and travel time of all passengers, but neglects railway infrastructure constraints. The second module is a Lagrangian-based heuristic algorithm that aims at modifying as little as possible the timetables obtained by the first module, while guaranteeing railway infrastructure constraints satisfaction. The output of the second module is then used, in a feedback loop, as input to the first module, when significant changes to the timetables turn out to be necessary.

■ TD-08

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S108

Applications in Industry and Services II

Stream: Combinatorial Optimization I
Chair: *Helena Ramalhinho Lourenco*

1 - A branch-price-and-cut algorithm for optimal decoding in LDPC-based communications
Banu Kabakulak, Z. Caner Taşkın, Ali Emre Pusane

In a digital communication system, information is sent from one place to another over a noisy communication channel using binary symbols (bits). Original information is encoded by adding redundant bits, which are then used by low-density parity-check (LDPC) codes to detect and correct errors that may have been introduced during transmission. In practice, heuristic iterative decoding algorithms are used to decode the received vector. However, these algorithms may fail to decode if the received vector contains multiple errors. We consider decoding the received vector with minimum error as an integer programming problem and propose a branch-price-and-cut method for its solution. We improve the performance of our method by introducing heuristic feasible solutions. Our proposed algorithm can find higher quality solutions than commonly used iterative decoding heuristics. Computational results reveal that our method significantly improves solvability of the problem compared to a commercial solver in high error rates.

2 - A dual-ramp algorithm for the uncapacitated multiple allocation hub location problem
Telmo Matos, Fábio Maia, Dorabela Gamboa

We address the Uncapacitated Multiple Allocation Hub Location (UMAHLP) which goal is to choose the set of nodes to be defined as hubs in a given network in such a way that the allocation from all nodes to the chosen hubs is optimal. Belonging to the NP-Hard class of problems, the UMAHLP has recently received a lot of attention by the scientific community regarding its application in telecommunications, airline industry, postal companies, among other areas. We propose a Relaxation Adaptive Memory Programming (RAMP) approach for the UMAHLP. The RAMP framework already proved to be very effective in finding optimal and near-optimal solutions for a variety of combinatorial optimization problems. Its underlying feature is the exploration of primal-dual relationships together with the creation of memory structures to help the algorithm search process. The RAMP algorithm for UMAHLP combines a Dual Ascent procedure with an Improvement Method in the exploration of the primal and dual sides of the problem. The algorithm was tested on AP (Australian Post) and CAB (Civil Aeronautics Boarding) standard dataset producing extremely competitive results. Comparisons with currently best-performing algorithms for the UMAHLP show that our RAMP algorithm achieved excellent results.

3 - Using mobile electric platforms for droid or drone-based last mile deliveries
Hagen Salewski, Dominik Goeke

Quicker deliveries, less traffic, and independence from roads are the advantages of drone (or UAV) shipments. Compared to UAVs autonomous transport vehicles (ATVs or droids) have lower flexibility and are usually slower, but also consume less energy per distance. Regardless if delivery vehicles are UAVs or ATVs, they are limited by their range and available battery capacity. Possible remedies: Platforms which carry multiple delivery vehicles. Amazon proposed UAV-dispatching flying platforms; Daimler presented prototypes of electric vans serving as road-based platforms for UAVs or ATVs. Electric vans offer reduced noise and local greenhouse gas emissions. Integrating ATVs or UAVs with platforms increase their range while potentially lowering costs and total energy consumption. In the last year, the amount of research utilizing combined truck-drone systems grew fast. However, most approaches consider only UAV (not ATVs) and trucks. To our knowledge none allow delivery vehicles to change their assigned platform. We propose a general model for the routing of electric platforms, applicable to all three use cases. It considers a fleet of platforms and integrates delivery vehicle scheduling. Each platform's range is restricted, and it shares its energy with the delivery vehicles. The model minimizes the energy consumption of the entire system. We solve example instances using the model and heuristic methods. We derive first hints when ATVs are more advantageous than UAVs.

4 - Optimizing factory logistics in an automotive industry
Helena Ramalhinho Lourenco, Marcelus Lima

Logistics chains do not end at the entrance of a Factory. Optimizing the processes of provision and disposal of the materials and the components for production lines are becoming key way to increase efficiency and decrease costs in manufacturing. This research mainly focuses on studying and modeling the Warehouse Shipping Routing Problem at the internal Warehouse at SEAT S.A. We propose a mathematical model and an Iterated Local Search metaheuristic combined with Simulation to solve this problem. We present computational results with real data and conclude that our proposed approach improves the actual solution and provides a tool to be used in scenarios of production on new car models.

■ TD-09

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S109

Evaluation as a Service for Optimization and Data Science

Stream: European Working Group: Data Science Meets Optimization
Chair: *Szymon Wasik*
Chair: *Maciej Antczak*

1 - Optil.io: platform supporting evaluation as a service architecture
Szymon Wasik, Maciej Antczak, Jan Badura, Artur Laskowski

Reliable and trustworthy evaluation of algorithms is a challenging process. Firstly, each algorithm has its strengths and weaknesses, and the selection of test instances can significantly influence the assessment process. Secondly, the measured performance of the algorithm highly depends on the test environment architecture, i.e., CPU model, available memory, cache configuration, operating system's kernel, and even compilation flags. Finally, it is often difficult to compare algorithm with software prepared by other researchers, because their algorithms are not available as open source, do not compile or do not work correctly for all test cases.

Evaluation as a Service (EaaS) is a cloud computing architecture that tries to make assessment process more reliable by providing online tools and test instances dedicated to the evaluation of algorithms. One of such platforms is Optil.io which gives the possibility to define problems, store evaluation data and evaluate solutions submitted by researchers in almost real time. Researchers can upload their algorithms in the form of binaries or the source code that is compiled online. Then the solution is executed and evaluated at the server, in the homogenous runtime environment and the live ranking of all submitted algorithms is presented. Optil.io is dedicated, but not limited, to optimization algorithms and allows for organization of programming challenges.

2 - Using contests to crack algorithmic and data science problems
Rinat Sergeev, Jin Paik

The mission of our Lab is spurring the development of a science of innovation through a systematic program of solving real-world technical challenges while simultaneously conducting rigorous scientific research and analysis. On the development side, we design and field competitions that generate the best computer code and data analytics for NASA, other Government Agencies, and Academia. The real-world problems are formulated as open-door challenges, where developers are awarded prizes for the production of finished packages that can be delivered at comparatively low cost. On the academic side, we are studying the process of crowdsourcing from the problems that can be most efficiently solved by the crowd, to incentives for crowd members to participate in the solution development, to contest mechanics that optimizes the effort of the crowd. In my talk, I am going to discuss: - The strong sides and trade-offs of crowdsourcing; - The niche of data science and algorithmic competitions; - The methodology of problem selection and adaptation for competitions; - The role, importance, and trade-offs of automatic evaluation and progress feedback in competitions; - Practical examples of automatic evaluation systems driving extreme value outcomes of competitions in diverse areas - from space to healthcare.

3 - Review of online platforms supporting evaluation of algorithms
Artur Laskowski, Maciej Antczak, Jan Badura, Szymon Wasik

There are plenty of online platforms that support evaluation of algorithms, such as Codeforeces, TopCoder, CheckIO, Optil.io, and many others. Such platforms have to provide a reliable, homogeneous runtime environment which compares algorithm implementations in precisely same conditions in a cloud. They can support a limited number of programming languages or a plethora of programming technologies. They can be open sourced or commercial. They can provide thousands of problems that users can solve or just give the possibility to upload self-designed content.

During this presentation, we would like to classify online platforms supporting evaluation of algorithms based on their applications, such as the organization of competitive programming challenges, facilitating teaching, providing tools for solving data mining challenges, or compiling and executing code in the cloud. During our work that we want to present, we have reviewed over one hundred of such platforms and compared them regarding their scientific and industrial potential. Furthermore, we proposed the formal definition of online judge system and summarized commonly used evaluation methodologies. During this short presentation, we would like to inspire everybody who is dealing with evaluation of algorithms to consider using online judge platforms.

4 - Brilliant challenges: lessons learned while collecting evaluation data for optimization problems
Maciej Antczak, Jan Badura, Artur Laskowski, Jacek Blazewicz, Szymon Wasik

Brilliant Challenges contest aimed to collect interesting, applicable, optimization problems that could have been published at the Optil.io platform and addressed by its users. Participants submitted problems related to classic areas of combinatorial optimization (i.e., knapsack problem, Steiner tree) but also to its modern applications such as Internet shopping optimization and even problems that require computationally complex simulation to calculate the objective function's value (i.e., simulation of cellular automaton). During this presentation, we will shortly describe these problems and the winners of the competition. Moreover, we will present the main shortcomings observed in evaluation data submitted by our participants demonstrating how difficult it is to prepare data and scripts allowing for reliable evaluation of algorithms.

■ TD-10

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S110

Decision Aiding Methods VIII

Stream: Multiple Criteria Decision Aiding
Chair: *Salvatore Corrente*

1 - Comparing consistency indices of multiplicative pairwise comparison matrices
Bice Cavallo

In multi-criteria decision making, it is common practice to pairwise compare the decision elements before obtaining a preference order; the main tool is the Pairwise Comparison Matrix (PCM). The main advantage in using PCMs is that they allow the decision makers to compare two alternatives at a time, thus reducing the complexity of a decision making problem. For each PCM, it is possible to define a consistency condition (i.e. a cardinal transitivity condition of preferences on triplets of decision elements) such that, if it holds, the decision maker is considered fully coherent and his/her judgments are not contradictory. In literature, for multiplicative PCMs (i.e each entry represents a preference ratio of a decision element over one other), there is a rather large number of proposals to evaluate the amount of inconsistency contained in the preferences. Finding that some indices are dependent on each other is very important in the process of inconsistency estimation. We look for functional relations and correlations among nine consistency indices. Thus, we prove that, if we deal with three decision elements, then seven on nine consistency indices are functionally dependent among them. For a bigger number of decision elements, only two on nine consistency indices are functionally dependent among them; for the remaining pairs of consistency indices, we compute Spearman correlation coefficient in order to measure the strength of a monotonic relationship between them.

2 - Some properties of the additive representation of preferences in pairwise comparisons
Michele Fedrizzi, Matteo Brunelli, Alexandra Caprila

We assume that pairwise comparisons between alternatives are representable using the additive representation of preferences and we extend some results by Koczkodaj & Orlowski and Barzilai. We study some algebraic properties of the set of pairwise comparison matrices and its subset of consistent ones. Both sets are vector spaces and we propose a simple basis for each one. We prove that in both cases a convenient scalar product can be found such that the basis is orthonormal with respect to the considered scalar product. We prove that with our basis for the set of consistent preferences we can reinterpret the well-known method of the logarithmic least squares used to estimate the weight vector. Then, we consider the orthogonal complement of the subspace of consistent matrices and we propose a basis for this subspace too. We discuss our results by stressing the interesting coexistence of algebraic formalization with intuitive understandability.

3 - Effectiveness-equity tradeoffs in the aggregation of preferences
Srinivas Prasad, Luis Novoa, Atilla Ay
We consider the problem of aggregating preferences of a group of individuals over a set of discrete alternatives. We develop models for analyzing effectiveness equity tradeoffs using a number of different equity measures, and study how well the models conform to actual choices made by individuals in empirical studies.

4 - Interactive evolutionary multiobjective optimization through dominance-based rough set approach: the knapsack problem
Salvatore Corrente, Salvatore Greco, Benedetto Matarazzo, Roman Slowinski
In interactive Evolutionary Multiobjective Optimization (EMO) one is looking for solutions that fit the best Decision Maker's (DM) preferences expressed in some way during the search process. In the procedure we are going to present, the DM is simply asked to indicate in a sample of solutions selected from a current population those ones that she considers relatively good. By application of the Dominance-based Rough Set Approach (DRSA) this information is represented in terms of "if ..., then ..." decision rules, and then used within EMO with the aim of generating at each step a new population of solutions getting closer to the most preferred part of the Pareto front for this DM. The decision rules induced through DRSA are also useful as arguments for explaining the solutions recommended to the DM and to support her for future decisions. An experimental analysis on the multi-dimensional knapsack problem demonstrates the effectiveness of the procedure.

■ TD-11
Tuesday, 14:30-16:00 - SOUTH BUILDING UV S111

Sales Forecasting

Stream: Business Analytics
Chair: *Kristof Coussement*

1 - Comparing the ability of Twitter and Facebook data to predict box office sales
Matthias Bogaert, Michel Ballings, Dirk Van den Poel, Asil Oztekin
This paper aims to (1) determine which social media platform (Facebook or Twitter) is most predictive of box office sale, (2) which algorithm performs best, and (3) which variables are important. To do so, we introduce a social media analytical approach that consists of two stages. In the first stage, we compare several models based on Facebook and Twitter data. We benchmark these model comparisons over seven algorithms (i.e., linear regression, k-nearest neighbors, decision trees, bagged trees, random forest, gradient boosting and neural networks). In the second stage, we apply information-fusion sensitivity analysis to evaluate which variables from which platform (i.e., Facebook or Twitter) and from which data type are driving predictive performance. The analysis shows that Facebook data outperform Twitter data at predicting box office sales by more than 11% in RMSE, 13% in MAE, 14% in MAPE, and 47% in R'. In terms of best algorithm, we find that random forest is the top performer across all performance measures. We also find that including user-generated content (UGC) does not significantly increase the predictive power for both Twitter and Facebook data. Our sensitivity analysis reveals that the number of Facebook page likes (i.e., a page popularity variable) is the most important variable, followed by the hype factor of Facebook comments (i.e., a UGC variable). The results also show that volume is a better predictor than valence.

2 - Gaussian processes for daily demand prediction in the hospitality industry
Wai Kit Tsang, Dries Benoit

In tourism forecasting literature, the majority of the studies relies on econometric models. While econometric models are effective for monthly or yearly data, many machine learning techniques are yet to be explored in the demand literature and it can be beneficial to do so on daily data. This study fills the research gap by predicting daily hotel occupancy rates on a city level in Brussels using booking.com data. A forecasting methodology is proposed with feature extraction and selection, processing steps that are missing in most approaches. Special attention is given to Gaussian Processes to make predictions with credible intervals, an uncertainty measure that is helpful for managers during decision-making. The novel approach uses online data to create a proxy measure for occupancy rate. The new methodology is verified with internal occupancy data from hotels in Brussels and can be extrapolated to cities for which no internal hotel data is available.

3 - Container dwell time prediction via analytics techniques
Rosa G. González-Ramírez, Sebastian Maldonado

Maritime ports have a key role as part of the international transport chain to guarantee efficient cargo handling. During the transfer services of a port terminal, containers require to be temporarily stored at the yard (stacking). The time spent by a container in the port terminal is defined as the "dwell time". For import containers, dwell times can present high uncertainty and variability. Hence, the stacking of containers may result very inefficient, requiring rehandles to retrieve containers from the yard during the dispatching process.

Motivated by this situation, we propose a methodology to support stacking decisions based on a dwell time prediction mechanism. The prediction values are used to segregate cargo into classes of containers with same range of dwell times. The dwell time prediction model considers as variables the container's weight, size, type, port of origin and the corresponding consignee. Three models were implemented with a subset of 20,000 observations: Multiple Linear Regression, Decision Trees and Random Forest. With the predictions obtained, three classes were generated: "Less than 7 days", "Between 7 and 14 days" and "Over 14 days" and results were evaluated using the Balanced Accuracy as a performance measure. With the prediction values and the classes, we propose a container stacking algorithm to locate containers in the yard and performed numerical results comparing with respect to current practices of a container terminal.

4 - Design and development of a business diagnostico tool
Jairo César Gómez Acero, Stefany Murillo, Eduardo Rodriguez Araque

In the business context, there are several factors that contribute to the sustainability and competitiveness of a company. The best known are related to productivity, profitability and the quality of its products or services. In these as in other organizational aspects take part variables that are necessary to know the condition of a company. Our Diagnostic Model developed allows the entrepreneur to obtain an analysis of the state of the different elements that make up his organization. It is based on the application of an Integral Diagnostic Tool that collects essential information of the company, from which it is possible to analyze the condition of the different elements that make it up. The model consists of a web tool, agile and easy to understand, as well as interviews and visits by experts to the organization. The application of the Diagnostic Tool allows entrepreneurs to identify strengths, difficulties and improvement opportunities in the areas of: Production and Technology, Logistics, TIC, Commercial, Finance, Management Systems, Human Talent and Innovation. Based on the results of this Diagnosis, it is possible to determine the critical aspects and establish the action plans to optimize the processes associated with these areas. Additionally, implement continuous improvement plans in the corresponding area, in order to correct a specific aspects or to implement a management system, among other actions.

■ TD-12

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S112

Liner Shipping Optimization

Stream: Maritime Transportation
Chair: *Kevin Tierney*

1 - Cargo fare class mix problem in synchromodal container transportation
Judith Mulder, Bart Van Riessen, Rudy Negenborn, Rommert Dekker

We consider an intermodal hinterland transportation network that is operated by a transport provider. The network consists of a set of scheduled services with a fixed daily capacity. We consider import of containers; the services run from a single deep-sea port towards multiple inland terminals. Available capacity can be used for free as the transport operator owns the trains and vessels that are allocated to the routes. In order to improve the planning flexibility of the network, the transport operator offers two types of services to its customers: standard and express. The express service is more expensive than the standard service, but guarantees a faster transit time. Each day, the transport operator observes the daily demand for both fare classes and needs to decide which containers should be accepted and which should be rejected. All accepted demand must be transported; if the network capacity is insufficient to transport all containers, the transport operator might use trucking to transport the remaining containers. Trucking is a fast, but expensive way of transportation. To include long-term commitments in the decision making, daily booking limits need to be determined. The transport operator guarantees that it will transport all containers up to the booking limit for both product types. The booking limits are fixed for a longer period. We will present a solution algorithm to determine the profit maximizing booking limits for the intermodal hinterland network.

2 - Container liner shipping cargo-mix: a study on capacity utilisation
Dario Pacino, Jonas Christensen

Aside from a few years of financial crisis, the liner shipping industry has had a continuous growth. The growing demand has resulted in a fierce competition to deliver the best product with respect to efficiency, reliability, but most important cost. As a result, the shipping rates are historically low, making it crucial for the carriers to utilise their vessels as efficiently as possible. In this presentation, we summarize the results of a doctoral study aimed at analysing optimal cargo composition for specific service rotations. Differently, than other studies, this work incorporates vessels' seaworthiness conditions such as hydrostatic stability, draft and trim restrictions. Those, alongside the expected cargo demands, are shown to have a significant impact on the utilisation of the vessel. We will show results on a deterministic problem when a complete cyclic service is analysed, and on a stochastic version of this problem where the out of region utilisation is studies taking into account container bookings, no-shows and stochastic demands. Finally, we will briefly discuss how such the results of such computational model might be used for more operational decisions.

3 - A decomposed Fourier-Motzkin framework to derive capacity models of container vessels
Mai Ajspur, Rune Jensen

In the liner shipping industry, utilizing the capacity of the vessels is essential. However, the free capacity depends heavily on the types of containers stowed, since e.g. stacking and stability rules interact to restrict the allowed cargo. However, in uptake, capacity, network and fleet management, vessel capacity is usually seen only as a maximum volume, weight and number of reefer containers, leading to suboptimal decisions. Previous work on stowage planning by e.g. Delgado et al. has contributed linear stowage models that, in principle, can be used as capacity models. However, they are usually very large, which is problematic since thousands of these models need to be embedded in a single model to be solved. In this work, we reduce the size of stowage models by projecting unneeded variables. We use a novel, decomposed Fourier-Motzkin framework (FM) that exploits the model's block structure to significantly speed-up the projection. Our experiments show that the number of constraints and non-zeros are typically reduced by an order of magnitude, and the projected models can be solved 20-130 times faster with only a negligible loss in accuracy. In this way, FM performs an off-line computation that factors out time when applying the capacity models as sub-models for uptake, capacity, network and fleet optimization. The block structure is frequent in LP models e.g. multi-commodity flow problems, and for such a problem we have found a similar speed-up of the projection.

4 - The stochastic liner shipping fleet repositioning problem with uncertain container demands
Stefan Kuhlemann, Kevin Tierney, Achim Koberstein

The repositioning of vessels is a costly process for liner shipping companies. During repositioning, vessels are moved between services in a liner shipping network to adjust the network to the changing demands of customers. A deterministic model for the Liner Shipping Fleet Repositioning Problem (LSFRP) exists, but many input parameters to the LSFRP are uncertain. Assuming these parameters are deterministic could lead to extra costs when plans computed by the deterministic model are realized. To get more realistic repositioning plans, uncertainties regarding influences on the travel time or the number of available containers must be considered. We introduce an optimization model for the stochastic LSFRP, focusing on the uncertainty involving container demands. This model is evaluated with several scenarios based on data from the industry and we discuss business insights related to considering uncertainty during planning. To assess the risk associated with a repositioning plan the conditional value-at-risk (CVaR) is used. Furthermore, the CVaR is added to the optimization model to enable a decision-maker to state his or her willingness to take risk before the optimization to obtain a fitting repositioning plan.

■ TD-13

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S201

Credit Risk Modeling

Stream: Financial Modeling, Risk Management and Managerial Accounting
Chair: *Cristian Bravo*

1 - A relabelling approach to handling the class imbalance problem in consumer credit risk modelling
Yazhe Li, Tony Bellotti, Niall Adams

In consumer credit, it is common to encounter classification tasks with highly imbalanced data sets where one class is very rare compared to the other. Owen (2007) demonstrated, asymptotically, that logistic regression only uses the rare class data points via the rare class mean vector, which results in information loss in highly imbalanced logistic regression. We propose a novel relabelling procedure combining multinomial logistic regression, clustering algorithms, and genetic algorithms when modelling consumer credit risk for highly imbalanced data sets. We illustrate applications of this method using simulated and real credit data sets to demonstrate its effectiveness. Our results show that relabelling can enhance the predictive performance of logistic regression when the minority class data points are clustered into several well-separated clusters.

2 - OR and sovereign contingent debt instruments
Andrea Consiglio, Stavros Zenios

After the Eurozone crisis and the record-breaking Greek sovereign default, governments and international organizations realized the need for appropriate mechanisms to deal with sovereign defaults. Sovereign contingent convertible bonds (an automatic debt payment rescheduling) and GDP-linked bonds (make debt payments contingent on a country's GDP) have been suggested in academic and policy papers as a potential solution. We will show how OR methods can be applied to design and evaluate such innovative instruments. From scenarios generation to pricing models, the whole spectrum of OR models (from non-linear programming to large scale linear models) can be exploited to make their use concrete. We will provide extensive numerical results for advanced and emergent economies, and to eurozone crisis country (Greece).

3 - Deep learning for text-based credit scoring for micro, small and medium enterprises
Matthew Stevenson, Cristian Bravo

Personal credit risk models are built upon a wealth of structured sociodemographic and behavioural data. It tends to be high in volume and low in cost and as a result, personal lending is a highly automated process. This, however, is not true for micro, medium and small business credit processing which is cumbersome and expensive for lenders. Often, a lack of sufficient structured data and the bespoke nature a credit request requires expert judgement on the creditworthiness of an organisation. This occurs in the first instance by a financial analyst who generates a written report, which is then usually passed onto a further assessor who makes the final decision based on the written report combined with other sources of available data.

The purpose of this research is to eliminate the requirement for a second stage of assessment - where both the traditional variables and text-based evaluation by the credit agent are considered - by developing Deep Learning models that can capture the rich and dynamic information available from the written financial analyst reports, outputting a probability score that can then be used alongside other structured sources of information.

The results suggest that the implementation of a semi-automated process would allow for both a more accurate and cost-effective approach assessing credit risk for micro, small and medium enterprises.

■ TD-14

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S202

Optimization and Equilibrium Problems

Stream: Nonlinear Programming: Methods
Chair: *Genaro Lopez*

1 - Linear convergence of gradient algorithm on Riemannian manifolds
Xiangmei Wang, Chong Li

Some convergence results of the gradient algorithm for the optimization on general Riemannian manifolds are established under mild conditions. Particularly, the global convergence result extends the corresponding ones (cite[Theorem 3.1]Papa2008 (or cite[Theorem 5.2]Bento2012M in the case when I=1)) from the manifold of non-negative curvatures to the one of curvatures bounded from below. Moreover, %to our best acknowledgement, the linear convergence result seems new even in Euclidean spaces. As an application, we consider the gradient algorithm for finding the Riemannian Lp centers of mass and some convergence results are established. The (linear) convergence result about the algorithm with the Armijo rule for this problem seems new; and the one about the algorithm with constant step sizes extends cite[Theorem 4.1]Afsari2013. At last, some numerical experiments are provided to illustrate the theoretic results.

2 - Equilibrium problems on Riemannian manifolds with applications
Chong Li, Genaro Lopez, Xiangmei Wang

We study the equilibrium problem on general Riemannian manifolds. The results on existence of solutions and on the convex structure of the solution set are established. Our approach consists in relating the equilibrium problem to a suitable variational inequality problem on Riemannian manifolds, and is completely different from previous ones on this topic in the literature. As applications, the corresponding results for the mixed variational inequality and the Nash equilibrium are obtained. Moreover, we formulate and analyze the convergence of the proximal point algorithm for the equilibrium problem. In particular, correct proofs are provided for the results claimed in J. Math. Anal. Appl. 388, 61-77, 2012 (i.e., Theorems 3.5 and 4.9 there) regarding the existence of the mixed variational inequality and the domain of the resolvent for the equilibrium problem on Hadamard manifolds.

3 - A variational equilibrium formulation for humanitarian organizations under competition
Patrizia Daniele, Anna Nagurney, Emilio Alvarez-Flores, Valeria Caruso

We consider a new Generalized Nash Equilibrium (GNE) model for post-disaster humanitarian relief by introducing novel financial funding functions and altruism functions, and by also capturing competition on the logistics side among humanitarian organizations. The shared constraints associated with the relief item deliveries at points of need are imposed by an upper level humanitarian organization or regulatory body and consist of lower and upper bounds to ensure the effective delivery of the estimated volumes of supplies to the victims of the disaster. We identify the network structure of the problem, with logistical and financial flows, and propose a variational equilibrium framework, which allows us to then formulate, analyze, and solve the model using the theory of variational inequalities (rather than quasivariational inequality theory). We then utilize Lagrange analysis and investigate qualitatively the humanitarian organizations' marginal utilities if and when the equilibrium relief item flows are (or are not) at the imposed demand point bounds.

4 - A continuous optimisation approach for aiming strategies in solar power tower plants
Thomas Ashley, Emilio Carrizosa, Enrique Fernández-Cara

Research into renewable energy sources has continued to increase in recent years, in particular, the research and application of solar energy systems. Concentrated Solar Power (CSP) used by a Solar Power Tower (SPT) plant is one technology that continues to be a promising research topic for advancement.

The distribution of temperature on an SPT plant receiver directly affects the lifespan of the structure and energy generated by the plant. Temperature peaks and uneven distributions can be caused by the aiming strategy enforced on the heliostat field.

A non-optimised aiming strategy can lead to suboptimal energy generation and, more importantly, to risk of permanent damage to receiver components from thermal overloading due to sharp flux gradients.

In this work, an optimised aiming strategy is found using a continuous optimisation approach, which maximises energy gained whilst maintaining a homogeneous flux distribution on the receiver.

■ TD-15

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S203

New Applications in Vehicle Routing I

Stream: Vehicle Routing and Logistics Optimization II
Chair: *Elena Fernandez*

1 - Delivery process with flexibility using automated parcel lockers
Ido Orenstein, Tal Raviv

In this study, we introduce a logistic model that is suited for delivery of parcels to a set of service points (SPs) and present effective solution methods for it. While in traditional delivery model each recipient specifies a single location, where they wish to receive the parcel, when using SPs, many recipients may be indifferent between several locations, e.g., near their home address, near their office, or in their favorite shopping mall. If some of the recipients are ready to show some flexibility and provide the sender with more than one delivery location, it is possible to perform the delivery task in lower costs and shorter time. Our solution methods are based on the ideas of the saving heuristic, petal method and tabu search with large neighborhood. An extensive numerical study is conducted in order to evaluate our solution methods and demonstrate the benefit of our model, compared to the traditional, non-flexible, one. We also present a simulation study to demonstrate that our model can be adapted to a stochastic and dynamic environment.

2 - Interday scheduling and routing of multi-skilled teams with consistency consideration and rescheduling option
Yulia Anoshkina, Frank Meisel

In this paper we consider a combined manpower scheduling and routing problem that was initially addressed as the subject of ROADEF challenge 2007. Over the last decade, various extensions of the problem have been proposed in the literature. However, there has been only limited discussion about how the staffing needs can be updated according to daily and weekly changes in demand. This study addresses this gap by approaching the problem from a multi-period perspective. More precisely, we propose a rolling horizon approach with different rescheduling strategies and team consistency consideration. On this basis we develop linked mathematical optimization models for the interday and intraday replanning. For the solution of larger problem instances, we propose a fix-and-optimize heuristic. Finally, the experimental results are presented to analyse the effectiveness of the proposed approach and to show the impact of integrating the team consistency into manpower scheduling.

3 - A ride-sharing problem with meeting points and return restrictions
Wenyi Chen, Martijn Mes, Marco Schutten

This paper considers the ridesharing problem of the scheduled commuter and business traffic within a closed community of companies that agree to share the calendars of their employees. We propose a general ILP formulation for the aforementioned ridesharing problem, which incorporates return restrictions in order to satisfy the business needs, as well as meeting points and the option for riders to transfer between drivers. All the instances with 40 and 60 participants, and most of the instances with 80 participants can be solved to optimality within a time limit of 2 hours. Using instances of up to 100 participants, the ILP can be solved with a gap of no more than 1.8% within the time limit. Due to the high computational complexity, we develop a constructive heuristic that is based on the saving concepts. This heuristic is also able to combine ridesharing with the use of an external mobility service provider. Our numerical study shows that ridesharing can be an effective way of reducing the number of trips and vehicle-miles. Particularly, ridesharing creates more benefits when the participation is high, and when the origins and the destinations of the trips are more spatially concentrated. The results show that ridesharing can create up to 31.3% mileage savings and up to 28.7% reduction in the number of cars needed to fulfill employees' travel schedules. We also illustrate our model using a real-life ridesharing problem of a Dutch consultancy and research firm.

4 - Target visitation arc routing with clustered demand
Elena Fernandez, Gilbert Laporte, Gerhard Reinelt, Jessica Rodríguez-Pereira

Target Visitation problems combine features from Linear Ordering and Vehicle Routing. There exist profits (targets) associated with the relative order in which demand requests are served, as well as costs incurred by the routes defined to provide service.

We study a Target Visitation problem where demand is located at some edges of a given graph and targets correspond to the components induced by demand edges. Furthermore, it is imposed that, once a component is visited, all demand edges in the component are served before leaving it.

The problem is formally introduced and a mathematical programming formulation that exploits some optimality conditions is given. We also present several families of valid inequalities as well as separation procedures for the families of constraints of exponential size. A branch-and-cut solution algorithm is proposed and the results of computational experiments are presented and analyzed.

■ TD-16

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S115

Discrete and Global Optimization I

Stream: Discrete and Global Optimization
Chair: *Dorit Hochbaum*

1 - An overview and comparison of metaheuristics for the two-dimensional strip packing problem
Georgina Rakotonirainy, Jan van Vuuren

The two-dimensional strip packing problem consists of packing a set of rectangular items into a single object of fixed width in a non-overlapping manner, with the objective of minimising its height. This problem has a wide range of applications, and is typically encountered in the wood, glass and paper industries.

In this presentation, an overview is provided with respect to a number of metaheuristic solution approaches for this problem from the literature. The focus is particularly on the application of hybrid genetic algorithms and the method of simulated annealing. Two improved strip packing metaheuristics are also presented.

The relative performances of these metaheuristic algorithms in respect of a large set of strip packing benchmark instances from the literature are compared in terms of both the solution quality and execution time. The benchmark data sets are clustered into different classes of test problems based on their underlying features, and the effectiveness of the designs of the metaheuristic algorithms under investigation are contrasted for each of the data categories.

2 - The solid assignment problem
Mohamed Mehbali, Dhia Kadhem, Abdellah Salhi, Xinan Yang

The Solid Assignment Problem (SAP) also known as the 3-dimensional assignment problem, consists in allocating n jobs to n machines in n factories such that exactly one job is allocated to one machine in one factory. The objective function is to minimise the total cost of the allocation. SAP is an extended version of the standard 2-dimensional assignment problem, which aims to assign n tasks to n operators at minimum total cost. This Combinatorial Optimisation problem appears in many applications and has stimulated intensive research works for decades. In this paper, we suggest a new heuristic algorithm Diagonal Method (DM) to solve SAP. The largest SAP solved with an exact solution to this day is of size n=26. As it is intractable, only approximate solutions are found in reasonable time for larger instances. Here, we suggest an approximate solution approach the DM, which relies on the Kuhn-Tucker Munkres algorithm, also known as the Hungarian method. The approach is discussed, hybridised, presented and compared with the Branch-and-Bound method (B&B). Tie cases are discussed with examples. Our numerical experiments show that DM finds an optimal or near-optimal solution in competitive computational times.

3 - Distributed integral simplex using decomposition for set partitioning problems
Omar Foutlane

The aim of this work is to propose a distributed version DISUD of the integral simplex using decomposition algorithm ISUD using multiple agents. We have been motivated by computer science trend to use network of computers. To do so, we implement a team of agents where each agent dynamically splits the overall set partitioning problem into sub-problems and solve them in parallel on a single machine. The new algorithm DISUD improves at each iteration the current integer solution until (near) optimality. It works better on set partitioning instances from the airline industry than the distributed version of CPLEX (DCPLEX).

4 - Multi-period probabilistic set covering problem
Konstantin Pavlikov

This study extends the classical probabilistic set coverage problem to a multi-period setting. The classical problem focuses on finding a least cost facility locations to cover random demand over one period of time with a specified probability. If facility engagement lasts more than one period of time, then little is known about how well the remaining operational facilities can satisfy demand in period two. Hence, the two-period model maximizes the probability of satisfying demand in period two by facilities not engaged in satisfying demand from period one. We demonstrate how solving multi-period version of the problem can be reduced to solution of a sequence of one-period probabilistic set coverage problems.

■ TD-17

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S205

Advances in Stochastic and Robust Optimization

Stream: Stochastic and Robust Optimization
Chair: *Francesca Maggioni*

1 - Optimization under uncertainty: a comparison of approaches based on dominance
Marie Schmidt

Stochastic, robust, and online optimization create frameworks on how to incorporate uncertainty into optimization. Various ways to incorporate uncertainty into the objective function (like, e.g., expected value, regret, or competitive ratio) have been proposed in these areas to define what is 'optimal' in the presence of uncertainty. However, even for optimization problems which are simple under deterministic circumstances, different ways of incorporating uncertainty into the objective may lead to very different 'optimal' solutions. We describe different ways of incorporating uncertainty into objective functions as a combination of a transformation of the original objective value for a given scenario, and an aggregation over all scenarios. We use and introduce various dominance concepts to describe which solutions are candidates for being optimal depending on properties of transformation and aggregation and of the uncertain set. We illustrate our approach on a simple optimization problem under uncertainty.

2 - Robust optimization with mixed-integer uncertainty sets
Juan Borrero, Leonardo Lozano

We consider linear optimization problems where the cost vector is subject to uncertainty. Following the robust optimization paradigm, we assume that the decision-maker knows that the cost vector belongs to an uncertainty set. However, in contrast with the usual framework, we assume that this set is non-convex, specifically; we assume that the uncertainty set is given by a mixed-integer linear feasibility region. Such a larger class of sets allows modeling complex uncertain phenomena where there are logical, combinatorial, or disjunctive relationships between the uncertain events that generate the uncertain data. We show that optimizing over mixed-integer uncertainty sets greatly reduce the conservativeness of the optimal solutions when compared with a convex counterpart which cannot capture all the information of the problem at hand. However, such a reduction comes at the price of increasing the computational complexity of the problem. In particular, the problem is NP-complete and we develop exact iterative solution methods based on cutting plane and decomposition techniques that can solve many instances of the problem in a reasonable time.

3 - Robust optimization approach for multivariate stratified sample surveys
Mohammad Asim Nomani, Jan Pablo Burgard, Mirjam Duer, Ralf Münnich

A central problem in survey sampling is the optimal allocation of samples to entities of the population. The primary goal of the allocation is to minimize the variances of estimated totals of the population under the given cost. The optimal solution in stratified sampling, where the strata are the entities, relies on the stratum specific variances of the (multiple) variables of interest. Usually, these stratum specific variances are assumed to be known, however, this assumption is often not realistic. Also, the stratum specific cost is not known precisely and can vary within a given interval. In order to account for these uncertainties, we formulate a robust optimization model for this multivariate stratified allocation problem. Using robust optimization, we seek an optimal allocation which is feasible for any realization of the uncertain variances and costs. A sample problem is considered and solved in order to validate the applicability of the model.

4 - Guaranteed bounds for general non-discrete multistage risk-averse stochastic optimization programs
Francesca Maggioni, Georg Pflug

In general, multistage stochastic optimization problems are formulated on the basis of continuous distributions describing the uncertainty. Such "infinite" problems are practically impossible to solve as they are formulated and finite tree approximations of the underlying stochastic processes are used as proxies. In this talk, we demonstrate how one can find guaranteed bounds, i.e. finite tree models, for which the optimal values give upper and lower bounds for the optimal values of the original infinite problem. Typically, there is a gap between the two bounds. However, this gap can be made arbitrarily small by making the approximating trees bushier. We consider approximations in the first order stochastic sense, in the convex order sense and based on subgradient approximations. Their use is shown in a multistage risk-averse production problem.

■ TD-18

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S206

Different Perspectives on Problem Structuring Methods

Stream: Soft OR, Problem Structuring Methods
Chair: *Isabella Lami*

1 - Aesthetic perspectives in OR interventions
Edoardo Fregonese, Isabella Lami, Elena Todella

In this paper we explore the role of aesthetic perspective in OR interventions, specifically in the construction of knowledge within decisional processes related to urban transformations. We investigate the aesthetic perspective through the wicked transformation problem of an important building in the centre of Turin, (i) by merging the Strategic Choice Approach with architectural design and (ii) by comparing it with Storytelling, as a method for problem-based instruction. The possibility to compare those two methods is given by the fact that both of them are oriented in the construction of a unique general will (or one "plural subject") between stakeholders. Also, we choose Storytelling - despite the fact that it cannot be fully defined a PSM - because narratives hold an intrinsic aesthetic value. We intend aesthetics as "scientia cognitionis sensitivæ" (Baumgarten 1750, ' 1), a particular process and way of knowing and experiencing the problem through the senses and/or empathy. We argue that (i) aesthetics and aesthetical features can (and do) convey knowledge about the problem and (ii) we can distinguish between two kinds of aesthetics: the aesthetics of the process (highlighted by SCA combined with architectural drawings), and the aesthetics of the product (made visible by Storytelling outcomes). The paper debates how these methods can help workshop participants articulate and negotiate their perspective and values.

2 - Design and integration of methodologies for the management of organizations

Maria Alejandra Castellini, Alberto Paucar-Caceres, Jose Luis Zanazzi

The paper reports on the combined use of Hard Operational Research (OR) methods, Problem Structured Methods (PSM) and Operation Management (OM) techniques, in a multi-methodological framework for studying organizational and operational complexity. We advance a modified version of the multi-methodological framework proposed by Mingers and Brocklesby in which we anchor these methodologies to enhance and nurture collaborative knowledge generation and participative work in problematic situations. Following Rosenhead and Mingers and to enhance the intervention design, we make use of the three notional systems that are present in any systemic intervention: Problem Content System, Intellectual Resources System and Intervention System. We use these three notional systems to design and shape the intervention and to assess the portfolio of OR methods deployed in bringing some improvement to a Small and Medium Enterprise (SME). We report on the application of the proposed framework to help the management of a SME operating in the textile industry in the Northwest of Argentina. The paper contributes to the current debate on multi-paradigm and multi-methodology practice in OR to combine hard methods with well-known UK-developed Soft OR methodologies with some less known ones from "outside" the traditional OR portfolio. It also advances a modified framework in which the different OR methods can be positioned to better guide a multi-methodological / multi-paradigmatic OR practice.

3 - A refreshed pedagogical agenda for problem structuring methods

Stephen Harwood, Maurizio Tomasella

Problem Structuring Methods (PSM) offer an approach to systemically handle complex social situations. Within a learning context this invites the question of how PSMs can be used. Two situations are presented. The first relates to the explicit embedding of PSMs into a postgraduate Business Analytics course, whereby student are given an appreciation of how PSMs can contextualise any analysis. The second relates to the tacit use of a PMS to guide the design of a postgraduate Research Methods course, focusing attention upon the difficult challenge of how to establish a research question as well as how to close off the research. Both applications highlight the important contribution they make in dealing with messy situations. This calls for more attention to PSMs, their embedding into university courses and the development of student capabilities for dealing with real world complex organisational situations.

4 - Exploring idea development in tool-supported group development

Isabella Lami, L. Alberto Franco, Elena Tavella

In this talk we report initial findings of an on-going research study that builds on group time studies. Our study aims to investigate whether and how patterns of idea development emerge and vary before and after what is known as the 'mid-point transition' in group development (Gersick 1988; 1989),within the content of a model-supported environment. Specifically, we conducted an examination of a wide range of data generated throughout the life-span of a postgraduate taught module, in which students addressed an urban decision problem. Students were tasked with exploring options for the reuse of an industrial building in Turin, Italy, following three different stages: (i) a market analysis ; (ii) a Strategic Choice Approach workshop; and (ii) a discounted cash flow analysis. We offer some reflections on our initial findings, its practical implications, and possible avenues for further research.

■ TD-19

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S207

Sustainable Supply Chain Operations

Stream: Supply Chain Management I

Chair: *Peter Berling*

1 - Where to exert carbon abatement efforts in a supply chain?

Yann Bouchery, Astrid Koomen, Tarkan Tan

Consider a supply chain leader committed to carbon emissions reduction within the supply chain. In this context, the company is facing a list of complex and intermingled questions. In this article, we first propose a methodology to decide on boundaries for carbon emissions, boundaries for the carbon abatement actions, and optimization strategy to follow. Then, we propose a modeling framework to determine the optimal portfolio of actions to implement and the level of effort on each action selected. We characterize the conditions under which internal, upstream, or downstream actions should be favored. We consider three key features: First, a carbon abatement action often influences several supply chain processes at different supply chain stages. Second, some actions enable to reduce carbon emissions for a given process while increasing the emissions of another process. Third, the relationship between the level of effort exerted and the resulting carbon emissions abatement is often non-linear and sometimes non-monotonic. We make use of convex optimization to derive key structural properties of an optimal solution and we derive managerial insights.

2 - Joint carbon abatement efforts in supply chains

Tarkan Tan, Mohsen Reisi Ardali, Behnam Fahimnia, Charles Corbett

We consider carbon emission abatement decisions taking manufacturer-supplier interactions into account. We present a set of models to identify the situations where cooperation can help invest in joint emissions abatement projects. Various approaches are used to allocate project costs based on the role and bargaining power of each project participant.

3 - A dual sourcing inventory model for modal split transport

Sandra Transchel, Chuanwen Dong, Stefan Minner

Shifting freight volumes from road to rail transport increases the economic and environmental performances of freight logistics. Compared to road, rail transport, in general, incurs a lower unit transport cost, but at the same time it is less responsive due to longer lead time and inflexible in delivery quantity and frequency. To capture the classical cost and responsiveness trade-off of transport services, a simultaneous usage of both transport modes in certain corridors is encouraged. We extend the classical tailored base-surge policy (TBS) policy of dual sourcing literature to support firms' modal split optimization. In TBS policies, firms receive a constant quantity from a distant but cheap supplier every period, and simultaneously, the firm can order from a nearby (fast) but expensive supplier. While TBS assumes that both supply modes have the same delivery frequency, in our modal split transport (MST) policy, we allow the slow transport mode to be used less frequently driven by a fixed cost occurring in rail transport. We show that under an MST policy, the base stock policy for the fast mode is still optimal. A stochastic dynamic programming (SDP) model is developed to obtain the base stock levels during a slow-mode cycle, i.e., the periods between two consecutive slow mode shipments. We find that these base stock levels do not converge to the same value in a steady state. Simulation-based optimization is used to determine the optimal rail transport policy.

4 - An assessment of the potential carbon emission savings from lot sizing decisions

Marcel Turkensteen, Wilco van den Heuvel

Logistics decisions can have a significant impact on carbon emissions, a driver of global warming. As of 2016, road freight transportation contributes to 4.95% of greenhouse gas emissions in the European Union and warehouses 0.55%. One possible way to reduce emissions is by adapting a lower delivery frequency, which can make that one can utilize vehicles well or one can use relatively efficient large vehicles. In our study, we use so-called lot-sizing problems, where we can order items in each period and/or keep items on inventory. Existing lot sizing approaches lack realistic emission values. Therefore, we conduct a survey of empirical studies in order to establish the possible marginal emissions from holding inventory and performing a shipment with a truck. We consider a case study based on real-life considerations and on the findings of the survey study, and introduce a novel bi-objective lot sizing model to find the Pareto optimal solutions with respect to costs and emissions. In our initial experiments, we consider various demand scenarios over 12 months and various relevant factors, such as product properties and driven distances. We find that it is often costly to reduce carbon emissions from the cost optimal solution (compared to carbon prices in the market), unless different vehicle types are available and demand fluctuates. We will investigate whether this is more strongly so for instances with many periods.

■ TD-20

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S301

Behavioural Aspects in Spatial Decisions

Stream: Decision Analysis and Decision Support Systems
Chair: *Valentina Ferretti*

1 - Several models for the comparison of decision maps

Valérie Brison, Marc Pirlot

Our focus concerns decision problems that occur in a geographic context. More precisely, we are dealing with the following question: how to help a decision maker to express his/her preferences over maps representing, for example, the state of a region at different stages of an evolution? As an answer, we provide models that rely on an interpretable axiomatic characterization of the decision maker's preference. Such a characterization entails an interactive elicitation procedure to determine all the parameters of the models developed. Algorithms for learning preferences over maps can also be based on such models.

2 - Multicriteria and multi-stakeholder negotiation related to strategic environmental assessment of ore ports development in maritime Guinea

Jean-Philippe Waaub, Mariama Diallo, Dan Lansana Kourouma

Maritime Guinea region has 300 km of coastal zones open over the Atlantic Ocean, characterized by the presence of mangrove swamps and a rich biodiversity. In addition to the five existing ports, eight projects of ore port facilities are at the planning stage without consultation between the different promoters involved. Each company plans its own port with a complete lack of global strategy. In this context, the use of strategic environmental assessment (SEA) is required upstream to take into account the ecological, economic, sociocultural and political issues of the decision-making process. An innovative approach coupling multicriteria and multi-stakeholder deliberative process for decision aid, spatial analysis using geographic information system (ArcGIS), and contributive participatory approach is implemented. Thirteen stakeholders from government, civil society, private sector and experts met during field work in Guinea. Eight regional scenarios are assessed against eleven impact criteria and related indicators of performance, using Visual PROMETHEE software. The following main elements are computed to support the stakeholder negotiations: scenario strengths and weaknesses, individual and multi-stakeholder scenario rankings and visual analysis of conflicts and synergies between criteria, and between stakeholders, sensitivity and robustness analysis.

3 - How to support spatial decision making?

Magdalena Wagner

The aim of the research is to examine possible applications of operational research in spatial planning in general and in city governance in particular. The need to develop new methods supporting spatial planning is nowadays one of the major challenges of modern urban planning. Reportedly, operational research and multi-criteria decision aiding could be promising and effective solutions to problem structuring and spatial decision making. This research discusses using operational research for the purpose of urban management and presents new solutions which could provide a support for coordinated, rational, and transparent decision making under conditions of risk and uncertainty. Combination of DEMATEL method and selected MCDA methods (such as PROMETHEE or TOPSIS) is presented in order to offer an original model of parametric city governance and spatial decision making. The model, consisting of innovative, OR-based solutions immersed into spatial procedures, could serve as a tool supporting problem structuring and strategy making at city level in order to make it more rational and inclusive. So far, it seems that bringing together operational research and the field of urban studies, could improve city policy making and urban management; therefore, the research encourages a discussion on whether methods derived from operational research could be used to support spatial decision making processes.

4 - Cognitive biases in spatial decision-making processes

Valentina Ferretti

The need and interest to consider cognitive and motivational biases has been recognized in different disciplines (e.g. economics, decision theory, finance, risk analysis, to name the most relevant ones) and has recently reached environmental decision making. Within this domain, the intrinsic presence of a spatial dimension of both alternatives and criteria calls for the use of maps throughout the decision-making processes in order to properly represent the spatial distribution of the features under analysis. This makes Spatial Multicriteria Decision Aiding a particularly interesting domain to explore new dimensions of behavioural and cognitive biases. This talk will present insights from a literature review on cognitive biases in spatial decisions, as well as some preliminary results from a first behavioural experiment on the spatial dimension of biases developed in the Behavioural Lab of the London School of Economics and Political Science. The aim of the experiment is to understand whether or not and to which extent the use of spatial information (maps) can bias the preference elicitation phase of a Multicriteria Decision Aiding process. The results of the experiment are expected to have implications for spatial planning and decision making procedures, by generating better awareness on the meta-choices available to decision analysts and planners when designing Spatial Multicriteria Decision Aiding processes, as well as on the consequences of these meta-choices.

■ TD-21

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S303

Optimization and Variational Analysis

Stream: Nonlinear Programming: Theory
Chair: *Rafael Correa*
Chair: *Marco A. López-Cerdá*

1 - Nonconvex integration using epsilon-subdifferentials

Rafael Correa

We provide an integration criterion for nonconvex functions defined in locally convex spaces. We prove that an inclusion-type relationship between the epsilon-subdifferentials for small epsilon, of two any functions, is sufficient for the equality of the associated closed convex envelopes, up to an additive constant, and to a recession term relying on the asymptotic behavior of the functions. Another criterion of integration is proposed for convex functions, giving rise to weaker conditions using epsilon-varying subdifferentials, and to strong conclusions involving only the closed convex envelopes. We use these results to represent both the values of convex envelopes and their epsilon-subdifferentials by means of epsilon-subdifferentials of the original function. This theory also applies in the standard integration theory framework of proper and lower semi-continuous convex functions defined on Banach spaces, leading to a unifying and alternative proofs for the classical integration result of Rockafellar.

2 - Lyapunov pairs for perturbed sweeping processes
Emilio Vilches

The sweeping process is a first-order differential inclusion involving the normal cone to a moving set depending on time. Roughly speaking, a point is swept by a moving closed set. The sweeping process was introduced and deeply studied by J.J. Moreau to model an elasto-plastic mechanical system. Since then, many other applications have been given, namely in, electrical circuits, crowd motion, hysteresis in elasto-plastic models, etc. In this talk, we present a full characterization of nonsmooth Lyapunov pairs for per- turbed sweeping processes under very general assumptions. As a consequence, we provide a criterion for weak invariance for perturbed sweeping process.

3 - Hiriart-Urruty'-Phelps-like formula for the subdifferential of integral sums
Abderrahim Hantoute

We provide subdifferential calculus rules for continuous sums parametrized in measurable spaces, that use the approximate subdifferentials of the data functions. As in (J. Funct. Anal. 118: 154-166, 1993) given for finite sums, the resulting formulas hold without any conditions of continuity type on the involved functions. All this analysis is done in the setting of locally convex Suslin spaces.

4 - Moreau-Rockafellar type for the subdifferential of the supremum function
Marco A. López-Cerdá, Rafael Correa, Abderrahim Hantoute

We present some characterizations of the subdifferential of the supremum function of a family of convex functions. They are similar to the Moreau-Rockafellar's sum rule, and involve either the relative interior of the domains in the finite-dimensional setting, or the continuity of the data functions in infinite dimensions. The resulting formulas are given in terms of the exact subdifferential of the data functions at the reference point, and not at nearby points. We also derive new Fritz-John and KKT-type optimality conditions for (semi-infinite) convex optimization, dropping the standard continuity assumptions.

■ TD-22

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S304

Multiobjective Integer and Mixed Integer Programming Problems: Methods and Applications II

Stream: Multiobjective Optimization
Chair: *Ozlem Karsu*
Chair: *Firdevs Ulus*

1 - Multiple stock size two dimensional cutting stock problem - an application to a marble company
Umutcan Ayasandir, Meral Azizoglu, Murat Koksalan

We consider a two dimensional cutting stock problem where rectangular items have to be obtained from a stock of different sizes. The required cut amounts and available stock quantities are specified. We define several performance measures based on item profits and stock costs, and evaluate their trade-offs using real life instances taken from a marble company in Turkey.

2 - Interactive approaches for bi-objective UAV route planning in continuous space
Hannan Tureci, Murat Koksalan, Diclehan Tezcaner Ozturk

We study the routing problem of unmanned air vehicles (UAVs) in a two dimensional continuous terrain. We consider two objectives; minimizing total distance travelled and minimizing total radar detection treat; that can be considered to jointly represent many relevant concerns. . We develop interactive algorithms that find the most preferred solutions of route planners. for the cases where the underlying preference function to be minimizedis linear and quasiconvex. We use approximated nondominated frontiers of the trajectories between targets since there exist infinitely many efficient trajectories when routing UAVs in a continuous terrain. We illustrate the algorithms on a number of example problems.

3 - Interactive multi response surface optimization under uncertainty for robust parameter design
Melis Özates Gürbüz, Gülser Köksal, Murat Koksalan

We develop an interactive approach for two-response robust parameter design problem considering preferences of a decision maker (DM) under model uncertainty associated with the parameters of response surface models assuming that the model structure is appropriate. It is desired to minimize the joint variation in the responses and the distances of response means from their target values by deciding on the parameter settings of the product. To provide relevant information on the consequences of solutions to the DM, we produce visual aids on performance measures such as joint response confidence and prediction regions of solutions under consideration. We show that prediction error of the response surface models affects the quality of the solutions and should be considered in evaluating them. We involve the problem analyst (PA) in the search for reaching the preferred solutions of the DM. At each iteration, the PA interprets and converts DM's verbal preferences into mathematical expressions and continues searching the solution space systematically to identify and present solutions that are in line with the DM's expressed preferences. The procedure continues until the DM finds a satisfactory solution.

4 - An efficient implementation for searching optimal paths in multi-objective networks
Natsumi Takahashi, Shao-Chin Sung

Network systems have been applied extensively in the real world, namely the Internet, traffic networks, production and distribution management system, etc.. Each path in such networks may evaluated by more than one criteria, such that distances, costs, speeds, etc., and hence, such networks are multi-objective networks. In this paper, we consider the optimal path problem for multi-objective networks, which aims to obtain the particular paths each of which has a minimum value of criteria. In general, multiple criteria are hardly optimized simultaneously, and thus, it is worth obtaining Pareto solutions as optimal paths. The extended Dijkstra's algorithm was proposed by Akiba et al (2012) for searching all Pareto solutions of multi-objective networks. However, during the searching process, this algorithm generates and stores many non-Pareto solutions, and thus a large memory area is required.

We focus on the advantage of an Dijkstra's algorithm in one-objective network. Based on this advantage, we implement the searching for optimal path efficiently in multi-objective networks and restrict generations of non-Pareto solutions. Numerical experiments suggest our algorithm can significantly reduce the number of searching paths which are not Pareto solutions to each node, compared with the extended Dijkstra's algorithm. Moreover, we consider a standard tree to further reduce search space and analyze the efficiency of our algorithm.

■ TD-23

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S305

Lot Sizing I - Stochastic Models

Stream: Lot Sizing, Lot Scheduling and Production Planning
Chair: *Roberto Rossi*
Chair: *Mengyuan Xiang*

1 - Multi-echelon multi-product capacitated lot-sizing problem with lead time and uncertain demand
Simon Thevenin, Yossiri Adulyasak, Jean-François Cordeau

Motivated by its application in Material Requirements Planning (MRP) systems, we study the multi-echelon multi-product capacitated lot-sizing problem with lead time and uncertain demand. A two-stage (resp. multi-stage) stochastic program models the static-static (resp. static-dynamic) execution of the MRP. In the static-static execution, the production quantities are decided in period 0 for the entire horizon. On the contrary, in the static-dynamic execution, the quantities to produce in period t+1 are decided in period t, after having observed the demands of period t. In both environments, the setup decisions are made in period 0 for the entire planning horizon. To address the scalability issues arising with stochastic optimization approaches, a fix-and-optimize heuristic and advanced sampling methods are proposed. In addition, to ease the execution, a S-policy is derived from the solution of the multi-stage model. The execution of the resulting methods is also simulated in a multi-stage simulation environment, where the plan is completely re-optimized in each period. Extensive simulations show that stochastic optimization methods lead to significantly lower costs than classical approaches. In addition, the multi-stage model slightly outperforms the two-stage model, whereas the latter one could be solved much more efficiently.

2 - Safety stock allocation under capacity constraints and customer-specific service-times in multi-echelon inventory routing
Sebastian Malicki, Stefan Minner

The stochastic inventory routing problem merges vehicle routing and inventory management under uncertainty. It simultaneously accounts for the quantity of goods, time of delivery, and delivery routes instead of solving the inventory and routing problems sequentially. This resembles the concept of vendor managed inventory and allows to reduce costs and shortages across supply chains. When optimizing such a supply chain, safety stocks have to be allocated across its different stages to meet the target end-item customer service levels. However, it is not obvious at which stages safety stocks need to be placed in order to meet the target service levels, at the same time minimizing overall supply chain costs. For this reason, we consider a multi-echelon inventory routing problem in which we address the problem of strategic safety stock allocation. We propose a mixed integer linear program with dynamic lot-sizing and safety stock planning and include the guaranteed service model for the underlying distribution system. We investigate the problem under non-stationary demands. Therefore, we also incorporate capacity constraints because it has been shown that they lead to solutions with lower overall holding costs in this context. Moreover, we include customer-specific service times by means of a customer-segmentation into different priority classes. We show under which circumstances stocks are kept either centrally or locally.

3 - Solving the integrated lot-sizing and cutting stock problem under demand uncertainty
Eduardo Curcio, Vinícius Loti de Lima, Flávio Keidi Miyazawa, Elsa Silva, Pedro Amorim

The interest in the integration of lot-sizing with cutting stock problems has been increasing over the years, however the acknowledgement of uncertainty sources in these problems has been scarcely approached by the scientific community. Hence, this work addresses the integrated lot-sizing and cutting stock problem under demand uncertainty, while considering a finite planning horizon, limited production capacity, and inventory and backlog adjustments for each period. For the cutting stock side, it addresses the two-dimensional non-staged guillotine problem. The study explores several instances with different values of demand, production capacity, inventory, shortage and plate costs. A robust optimization based on polyhedral uncertainty sets is developed to incorporate demand uncertainty and maintain the computational complexity of the problem. In addition, a column-generation, built on dynamic programming, is proposed to efficiently solve the problem. Two computational experiments are proposed. The first focuses on the study of the (actual) price of robustness. The second aims to evaluate the column generation method. Initial results indicate that: 1) the robust optimization provides a reliable trade-off between performance and robustness and; 2) the solution method proposed is adequate to tackle the problem.

4 - An efficient heuristic for joint replenishment problems
Mengyuan Xiang, Roberto Rossi, Belen Martin-Barragan

We consider joint replenishment problems with stochastic demands. A major setup cost is incurred for every order, and a minor, item specific setup cost is incurred for every item. Proportional holding cost is incurred for every item carried from one period to the next period, and proportional shortage cost is incurred for every item unable to be filled immediately on demand. In this paper, we present a mixed integer linear programming (MILP) formulation, which employs the piecewise linearization technique, for computing the near-optimal policies. In contrast to other approaches in the literature, our heuristic can be easily implemented and solved by using off-the-shelf mathematical programming packages. Computational experiments demonstrate that the optimality gap of the MILP model is tighter and the computational time is reasonable.

■ TD-24

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S306

Dynamical Models in Sustainable Development II

Stream: Dynamical Models in Sustainable Development
Chair: *Penka Petrova*

1 - Optimal pest control through geometric catastrophes
Theodosis Dimitrakos, Epaminondas Kyriakidis

Optimal pest control through geometric catastrophes

Theodosis D. Dimitrakos*, Epaminondas G. Kyriakidis**

* Department of Mathematics, University of the Aegean, Karlovassi 83200 Samos, Greece (e-mail: dimitheo@aegean.gr) ** Department of Statistics, Athens University of Economics and Business, Patission 76, 10434 Athens, Greece (e-mail: ekyriak@aueb.gr)

Abstract. The problem of controlling the stochastic growth of a pest population by the introduction of geometric catastrophes is studied. The damage done by the pests is represented by a cost and another cost is also incurred when the controlling action of introducing geometric catastrophes to the population is chosen. It is assumed that the catastrophe rate is constant. We aim to find a stationary policy which minimizes the long-run expected average cost per unit time. A semi-Markov decision formulation of the problem is given. It seems intuitively reasonable that the optimal policy is of control-limit type, i.e. it introduces geometric catastrophes if and only if the pest population is greater than or equal to a critical size. Although a rigorous proof of this assertion is difficult, a computational treatment of the problem is possible. Various Markov decision algorithms are implemented for the computation of the optimal policy. From a great number of numerical examples that we have tested, there is strong evidence that the optimal policy is of control-limit type.

2 - System dynamics modeling for sustainable development in agricultural value chains
Busra Atamer Balkan, Sedef Meral

Agricultural Value Chains refer to the set of processes which transform the raw agricultural crop in the farm to the final agricultural product on the consumer's table and add value to the product along the chain. In recent decades, remarkable increases in prices of agricultural products reveal the importance of understanding agricultural value chain dynamics and making policy recommendations for sustainable development. In this study, we build a System Dynamics model which includes both the agricultural supply chain, i.e. the physical flow and transformation of the product from seed to table, and the agricultural value chain, i.e. the formation of the value added to the product during the flow and transformation. We aim to (1) understand and explain how the values of intermediary and final agricultural products emerge along the chain, and (2) investigate the risks and discuss the precautions to ensure the economic sustainability of an agricultural industry in a developing country. To illustrate the analytical and mathematical structure of the model, we select one strategically very important agricultural product of Turkey, olive oil, and its raw material, olive fruit. Initial model validation and calibration results are found to comply with real world observations based on the data sets from 2007 to 2017. Policy analyses with strategic decision variables (financial subsidies, export regulations, consumption tax etc.) are accomplished in the following phase of the study.

3 - Developing a water sustainable development index (WSDI)

Jonathan Morris

The pressures of rapid economic growth, population increase and global warming pose a threat to the availability of natural freshwater resources which has implications for continued economic prosperity and social development (UN, 1987; IPCC, 2014). Water resource consumption is entwined in a complex socio-economic system and embeds many manufacturing and logistical processes (Hoekstra, 2014; Hoekstra et al., 2015; CDP, 2016). The ability to measure the productive use of water resources can ensure such scarce resources generate economic and social benefits. As water stresses become more pronounced worldwide the ability to demonstrate water sustainability is crucial for satisfying corporate social responsibility objectives and regulatory compliance. Research highlighted in this paper uses statistics on freshwater productivity (volume required to generate $1) from the World Bank, as well as economic and social measures underpinning the Human Development Index to calculate the WSDI, revealing that the highest WSDI in Northern and lowest in Eastern Europe and the Americas. Improving the quality and scope of freshwater productivity data has implications for practitioners and policy makers. This has the potential to provide a framework for policy makers to measure and monitor compliance against regulations, whilst supply chain managers will able to integrate sustainable water practices into supplier selection decisions and assess water sustainability of supplier locations.

4 - Explaining the link between the sustainable economic system and the efficient education system: the opposite example of Bulgaria

Penka Petrova, Ross Kazakov

Key for the sustainability of the economic system is the sustainable education system, which ensures the qualified individuals are genuinely educated in order to support long term economic productivity. The paper reports the findings from a system dynamics modelling analysis of the Bulgarian economy, related to its dependence on the inefficient national education system. Due to its corrupted regulatory framework and institutional budgeting defined by the principle of "quantity" rather than "quality", and the lack of efficient control, the system produces larger proportion of "fake" professionals than the proportion of the "genuine" experts, eroding the overall economic efficiency. The modelling analysis illustrates the paradox of having large number of "qualified" specialists in the country that maintains the lowest GDP in the EU in the last decades. Other important factors like favouritism, plagiarism and corrupted knowledge evaluation system, resulting in equalization between the industrious and the lazy, the clever and the stupid, further contribute to the above inefficiency and undermine the economic sustainability. Both, the inefficient educational and unsustainable economic systems lead to higher rate of demotivation among the genuinely skilled experts, higher demand for quality education abroad and higher level of professional immigration,leaving higher number of "fake" specialists and higher level of economic unsustainability in the future.

■ TD-25

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S307

EURO Young O.R. Researchers

Stream: Combinatorial Optimization II

Chair: *Alberto Santini*
Chair: *Martina Fischetti*

1 - Branch-and-cut-and-price strategy for the port-scheduling problem

David Sacramento Lechado

Port operations are essential logistics problems within Liner Shipping. Among them, we can find problems such as Stowage Planning, Quay Crane Scheduling or Berth Allocation. Normally, these problems are solved independently after the services in Liner Shipping have been determined. In this talk we present a less studied problem that we will denote the Port-Scheduling Problem.

The motivation of this problem arises from large ports, such as the Port of Rotterdam, which are divided into several terminals. Vessels and in particular feeder vessels need to move between the terminals to pick-up and deliver containers while respecting capacity constraints in each terminal. In this paper, we propose a mathematical model, inspired by the Job-Shop Scheduling Problems, to design the routing and scheduling of vessels in the port during a given time horizon.

The solution method is based on column-generation, where the vessel routes are handled in the Sub-Problem, and the master problem selects the routes respecting the precedence constraints in terminals. Overlap of vessels in terminals is controlled afterwards, by adding valid cuts (as new precedence parameters) imposing an ordering in which the vessels should visit the (previously overlapped) terminals.

2 - A tabu-search algorithm for the routing open shop problem with time windows and precedence constraints

Erik Hellsten

Large ports, such as Rotterdam, have several terminals which are spread out over a wide area. Each visiting vessel has cargo to pick up and deliver at several different terminals, and must be routed to visit each of them. The objective is to minimise the departure times, of the vessels, from the port, not seldom under precedence constraints and strict time windows. When one adds capacity constraints to the terminals, such that a terminal can only serve one vessel simultaneously, the problem becomes a generalisation of the m-machine routing open shop scheduling problem with time windows and precedence constraints for both vessels and terminals. The problem is strongly NP-hard, as it has the travelling salesman problem, as well as the m-machine open shop problem, as special cases. Approximation algorithms for the routing open shop problem without additional constraints, have previously been developed, but the problem with time windows and/or precedence constraints is, to our knowledge, not yet studied.

We present the problem, discuss its structure and properties and present a TABU-search and a branch-and-cut algorithm for solving it. We then compare computational results for the methods on a set of instances, developed in cooperation with industry, with up to 25 vessels and 25 terminals. Lastly, we explore additional constraints, such as opening hours for the terminals, as well as the possibility to let multiple vessels be served simultaneously at certain terminals.

3 - The energy collection problem in offshore wind parks

Martina Fischetti

Wind energy is the fastest growing source of renewable energy, and a lot of attention is now on offshore solutions. As offshore wind farms are getting larger and more remotely located, installation and infrastructure costs are rising. In this work we focus on the energy-collection optimization: all the energy production from the turbines should be collected and moved to the onshore grid connection point. This task is achieved by connecting turbines with the usage of different kinds of cables. In the traditional version of the problem, turbines are connected through low voltage cables (the so-called inter-array cables) to an offshore collection point (called substation) and then through a high voltage cable (the export cable) the energy is moved to shore. In the last years Siemens proposed a new concept, called Offshore Transformer Module (OTM): these OTMs are voltage transformers to be attached to a turbine directly, removing the need for substations. In this work we formulate the two versions of the collection problem using Mixed Integer Programming Models, that are solved on real-size instances using a matheuristic approach. Computational results on real world data from Vattenfall show the large savings obtained by optimizing cable selection, substation position, and OTMs number/position for this real-world problem. The developed optimization tool is extremely valuable from a company perspective, as it allows Vattenfall to take informed decisions when designing parks.

4 - A hybrid machine learning and ALNS approach to the orienteering problem
Alberto Santini

The Orienteering Problem (OP) is defined on a complete undirected graph equipped with a travel time function (on the edges) and a prize function (on the vertices). A special vertex is denoted as the depot, while the others are called customers. Given a closed tour, its travel time is the sum of the travel times of the edges traversed; its prize is the sum of the prizes collected at the vertices visited. The OP asks to find a closed tour maximising the prize, while visiting the depot and exceeding a given travel time budget. We propose a heuristic algorithm which uses the ALNS paradigm, and exploits a clustering of the customer set, i.e. a collection of mutually disjoint subsets of customers. Each subset represents points which are at a short travel time from each other, so that points in the same cluster have a higher probability of ending up in the same solution. Once a point is visited, in fact, visiting other points might provide a good prize with a smaller travel time investment. Clustering is a typical unsupervised Machine Learning task, and we will use a parameterless implementation of the DBSCAN algorithm. We will reduce the graph collapsing clusters into their centre of mass and provide an initial solution by solving the OP exactly on this reduced graph. Furthermore, the clustering will be used when destroying and repairing tours at each ALNS iteration. Extensive computational experiments on a standard benchmark prove the effectiveness of this approach.

■ TD-26

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S308

Railway Optimization

Stream: Public Transportation I
Chair: *Samuel Deleplanque*

1 - Real-time train rescheduling
Andrea Bettinelli, Matteo Pozzi, Luigi Marzio, Daniele Vigo, Massimo Rosti, Rosalba Suffritti, Davide Nucci, Antonio Di Carmine

Given a planned timetable for a set of trains and a set of modifications caused by delays or resources unavailability, train rescheduling aims at determining a feasible timetable with the goal of minimizing train delays. A set of actions can be applied to avoid potential conflicts such as train collisions or headway violations, and restore feasibility. We consider a real-world application of train rescheduling, in which the required actions must be determined in few seconds. To this aim, we propose a fast and effective parallel algorithm based on an iterated greedy scheduling of trains on a time-space network. The algorithm is enhanced by graph sparsification techniques and time aggregation strategies to reduce computing time. The proposed heuristic is tested on instances involving up to 130 trains and two hours of planning time horizon. The obtained computational results show that good solutions can be derived within the very short computing time limit.

2 - A stochastic optimization approach to rail yield management at Trenitalia by IBM
Alessandra Berto, Stefano Gliozzi

Yield management (YM) is an umbrella term for a set of strategies enabling capacity-constrained industries to realize optimum revenue from operations. Rail YM aims at maximizing revenues on each combination train/date of departure by optimally managing the seats availability or price per Origin-Destination (O&D) or leg. Since 2005 Trenitalia, main Italian and 3rd European railway undertaking, operates a YM System (YMS) developed by IBM which: (i) provides the forecast of the unconstrained demand - based on an additive method with multiplicative correction - at each point of the booking horizon, (ii) optimizes the capacity allocation per O&D and fare cluster, (iii) simulates the effects of the new set of inventory controls, resilient with distinct orders of arrival, (iv) monitors spill, spoilage, stifling and results based on a revenue opportunity estimation. The two-stage, scenario-based stochastic optimization model is represented as a linear program, considering O&D, fares, scenarios, legs. Protection levels are set against dilution, with a partial nesting technique. The YMS has been capable to manage dynamically more than 220 Frecce trains average/day, carrying more than 45 million passengers on yearly basis and since 2005 it has optimized approximately 4 Million model instances, leading to nearly 120 Billion train-date-class-O&D-fare-quantity decisions. Ongoing developments aim to include the price sensitivity and willingness to pay of customers in the models.

3 - Modelling train movements for time-tabling
Per Olov Lindberg, Disa Asplund, Martin Aronsson, Jan-Eric Nilsson

30 years ago we suggested solving the Train Time-Tabling Problem (TTP) by lagrangean relaxing capacity and safety (C&S) constraints, generating train paths in space-time, and updating multipliers by dual optimization. This approach has been criticized, on the one hand for not being able handle said C&S constraints, on the other hand for that the introduction of binary variables for said train paths leads to inefficiencies. In this talk we will disprove said critique. Concerning the critique of not being able to model C&S constraints, we disprove that by showing how the Swedish (quite complicated) C&S constraints may be modelled within our setting. We believe that C&S constraints in other countries may be modelled in a similar way. Concerning the critique of inefficiency, we will "disprove" that by pointing at how the rich structure of our model may be utilized in many ways, to get considerable speedups. The versatility of our model also allows for treating more "global" problems, such as constraints on the turnaround of trains.

4 - Optimizing the shunting yards
Samuel Deleplanque, Paola Pellegrini, Joaquin Rodriguez

The efficiency of rail good transportation is dependent on the processes implemented in shunting yards. Specifically, from the network, trains arrive and depart through the receiving and the departure bowl, respectively. The railcars of the inbound trains are recombined to form the desired outbound trains with the use of a hump from where they slide downhill to the classification bowl. If necessary, railcars may have to be pulled back and made slide again to achieve specific sortings. It is this going back and forth between the hump and the classification bowl that the optimization is most critical. Today, the recombination of the freight trains in yards can represent up to 50% of total transportation time. This large value can be explained by the weak automation and the lack of optimization.

As part of the European project, OptiYard we will present an optimization tool designed to fit shunting yards in Europe. For assessing this tool, we will exploit microscopic simulation in a closed-loop framework.

In this work, we realize a state of the art on the optimization of yard processes. We study different types of train sorting: simultaneous sorting, triangular sorting or geometric sorting. Recently quite complex methods have been published, many of them being based on integer programming. However, rather few papers exist on the real-time optimization of shunting yards, which could explain why, today, problems are solved "by hand" with empirically designed methods.

■ TD-27

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S309

Line Balancing

Stream: Production, Service and Supply Chain Management
Chair: *Dug Hee Moon*

1 - Balancing and sequencing assembly lines for stochastic demand product mixes
Celso Gustavo Stall Sikora

In several industries, differentiation is used to fulfil the increasing demand for customized products. The combinations of features can produce an exponential number of final products, although they may be produced in a single manufacturing system. Thus, assembly lines must be able to handle such product variety. In the context of mass customization, the potential product mixes has to be considered already in the planning of such production systems. In this work, the balancing problem of an assembly line is extended to consider forecasts on demand mixture. The balancing of workload is solved along with sequencing in a stochastic framework. By explicitly considering a stochastic demand, assembly line projects are expected to be more reliable and robust. A Mixed-Integer Linear Programming formulation is presented to optimize assembly lines for given demand scenarios. The model is solved with a decomposition method based on decomposition strategies and specific and general cuts. Due to the complexity of the aggregation of already difficult problems, only small instances are expected to be solvable with exact procedures. Moreover, numerical results for test instances are discussed.

2 - Simultaneous line balancing and buffer allocation for single model assembly line with stochastic task times
Elif Gizem Göçer, Salih Tekin

Assembly lines are important part of many production systems. The most basic problem about design of assembly lines is assembly line balancing problem. Assembly line balancing problem is to determine the number of work stations (workers) for a given throughput and to assign the tasks to stations considering the precedence relations of tasks. The most common goal in this problem is to reduce the number of work stations. Different versions of this problem have been studied in the literature. In our thesis we will consider the assembly line balancing problem for a real-life assembly line of a dishwasher manufacturing plant. In the problem we will deal with, task times will be considered stochastic. Our thesis distinguishes from classical assembly line problems is that the number of inter-station buffers is limited and the assignment of buffers to inter-station is a factor that affects the throughput of production. Because buffer assignment affects blockage probability of the station due to stochastic tasks that assigned to stations. Thereby assembly line balancing and buffer allocation problem should be considered simultaneously for the finding best solution. The aim of our thesis is to develop an approach that assigning task and allocating buffer simultaneously. Additionally, with a fixed probability this approach helps us to capture the given production throughput with minimum number of stations. Finally developed approach will be implemented on a dishwasher assembly line.

3 - Collision-free multi-robot collaboration in assembly line balancing
Erdal Emel, İsmail Enes Parlak

Many applications exist where multiple robotic arms must work in a crowded workspace and avoid colliding with each other and the workpiece. Those collaborative robotic applications in assembly of vehicle body parts is of our main concern here. In this work, we study on the optimal assignment of spot-welding tasks to the collaborative robots so as not to exceed the station cycle times while avoiding any collision on uninterrupted motion trajectories. To detect collision, global cartesian projections of manipulator links, joints and end-effectors are compared in global time scale at each time unit for sharing at least one digitized vectoral position. At each time unit, for each task to be executed by the end-effectors, the coordinates of joints and links are calculated by using the forward and inverse kinematics of the robotic arms. One of the collision avoidance strategies is the pure randomized reassignment of spot welding tasks under precedence and station space constraints. Balancing the station loads on an assembly line based on such a strategy must also satisfy the maximum utilization of collaborative robots for a given cycle time. The robotic manipulators that are used in the study are non-redundant manipulators with 6-DOF. Inverse kinematics, trajectory collision detection algorithms and assembly station balancing heuristics are all coded and run for sets with various complexity yielding promising results for improving the productivity of future industrial applications.

4 - Effects of buffer allocations in a mixed-models flow lines considering designated workers
Dug Hee Moon, Lee Younghoon, Yang Woo Shin, Chang Seong Ko

The production of multi-products in a same line is popular in manufacturing industries and we call this system as the mixed-models production system when the lot sizes are very small. In general the number of operations and their production cycle times are not equal for mixed-models. Thus, the imbalance of cycle times among mixed models exist and it results in the blocking and starving in manufacturing lines. There have been many articles dealing the general mixed-models as-sembly line balancing problems and mixed model scheduling problems. In this research we will consider a special mixed-models flow lines in which n workers are assigned to m physical stations (working spaces). The required number of workers can be varied following to the model types, and the cycle times are not constant. Furthermore, since some workers are designated (or certificated) workers, their operations and working stations should be fixed. This means that other workers can't process the special operations and the designated workers should move from one station to another station when the production sequence of models are changed following to the routings of products. It is known that the throughput would be equal or be increased, when additional buffer spaces are allowed in flow lines. However, this fact is not always true in the mixed-models flow lines considered in this study. This exception is proven by various simulation experiments, and we will discuss the reasons of this paradox.

■ TD-28
Tuesday, 14:30-16:00 - SOUTH BUILDING UV S310

Incentives and customers in services

Stream: Service Operations Management
Chair: *Kenan Arifoglu*

1 - Service systems with rationally inattentive customers
Caner Canyakmaz, Tamer Boyaci

Many service systems in practice are arguably opaque or only "partially visible" in the sense that customers are not always able to discern precise queue lengths upon arrival. This stems mainly from potential information frictions due to the physical environment and/or cognitive capabilities of customers. Determining the exact queue size requires attention and cognitive capacity (and time), which are all limited in quantity. We capture the salient features of rational queueing behavior under limited customer attention through rational inattention framework. Customers optimally select the type and quantity of information they need and ignore the information that is not worth obtaining in a completely endogenized information acquisition process, trading-off the benefits of better information against the cost associated to it (measured as the reduction in Shannon entropy). In a service system with inattentive customers, beliefs about the queue size distribution are shaped by both endogenously optimized information processing strategies and resulting joining decisions of other inattentive customers in equilibrium. We show that such an equilibrium exists and that it is unique. We also investigate the impact of information cost and characterize its implications regarding information provisioning strategies of firms. Our unifying framework retrieves existing results for visible and invisible queues in extant literature as special cases.

2 - Spatio-temporal service performance of two car-sharing operators under customer substitution
Szymon Albinski, Stefan Minner

In this work, we determine the booking behaviour and the customer-oriented service performances of two free-floating car-sharing providers in Munich: car2go and DriveNow. To do so, we leverage 1.2 million records on car bookings and idle vehicles. To specify the demand and service-levels correctly, we consider censored demand. Thus, we use a data-driven approach that imputes missing demand observations. Since a study showed that many customers are registered with both providers, we introduce two substitution-responsive measures: the capacity-oriented fill rate and the customer-oriented fill rate. The first one describes the provider's ability to cover all demand streams with his available vehicles. The latter one assesses the ability to satisfy demand by any of the two providers' vehicles. Furthermore, we compare the performances of both service providers in terms of competitive behavior. In addition, a Mobility-as-a-Service scenario is analyzed where customers can switch seamlessly between both providers' vehicles. Our results show that substitution improves the customer-oriented service level while it may increase competition among the car-sharing providers. Furthermore, we provide insights into the performance of a joint system of car2go and DriveNow, which notably improves the service level. These insights might be also useful for urban policy makers who can negotiate with the providers based on the obtained results and build effective service-level agreements.

3 - Outsourcing and reservation: tools to manage blended sales and services operations in call centers

Benjamin Legros, Oualid Jouini, Ger Koole

We consider a call center with inbound and outbound calls in a cross-selling environment. The willingness of inbound callers to buy is related to their waiting experience. An outsourcing strategy based on either the expected or the experienced waiting time is proposed to avoid congestion in combination with a reservation strategy. The optimization of these strategies is done in order to maximize the call center revenue under classical contracts with an outsourcer. The first novelty of our model stands in the possibility of initiating outbound calls together with the outsourcing of some inbound calls. The second novelty is the possibility of outsourcing calls after letting them wait in-house. To the best of our knowledge, these opportunities haven't been studied in the academic literature in a single framework. We apply a Markov decision process approach to find the optimal routing for agent reservation and call outsourcing. The particularity of our approach is that we use the experienced waiting time as a decision variable. We prove that the optimal policy for reservation and outsourcing is of threshold type when the expected waiting time is involved in the optimization problem. We demonstrate the economic value of combining partial reservation together with partial outsourcing. In addition, we prove that outsourcing customers after letting them wait in-house generates higher revenue than outsourcing calls at arrival.

4 - Hospital readmission reduction program: the roles of yardstick competition and limited capacity

Kenan Arifoglu, Hang Ren, Tolga Tezcan

We study the effectiveness of Hospital Readmission Reduction Program (HRRP), which is being implemented in US, in reducing the social cost of health care. Using a game-theoretical model, we find that HRRP may induce excess healthcare cost, and we propose a new compensation scheme that coordinates the healthcare system.

■ TD-29

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S311

Game Theory, Solutions and Structures III

Stream: Game Theory, Solutions and Structures
Chair: *Marco Dall'Aglio*

1 - Assignment games with an informed player

Saadia El Obadi, Silvia Miquel, Marina Nunez

Assignment markets and their games (Shapley and Shubik, 1972) have been widely studied.In the markets they consider, there is a partition of agents into two sectors (usually named as sellers and buyers) and the model assumes that the objects of trade are indivisible. A central feature of these markets is that each seller has exactly one item and each buyer desires exactly one item.

In this paper we consider an assignment market where a powerful player conditions the trade and has a double role as both seller and buyer. We can think on a social bank of flats where customers can sell and buy houses with reasonable prices under the supervision of the bank which is the informed player who can also sell and buy. We study some solutions for the corresponding cooperative game as the core and its stability. Further, the tau value and its belonging to the core is studied. Finally, we allow for the two-sided informed player to sell and buy more than one item.

2 - Characterization of allocation rules for set covering situations

Manuel A. Pulido Cayuela, Gustavo Bergantinos, Gómez-Rúa María, Natividad Llorca, Joaquin Sánchez-Soriano

In a set covering problem, a set of customers need a service that can be provided by a set of facilities. In operations research literature, a key question is to decide which facilities to open, from a given set of possible locations, in order to connect every customer to at least one facility. In this paper we address the question of how to allocate the total cost in a set covering situation through a game theoretic approach. We focus on set covering situations where the optimal covering is given in advance, i.e., the related set covering problem has been solved by means of an exact or by an heuristic algorithm. We take only into account the opened facilities and we will look for rules distributing the cost of the given coverage. Associated with each set covering situation a cooperative game can be defined. We characterize the core of this game which is always non empty. In the second part of the work, we consider some suitable properties that an allocation rule for set covering situations could satisfy. Three allocation rules for set covering situations are introduced and characterized by means of some of these properties.

3 - Construction of contractually stable partitions for additive hedonic games

Masaya Tanaka, Shao-Chin Sung

We are concerned with the problems of constructing stable partitions for additive hedonic games w.r.t. contractually stability concepts, including contractually individual (CI) stability, contractually core (CC) stability, and contractually strict core (CSC) stability. The problem w.r.t. CI stability is claimed to be polynomial time solvable by Aziz et al. (2013). However their algorithm fails for some instances. Moreover, polynomial time solvabilities of the problems w.r.t. CC stability and CSC stability were remained open.

Here, we propose algorithms for solving the problem w.r.t. CI stability and CC stability, each of which has linear running time in terms of the instance size. It follows that our proposed algorithms are asymptotically optimal w.r.t. running time. For CSC stability, we show that the problem is again linear time solvable when instances are restricted to be strictly additive.

On the other hand, we consider the situation that individual rationality (IR) is imposed. Even each of the above stabilities does not imply IR, the existences of corresponding stable partitions are guaranteed, but the polynomial time solvabilities become unclear. Here, we propose a fast heuristic for constructing CI stable partitions, and based on numerical experiments, we show that the heuristic terminates after a linear number of deviations.

4 - Algorithms in the court: the CREA project

Marco Dall'Aglio

We introduce the CREA (Conflict Resolution through Equitative Algorithms) project.

This is a two-year project funded by the European Union. It aims at introducing procedures for dispute resolution as a helping tool in legal procedures for lawyers, mediators and judges with the objective to reach an agreement between the parties.

The primary objectives of the project are the following: 1. to apply game-theoretical algorithmic mechanisms to the solution of certain national and cross-border civil matters, including matrimonial regimes, successions and trusts, commercial law and consumer law, facilitating the agreement process among the parties; 2. to demonstrate the efficacy of an algorithmic approach, applying it to the allocation of goods or the resolution of issues in disputes, leading the parties to a friendly solution before or during the trial; 3. to analyse new areas in which fair division procedures could be tried out. 4. to develop new algorithms - in order to help the parties to reach a settlement that mirrors the most salient concern of each side; 5. to develop a software accessible on the EU ODR platform and/or the e-justice portal.

This presentation is funded by the European Union's Justice Programme (2014-2020). The content of this presentation represents the views of the author only and is his sole responsibility. The European Commission does not accept any responsibility for use that may be made of the information it con

■ TD-30

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S312

Game Theoretic Models in Sustainable Operations

Stream: Game Theory and Operations Management
Chair: *Sam Aflaki*

1 - Hedging and strategic forward trading with renewable energy in electricity supply chains
Derck Koolen, Wolfgang Ketter, Liangfei Qiu, Alok Gupta

Electricity markets are currently in a state of flux and uncertainty under the increasing share of intermittent renewable production sources. We propose a multi-stage competitive equilibrium model to analyze the notion of hedging and strategic trading in sequential electricity markets. This allows us to evaluate the effects of the production technology mix on forward price formation and risk related hedging pressure of all market participants. Via a set of simulations, we evaluate the model in a heterogeneous agent-based setting and find evidence for a tipping point in market efficiency along an increasing market share of intermittent production sources. The result shows a convenience yield for implementing flexible assets and indicates a first mover advantage to do so. Thereby, the study raises awareness on how to achieve a sustainable integration of renewable energy in electricity supply chains.

2 - Retail location competition under carbon penalty
Ozgen Karaer, Emre Nadar, Hande Dilek

We study the retail location problem in a competitive linear market in which two retailers simultaneously choose their locations. Both retailers procure identical products from a common supplier and each consumer purchases from the closest retailer. Each retailer incurs transportation costs for inventory replenishment from the warehouse and consumer travels to the store. We consider two carbon tax schemes imposed on retailers: for supply-chain-related transportation and for consumer-related transportation. Our analysis indicates that intense competition between retailers leads to a "minimal differentiation"equilibrium, which substantially increases the total system emissions. According to our numerical experiments with realistic parameter values, carbon tax on supply-chain-related transportation does not affect retail location decisions. Carbon tax on consumer transportation, however, may effectively induce the retailers to approach the middle of their respective markets, reducing the total system emissions. Our analysis also indicates that a low carbon price, relative to market profitability, only reduces the total system profit without any effect on emissions. Our findings suggest that the central policymaker avoid a uniform carbon price across different sources of emission and sectors with different characteristics.

3 - Performance-based contracts for energy efficiency projects
Sam Aflaki

Energy efficiency projects are often executed by specialized entities, namely energy service companies (ESCOs). A typical ESCO's core business is conducted using performance-based contracts, whereby payment terms depend on the energy savings achieved. Despite their success in public, commercial, and industrial sectors, ESCOs in the residential sector are involved in fewer projects and face several challenges. First, an energy efficiency project often leads to changed consumption behavior; hence it is more difficult to evaluate the energy savings that are due to the project itself. The second challenge is that residential clients are more risk-averse and, thus, less willing to contract for projects whose outcomes are uncertain. Third, a lack of monitoring protocols leads to ESCO's moral hazard problems. This paper studies ESCO contract design issues, focusing primarily on the residential market for energy efficiency. As opposed to other sectors, coordinating contracts do not exist. We show, however, that simple piecewise linear contracts work reasonably well. To improve their profitability, ESCOs can reduce uncertainty about the technology employed and/or develop ways of verifying post-project energy efficiency. Since policymakers are understandably keen to promote energy efficiency, we show also how regulations and monetary incentives can reduce inefficiencies in ESCOs' relationships and thereby maximize environmental benefits.

4 - Competition in carbon-offset markets
Gokce Esenduran

Individuals who want to counteract their carbon emission may purchase voluntary carbon offsets from providers. Due to increasing consumer awareness in environmental issues, globally-traded carbon market has been expanding quickly over the past years. One of the most fundamental issues with carbon offsetting is additionality, i.e., whether the project would have happened even if it were not financed through carbon offset market. One way for providers in carbon markets to ensure additionality of their projects is through the choice of delivery terms, specifically through "forward crediting of ex-ante offsets." Alternatively, providers can choose "prompt delivery of existing offsets" as their delivery terms and ensure risk-free deliveries. We analyze the competition between offset providers and identify their equilibrium choice of delivery terms. We identify when a provider chooses prompt delivery over forward crediting and under what conditions prompt delivery achieves higher expected emission reduction than forward crediting.

■ TD-31

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S313

Behavioural Impacts in OR-Supported Processes II

Stream: Behavioural OR
Chair: *Raimo P. Hämäläinen*

1 - Can we learn from wrong simulation models? An experimental study exploring simple models
Naoum Tsioptsias, Antuela Tako, Stewart Robinson

Do oversimplified simulation models support users' learning and are they useful? This paper presents an experimental study that aims to understand whether the level of model complexity affects the users' learning and perceived usefulness. We investigate differences in learning and perceived usefulness by using an oversimplified and a more complex model. Ninety undergraduate business school students are asked to solve a resource utilization task for an ambulance service problem. The treatment conditions are defined based on the type of model used: adequate (more complex model), oversimplified model, and no model. Two questionnaires are administered: pre- and post-questionnaires, which capture participants' attitudes towards the solution to the problem before and after using the treatment condition (model). The second questionnaire evaluates also the users' perceived usefulness of the models used. The results of the experiment are presented. We compare the results in terms of learning and model usefulness as perceived by the participants in the three treatment groups in order to establish the influence of model complexity. This study aims to gather insights about how the level of model complexity can affect learning and decision making.

2 - Impact of dashboards visualizing causal and stock-flow structure on operations management performance
Michael Leyer, Jürgen Strohhecker

Decision making in dynamic operations management systems characterized by stocks, flows, and feedback poses considerable challenges for operations managers. Dynamic decision making (DDM) theory, specifically instance-based learning theory, predicts improvements in DDM performance if decision-supporting dashboards not only present the system's performance indicators, but integrate them in a visualization of its causal and stock-flow structure. However, cognitive load theory points towards a potential counter-effect by introducing an unfamiliar notation of stocks and flows and causal link symbols. Using a computer simulator, we conduct laboratory experiments in which participants make repeated decisions on staff scheduling in a financial service environment in which service quality influences demand. The results indicate that visualizing stocks and flows and causal links between decision variables and performance indicators leads to better decisions, which outweigh the proposed adverse effects. Participants following an analytic reasoning style benefit more than participants relying on intuitive reasoning. Even more interestingly, we find some evidence that a dashboard visualizing the system's stock and flow structure prompts decision makers to analytic reasoning instead of relying on intuitive approaches. As a practical implication, we recommend integrating visual representations of the structure of operations systems in dashboards and reports to support decision making.

3 - A drop in the bucket? Evaluating decision aiding tools in wastewater infrastructure planning cases
Fridolin Haag, Judit Lienert

Strategic decisions regarding public infrastructure are often multi-organizational group decision processes over years. Many tools and procedures to aid decision-making may be employed at different time points and with varying degrees of (in-)formality. To improve practices and processes we would like to evaluate the impacts of these interventions. Such an evaluation is fraught with challenges in conception, data collection, analysis, interpretation, and generalization. Due to the inherent complexity of the decision processes, rigorous experimental or survey research designs are hardly viable. We developed a framework for structuring and understanding these research challenges. On this basis, we discuss evaluative lenses which might nevertheless be useful for providing insights. We argue for complementing instrumental perspectives (were methods useful for, e.g., faster decision-making, consensus building, legitimization) by normative ones (contribution of tools to, e.g., actor inclusion, breadth of objectives or alternatives considered, process fairness). Evaluative lenses such as learning may be used to investigate both perspectives at once, e.g., when assessing changes in knowledge, viewpoints, or relationships. The questions are explored along case studies on regional mergers of wastewater treatment plants in Switzerland. By mergers, the wastewater would be routed to one or few - possibly newly built - treatment plants instead of operating several small facilities.

4 - Behavioural effects in two procedures for creating a strategy portfolio for climate change mitigation
Raimo P. Hämäläinen, Tuomas Lahtinen

In environmental problems we often need to find a set of actions, i.e. a portfolio, in order to meet the diverse goals of the stakeholders in an acceptable way. In practice, it is common that the portfolios are generated in a step-by-step manner without using modeling support. Such processes can lead to suboptimal results and path dependence can easily emerge . The outcome of the process can depend on the order in which different actions are considered and added into the portfolio. The drivers of this phenomenon can be, e.g. biases and cognitive limitations . It can also be very challenging to evaluate how each action contributes to the overall effect when there already is a set of other actions whose effects can be interdependent. This can lead, e.g. to double counting of the benefits, or to not seeing that different actions can complement each other. Behavioral research on environmental portfolio problems is important as there can be unanticipated risks related to the systemic nature of the problems. We report results of an experiment using an interactive decision tool to study behavioral effects in a portfolio generation task related to climate change mitigation. The case is based on the Climate Wedges Game originally developed in Princeton University.

■ TD-32

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S314

Evacuation and Route Planning

Stream: Routing, Logistics, Location and Transportation
Chair: *Pedro M. Casas*

1 - A mesoscopic framework to model evacuation dynamics: a case study on a university campus
Jorge Huertas, Jony Zambrano, Andres Medaglia

In this work, we present a mesoscopic framework to model and evaluate evacuation dynamics. Our framework is comprised of a macroscopic model that determines the optimal flow of evacuees during an evacuation; and a microscopic model that incorporates the attributes of the evacuees and their interaction during the evacuation. To do so, the macroscopic model is derived from an LP with an underlying network structure, while the microscopic model is based on a discrete event simulation. In this way, we propose an iterative process, in which the output from one model is the input of the other one: the movement of the evacuees through the network paths are simulated, resulting in new information about the transit times during the evacuation, which is used to execute the optimization model again. This process is iterated until the convergence of the optimization flows, producing a mesoscopic framework that considers bottlenecks, flows direction, pedestrian speed variations, and congestion. The model performance is evaluated in real evacuation scenarios in a university campus in Bogotá, Colombia, resulting on a model that considers pedestrian interactions and more realistic evacuation dynamics in the studied network.

2 - Bi-level sustainable random regret minimization problem
Shabnam Najafi

In this work we develop a bi-level sustainable optimization model. An important feature of bi-level programs is the hierarchical relationship between two autonomous, and possibly conflictual, decision makers. In upper level problem network managers try to minimize emission amount by deciding about toll pricing and capacity enhancement strategies. In upper level problem decision variables are toll values, capacity enhancement values and link flows. The objective function value for network managers' problem cannot be computed until flows are known. These flows are not in the direct control of the manager. The hierarchical relationship results from the fact that the mathematical program related to the users' behavior is part of the manager's problem. Lower level problem is drivers' problems. Once the network managers have set tolls and route capacities, travelers react to these values and select their itinerary in order to minimize total random regret value of their route choices. Regret is postulated to be anticipated with respect to all foregone routes that perform better than a considered one in terms of one or more attributes. These attributes are toll and travel time values in our model. Decision variables of lower level problem are travel time and link flows. In this work it is for the first time that sustainable network based bi-level random regret minimization optimization program is modeled and solved.

3 - The free route flight planning problem
Adam Schienle, Ralf Borndörfer, Marco Blanco

The Flight Planning Problem (FPP) deals with finding a minimum cost flight trajectory subject to initial conditions such as departure and destination airports, fuel cost and weather conditions. Traditionally, an aircraft's horizontal route is restricted to the Airway Network, a directed graph. Time dependent weather conditions allow us to model the FPP as a Time-Dependent Shortest Path Problem. Since the Airway Network is prevalent almost everywhere on earth, combinatorial shortest path algorithms, such as Dijkstra's algorithm and its derivates, are a natural choice for solving the FPP. To deal with the ever-growing air traffic, the concept of "free route airspaces" has seen significant increase in the last few years (e.g., in Germany since March 2018). In such airspaces, an aircraft may, within certain limits, fly directly between any two nodes of the graph, and need not adhere to the predefined arcs. Mathematically, this corresponds to a locally complete graph. The introduction of free route airspaces leads to the Free Route Flight Planning Problem, whose altered network structure renders classical combinatorial shortest path algorithms ineffective. In the talk, we will discuss algorithmic approaches to solve the Free Route Flight Planning Problem.

4 - Airspace evacuation strategies
Pedro M. Casas

In air traffic, safety and security (SaS) are two non-negotiable operational aspects. Hence, Air Navigation Service Providers have to be able to properly advice flying aircraft in almost any situation. Sometimes, after a sudden nature catastrophe or damage to the infrastructure, SaS can only be guaranteed by evacuating an airspace.

In this talk we will model a scenario in which a part of the Airway Network (AN) has to be evacuated as fast as possible. To do so, the AN is modeled as a digraph on which we run different time-dependent flow algorithms. In this setting, flying aircraft are considered to be the source nodes and the sinks are nearby airports. The Quickest Transshipment and Earliest Arrival Transshipment problems capture the core of the discussed scenario but additional constraints have to be considered to get a realistic model. For example, there is an upper bound on the number of aircraft that may reach an airport during the whole evacuation. To capture this behavior, we need to reformulate the problem such that we can use the notion of bridge capacities at sink nodes.

We will give a combinatorial formulation of the Airspace Evacuation Problem (AEP), place it within the landscape of existing evacuation problems, and discuss its complexity. Moreover, using real world instances, we will discuss what max-flow and min-cost-flow algorithms should be used in an AEP solver. At the end of the talk we will visualize the computed results.

■ TD-33

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S315

Recent Perspectives and Advances in Statistics

Stream: Data Mining and Statistics
Chair: *Müjgan Tez*

1 - A simulation study comparing the performances of GAM, GAM with B-spline(GAMB) and GLM in classification
Pakize Taylan

Classification is a statistical technique that provides prediction models by set up decision function for separating data points into different groups or classes, given a dataset related to any science and application area. There are many classification methods for classifying data points. The generalized Additive Model (GAM) and the generalized linear model (GLM) are very well known and used classification methods. In this research, a contribution will be given to the generalized Additive Model, by using B-Splines as smooth functions in it, and the performances of these three methods are compared based on a number of simulations studies that is performed.

2 - Financial time series forecasting using a fuzzy support vector machine
Engin Tas, Ayca H. Turkan

Support vector machines were originally developed for binary classification and then it is also extended for solving regression problems. Recently, numerous approaches have been proposed based on the popular sequential minimal optimization (SMO). This paper focuses on combining fuzzy logic with support vector machines in financial time series forecasting. For this purpose, based on the data with time property, SMO is reformulated in order to forecast a sample of stock prices from Borsa Istanbul.

3 - Study of the European Parliament votes through the multiple partitioning of signed multiplex networks
Nejat Arinik, Rosa Figueiredo, Vincent Labatut

For more than a decade, graphs have been used to model the voting behavior taking place in parliaments. However, the methods described in the literature suffer from several limitations. The two main ones are that 1) they rely on some temporal integration of the raw data, which causes some information loss; and/or 2) they identify groups of antagonistic voters, but not the context associated to their occurrence. In this article, we propose a novel method taking advantage of multiplex signed graphs to solve both these issues. It consists in first partitioning separately each layer, before grouping these partitions by similarity. We show the interest of our approach by applying it to a European Parliament dataset.

By comparison to existing approaches, our method has the following advantages. First, it undergoes much less of the information loss appearing when integrating the raw voting data to extract the voting similarity networks. Second, in addition to antagonistic groups of voters, it allows identifying sets of legislative propositions causing the same polarization among these groups. Third, it does not require to filter out (quasi-)unanimous propositions, or to discard week links appearing in the model for interpretation or computational purposes. Fourth, it explicitly represents abstention in each roll-call vote layer, which allows detecting relevant groups of abstentionists.

4 - A numerical approach for statistical inference of nonlinear regression model parameters
Özlem Türkşen, Müjgan Tez

Regression analysis is one of the commonly used statistical tool to define the functional relationship between a response variable and one or more input variables through unknown model parameters. If the functional form can not be written as linear in the model parameters, the model is called nonlinear regression model. There have been quite useful nonlinear regression functions in the literature, e.g., Michaelis-Menten function, Mitscherlisch function, Cobb-Douglas production function, Compartment model function. The main aim of the analysis of these nonlinear regression models can be considered as obtaining point and interval estimates of model parameters. Generally, the least squares principle, which is based on minimization of sum of the squared deviations, is applied for point estimates of nonlinear model parameters. The interval estimation is achieved by using linearization or Bootstrap approach in many of the studies. Besides point and interval estimations of the nonlinear regression model parameters, asymptotic properties of the estimators should be defined. In this study, the asymptotic properties of the estimators are derived from the nonlinear functional form of the model. The distribution of the estimated parameters is approximately determined by using previously proposed hybrid of derivative-free optimization algorithms. For application purpose, data set is chosen from the literature and proposed approximate statistical inference approach is applied.

■ TD-34

Tuesday, 14:30-16:00 - SOUTH BUILDING UV S113

Game Theory and its Applications

Stream: Dynamical Systems and Mathematical Modelling in OR
Chair: *Ryusuke Hohzaki*

1 - Rationalizability in multicriteria games
Yasuo Sasaki

We define rationalizability for multicriteria games and examine its properties. In a multicriteria game, each agent (decision maker) can have multiple decision criteria and has a vector-valued utility function. An agent's rationalizable action is defined as such an action that can survive iterated elimination of never-Pareto optimal actions. Thus, it is a natural extension of the standard notion of rationalizability. Our rationalizability captures in a sense common knowledge of Pareto rationality, that is, it supposes that an agent will never play non-Pareto optimal action under given conjecture about the opponents' choices. We first generalize some properties of standard rationalizability such as existence to the multicriteria case. We then compare rationalizable actions in a multicriteria game and its weighted games, as Shapley did for Pareto equilibria. It will be shown that a rationalizable action in some weighted game is also rationalizable in the original multicriteria game, though the converse may not hold. This implies that non-rationalizable actions are robust in any utility aggregation procedure, while the prediction may be redundant in some situations. We also show a sufficient condition that the converse of the above statement holds true.

2 - A search game with an interdictor
Atsushi Kurosu, Ryusuke Hohzaki, Takamori Ukai, Yutaka Sakuma, Syuuji Yamada

We discuss a search game with an interdictor, where a searcher allocates search efforts to detect a target and capture it by the interdictor placed at a specific position in advance while the target moves to evade the searcher in a search space. In this problem, the search operation is completed by the target capture by the interdictor following the target detection. It takes some time for the interdictor to capture the detected target after its detection. In the game, the searcher determines an allocation of search efforts in the search space and a standby position of the interdictor although the pre-planned interdictor's position is known to the target. The target chooses a path among its feasible options. If the target takes a mixed strategy of randomizing its path, the problem is defined as a two-person zero-sum game with the expected capture probability of the target as payoff. The searcher wants to maximize the payoff, but the target desires to minimize it. We prove that there exists an equilibrium point with the searcher's pure strategy and the target's mixed strategy. We propose a difference of two convex functions (DC) formulation to derive an optimal searcher's strategy and a linear programing formulation for an optimal mixed strategy of the target.

3 - Effect of retailer's profit maximization on the amount of unsold products in the presence of strategic customers
Yasushi Masuda, Taishi Kawahara, Hideaki Takagi

Consider a retailer of perishable products. It is well documented in literature that the presence of strategic customers diminishes the effectiveness of the responsive pricing. If the retailer adopts the responsive pricing strategy, the strategic customers may hold off purchases at the regular price and wait for the bargain price, hampering the profitability of the retailer. There are two types of strategies for the retailer to discourage such customers' strategic behavior: quantity commitment and price commitment. We investigate how the responsive pricing and the quantity/price commitment influence the retailer's profit and the amount of unsold products. The model has two periods where a monopolistic retailer sets the order quantity at the beginning of the first period and the responsive bargain price for the second period in case of overage. The customers are strategic and have heterogeneous valuation of the product. Their valuation is discounted when they wait for a bargain sale, where the discount rate is the same for all customers. In addition, there are bargain hunters who have a valuation lower than the strategic customers. This study helps us to understand the effect of retailer's profit maximization behavior on the efforts for reducing the unsold perishable products such as food loss, which is one of major social issues.

4 - A dynamic security game considering cameras and invaders' passage time
Ryusuke Hohzaki

This report deals with a security game with multiple types of invaders/attackers and several types of security/defender teams in a facility represented by a network. The invaders desire to give as much damage as possible to the facility and the defenders want to minimize it. We already have proposed a security game with players' attrition by a conflict between the invaders and the defenders, in which the defenders deploy some security staffs on arcs to intercept the invaders as an interception strategy. Acquiring some invader's information via security cameras or CCTVs, however, the security teams could take more flexible defense such as a dispatch strategy to dispatch some staffs on the route the invaders will go through to intercept them if the staffs arrive there earlier than the invaders. But the dispatch strategy requires us to model a dynamic game considering invaders' passage time on the network. In this report, we propose a two-person zero-sum dynamic security game, in which the invaders take a movement strategy on the network and the defenders have the interception strategy and the dispatch strategy. The game has the damage of the facility as payoff. We also develop a solution method to derive an equilibrium point of optimal invasion and defense strategies.

■ TD-48

Tuesday, 14:30-16:00 - 4D UPV B.3

Humanitarian Strategical and Risk Management Problems

Stream: Humanitarian Operations
Chair: *Celso Satoshi Sakuraba*
Chair: *Andréa Cynthia Santos*

1 - Location model of shelters and warehouses, and stock prepositioning, considering the population behavior of evacuation at home level
Pamela P. Alvarez, Andrés Bronfman, Francisca Carrera

The geographical and geological characteristics of Chile cause that practically all of its territory, and a large part of its population, are constantly exposed to various types of natural disasters. Historically, earthquakes, tsunamis and floods have been the most recurrent disasters and have caused the greatest impact in Chile, both in economic and social terms. Due to this, working in the natural disasters management, in particular in an adequate preparation in front of these events is crucial to save lives, diminish the suffering of the population and be efficient in the use of resources. This work addresses the problem of population evacuation along with the location of shelters and warehouses to deal with flood-type disasters by alluvium, incorporating evacuation behavior at the household level of the population. The population behavior is determined by discrete choice models and this information is considered for the decisions of opening of shelters and establishment of warehouses. The methodology is implemented in the city of Copiapó, Chile, comparing the results with those obtained through traditional models that assume that the affected population moves to the nearest refuge.

2 - An integrated acquisition and download schedule for satellite constellations given environmental and security scenario requirements
Maria José Pinto, Ana Isabel Barros, Pieter van Gelder, Ron Noomen, Monica M De Marchi

As technology advances the operational use of satellite systems requires determining how to make the most out of this technology. This is particularly important for Brazil that is investing in the management and development of satellite systems to increase the autonomy and sovereignty of the country. Given the vast Brazilian territory into account, space monitoring is an interesting option to surveillance and to provide early detection for environmental and security issues. This paper focuses on the problem scheduling of the imagery collection and download of different types of locations (targets) that have different priorities for a given planning horizon and given a constellation of satellites and associated ground stations. A mathematical model is proposed that considers explicitly the scenario requirements such as the time between successive observations of the same target (revisit time) as well as the latest possible moment that the collected imagery is available at the ground station (due time). The application of the developed approach for different Brazilian scenarios and for randomly generated scenarios will also be presented.

3 - Forecasting for disaster relief
Nezih Altay

In this paper we present the results of a systematic literature review of forecasting approaches to disasters and disaster relief operations. Our findings have significant implications on disaster management decisions. Results will be presented and future research directions identified.

4 - Interactive what-if oriented PDDL planning for collaborative crisis management
Yann Semet, Bruno Marcon, Mario Fiorentino, Marcello Cinque

Leveraging optimization algorithms or artificial intelligence in a first response, cross-border, cross-agency crisis context can only work if good data is available for situation, risk and resource assessment. We describe the application of temporal PDDL AI Planning to two real-world flooding scenarios where the best possible action plans are sought to maximize crisis mitigation speed while taking all available aspects of the Common Operational Picture into account such as heterogeneous legal evacuation procedures, dynamically increasing water levels or geographical dispersion of victims and rescue units. The Secplan system builds on the Common Information Space concept proposed by the Sector FP7 project which addresses international crisis management with an agile, field-proof, event-driven interoperability platform. By optimizing temporal rescue operations, several optimization problems are actually solved in parallel: on top of the Vehicle Routing Problem basis formed by the issue of matching localized victims to rescue vehicles and route them through fastest paths, solutions are found to temporal tactical decisions such as bridge closing or dyke management and to advanced medical posts placement determination. Experiments and discussions with actual end-users suggest that significant tactical dilemmas can thus be tackled for the decision maker's benefit, in the crisis room, to help her make the most of all available information.

■ TD-49
Tuesday, 14:30-16:00 - 4D UPV B.4

OR in Forestry I

Stream: OR in Agriculture, Forestry and Fisheries
Chair: *Lidija Zadnik Stirn*

1 - Integrating biodiversity conservation in forest management planning through multicriteria decision making techniques
Marta Ezquerro, Marta Pardos, Luis Diaz-Balteiro

It is widely accepted that there is a change in forest goods demanded by society, thus, forest management must adapt to this new concern for different ecosystem services. The current planning is no longer focused on timber production, so alternative strategies must be addressed to other aspects such as biodiversity conservation. In this paper, several criteria, considering productive, technical and environmental issues have been integrated into a strategic forest planning over a long-term horizon and different silvicultural treatments are included. In a first step, to analyze the degree of conflict between objectives, a pay-off matrix has been generated. In view of the results, multicriteria techniques are used to handle conflicting objectives and decision maker's interactions are introduced. These interactions span from the criteria selection, the allocation of preferential weights to them until the best solution among a set of possible alternatives is chosen. The analytical procedure is based upon the extended goal programming method that has been applied in an emblematic forest in Central Spain. The results show how the methodology proposed yields acceptable solutions for the decision-maker and the opportunity cost of leaving stands uncut has been estimated in physical (timber volume) and economic (euros) terms in order to fulfil conservation measures.

2 - Integrated management of forest ecosystem services: an optimisation model based on multicriteria analysis and methaeuristic approach
Sandro Sacchelli, Iacopo Bernetti

Sustainable forest management has to evaluate the effect of potential intervention on the level of provided ecosystem services (ES). This effect - for example due to presence of thinning, rotation age etc. - should consider the dynamic trend of goods and services from temporal point of view. Literature review as well as empirical evidences highlight a lack in trade-off quantification among forest ES related to varied management strategies of stands. Within this framework the goal of the research is to implemented an optimisation model allowing for definition of best management strategies in forest sector. The case study is depicted in a coniferous stand of central Italy. Four ecosystem services are quantified from biophysical viewpoint (timber produced, carbon stored, ecosystem diversity, recreational function) and one from economic perspective (total economic value of the above indicators). The indicators are aggregated through a multicriteria approach (compromise programming). Results of multicriteria analysis are optimised with genetic algorithm; in other terms the Differential Evolution and Particle Swarm algorithm is applied to minimize the distance from ideal point. Best value of decision variable (rotation period) is defined for different scenario based on compensatory level of criteria, constraints, presence/absence of thinning and discount rate. Strengths and weaknesses of the model as well as potential future improvement are finally discussed.

3 - Robust optimization vs. simulation-based approach in timber harvest scheduling
Robert Hlavatý, Jan Kaspar

In our contribution, we focus on advantages of robust optimization approach in timber harvest scheduling. There are many aspects of uncertainty in the harvest scheduling that a decision-maker should take into consideration. We are specifically concerned with the uncertainty arising from the growth prediction errors of stand volume as well as forest inventory errors. We assume a classical harvest-scheduling model with harvest-flow constraints formulated as a deterministic integer linear program based on the real data under the conditions of Central Europe. The deterministic program is consequently transformed into its robust counterpart whereas it was shown how to overcome difficulties in this particular model formulation. The results of the robust optimization model were then compared with randomly simulated errors occurring in stand volumes. The comparison confirmed that the usage of the robust approach ensures significantly better solutions in terms of achieving given objective than the worst-case scenarios based on the simulations performed. As a secondary outcome, we address the computational complexity of the robust modelling being carried out on the large-scale level.

4 - Analysis of public's perception of forest management (FM) alternatives using multivariate and multi-objective methodology
Lidija Zadnik Stirn, Petra Groselj

Forests contribute to society benefits, such as human health, recreation, tourism, non-wood forest products; they offer home for plants and animals protect water and soil, and reduce climate changes. With the aim to achieve these challenges and the targets given in strategic documents, like FTP Vision 2030 and Europe 2020 strategy, the policymakers, stakeholders, citizens, i.e., public as a whole, have to develop through cooperation, research and innovation such FM alternatives which preserve sustainable FM and respond to multiple demands on forests. Consequently, we are faced with decision process in which the decisions have to be determined and evaluated according to the preferences of the public. Incorporation of local actors in the decision process is one of the most important objectives when measuring social consequences of the alternatives. To provide public's assessment of viable FM alternatives within selected alternatives, public formulates the preferences, measured by objective and subjective indicators, by fulfilling the questionnaire which addresses goals of the alternatives and local characteristics. The surveys' data are then analyzed by statistical and optimization methods. The combination of multivariate analysis (factor analysis) and multi-criteria methods (group AHP) has proven to be effective in evaluating FM alternatives. This methodology is illustrated by an urban forest where three possible alternatives are considered.

■ TD-50

Tuesday, 14:30-16:00 - 4D UPV 1.1

Machine Learning for Energy Applications

Stream: Long-term Planning in Energy, Environment and Climate
Chair: *Gilles Guerassimoff*

1 - Machine-learning for energy, environment and climate
Valérie Roy

The actual conjunction of multi-core high-powerful computers, very large storage capacities, large transmission speed of computer networks, decisive breakthrough in algorithmic and in algorithm distribution allowed for the development, dissemination and democratization of techniques related to big data in many areas, in particular in the energy sector.

If the data has of course always been used in the field of production and transformation of energy, the operated models were classically physic-based behavioral models. This approach is now supplemented and even rivaled by decision-support models based on machine-learning techniques taking advantages of the huge amounts of data currently available, that these data are directly generated by the energetic systems or help describing their environments.

This talk will introduce machine learning techniques and illustrate them on applications from the energy domain. The approach, intentionally didactic, will nevertheless introduce the general scientific concepts underlying the techniques and their hypotheses of use and give an idea of the complexity of their implementations. The validation of those models will then be discussed.

2 - Machine learning for energy demand model from a load curve
Hamza Mraihi, Edi Assoumou, Gilles Guerassimoff, Valérie Roy

The strong deployment of intermittent renewable energy in the European electric system has to be anticipated to optimize the power plant planning. A better knowledge of the correlation between the hour step load curves and the national level in the European country is crucial. Depending on the size of the future horizon we are regarding, the demand level determines the profitability of the solutions for the flexibility.

The results presented in this communication represent the first step in the assessment of the forecasted electric load curve for a residential park of buildings. After a statistical analysis of the time series proposed by the European Network of Transmission System Operators for Electricity, we show some results of the application of machine learning technique for the demand projection characterization for prospective studies.

3 - Household behavior by load curve analysis with machine learning techniques
Ahmed Chaabane, Gilles Guerassimoff, Valérie Roy

With the recent deployment of the smart meters in a French context, energy efficiency improvement in residential sector can be approach by the households load curve analysis completed by a detailed survey of the household's characteristics and habits.

As buildings are becoming more and more efficient, the energy consumption tends to be more and more behaviorally influenced. It is important to be able to quantify this part to give the pertinent advices to the users to improve their relationship to energy consumption.

We present the first result obtained by machine learning technique application on the coupled information given by their load curve and their status and habits. This exploration gives some patterns that can be coupled with some population categories that may help an energy provider having a new customer similar to a category to advise him in improving its energy consumption performance.

■ TD-51

Tuesday, 14:30-16:00 - 4D UPV 1.2

Optimization Problems for Critical Medical Resource Allocation

Stream: OR for Health and Care II
Chair: *Bismark Singh*

1 - Column generation for the kidney exchange problem
Lucie Pansart, Hadrien Cambazard, Nicolas Catusse, Gautier Stauffer

The Kidney Exchange Problem aims at finding the best exchanges in a barter market where agents are patients with a willing but incompatible donor. In 2007, Abraham et al. introduced a natural (exponential) integer programming formulation called the cycle formulation that they could solve efficiently by a branch-and-price approach. Recently, several countries allowed for the participation of altruistic donors in the exchanges. The corresponding variant of the kidney exchange problem is harder to solve as the pricing problem becomes NP-complete. We study and experiment a column generation approach that takes into account altruistic donors. We use advanced techniques to circumvent the NP-hardness of the pricing problem and show that the corresponding method can provide excellent guaranteed feasible solutions in a small amount of time.

2 - An evaluation of the logistics of a university hospital supply
Karina Lyra Fontes, Marcos Estellita Lins

Public health organizations in Brazil are much more complex than private ones, since incentives and motivation are not profit-driven, but concern a range of social interests and human values. University Hospital Clementino Fraga Filho (HUCFF) is a university hospital at the Federal University of Rio de Janeiro that provides daily outpatient care for nearly 1,300 patients and around 200 daily hospitalizations. The difficulties encountered in public hospitals arise from a range of complex causes, involving technical, economic and cultural issues. The present article uses a methodology for the structuring of problems of the HUCFF, which aided the prioritizing of one theme for the application of a formal model, based on criteria concerning feasibility. This was the logistics of material supplies, endowed with greater internal autonomy for intervention. This methodology makes extensive use of cognitive maps as a tool that helps problems structuring and provides an interface with formal models.The latter, in this study, consist of process mapping of current and proposed processes, capable of representing HUCFF's supply network and suggest changes. The results present direct actions, which support and require greater communication among the parties involved.

3 - A new logistic approach for a health care supply chain
Sylvain Bertel

This article discusses a new approach to logistics in the hospital supply chain. The hospital environment is seen as an organization centered on the practice of medical care. As a result, most professions in hospital staff are focused on the reception and care of the patient. However, logistics is a very important part of the support function. The purpose of logistical support is to ensure the smooth running of the hospital's services. It implements a set of processes and resources (refueling, procurement and management of consumables, packaging, storage, transport and handling in the care services to supply each service according to its specific needs (Central Operating Room, Surgery, Pediatrics ...) We can imagine the consequences of a service like reception and the treatment of emergencies in case of malfunction of the logistic system. This is one of the reasons for the direction of the hospital decided to pass of a monthly supply to a weekly supply (supplementation) This new system allows for periodic monitoring of stocks of non-sterile medical supplies, consumables, etc., in each service, to avoid stockouts.

4 - Decision-support tools for influenza pandemic preparedness
Bismark Singh, Hsin-Chan Huang, David Morton, Gregory Johnson, Bruce Clements, Lauren Meyers

To prepare for future influenza pandemics, the Texas Department of State Health Services collaborated with academic researchers to build the Texas Pandemic Flu Toolkit (TPFT). These optimization-based decision-support tools have user-friendly interfaces, and are freely available at http://flu.tacc.utexas.edu/. We describe three TPFT tools to guide medical resource stockpiling, allocation, and distribution.

■ TD-52

Tuesday, 14:30-16:00 - 4D UPV 1.3

Pricing and Revenue Management I

Stream: Analytics and Pricing
Chair: *Fredrik Odegaard*

1 - Exploration and exploitation for decision making
Andria Ellina, Christine Currie, Christophe Mues

Finding the revenue-maximising option in a set of pricing policies, versions of a website or lists of products to display is a common problem in revenue management. It is made more difficult when little is known about the performance of different options before selling begins, especially given the uncertain environment that the majority of retailers work in. Since there is very limited information at the beginning of the selling period, the retailer needs to simultaneously learn about the different policies and earn money from the transactions made. This introduces a trade-off between "exploration", the phase where new information is being acquired, and "exploitation", where the retailer is maximising revenue. In this talk we describe a methodology based on Thompson Sampling, a Bayesian exploration algorithm from the area of Multi-Armed Bandits. The algorithm aims to minimise total regret over the selling period where regret is defined as the difference between the reward of an oracle strategy that selects the best option at each time step and the reward of the option chosen. A common complication in Revenue Management problems is regular patterns and seasonal changes that have an impact on the performance of the different options and consequently affect our decisions. Extensions of the basic methodology to handle seasonality, along with a discussion of how robust the developed methodology is in different environments will be included in this talk.

2 - Vertical probabilistic selling under competition: the role of consumer anticipated regret
Dongyuan Zhan

Probabilistic selling is an innovative business practice of selling a random product that mixes several alternatives with some hidden attributes. Consumers are likely to regret purchasing random products, because less desirable alternative might be obtained due to the hidden features at the time of purchase, and return is prohibited by the "no return" policy after purchase. When consumers can anticipate this potential post-purchase regret, the attractiveness of random products is lowered, which, intuitively, challenges the merits of probabilistic selling strategy. However, we show that, rather than being a curse, the anticipated regret is actually a blessing to the random product provider. We identify a new mechanism associated with anticipated regret and probabilistic selling, reverse quality discrimination, in which the anticipated regret deteriorates the perceived quality of the random product to a greater extent for higher taste consumers. By increasing the product differentiation, this effect may soften competition or soften cannibalization, making probabilistic selling more profitable and more likely to arise.

3 - Stacking the house - revenue management in live entertainment
Fredrik Odegaard, Kyle Maclean

A persistent problem within live entertainment is lost revenue due to unsold seats. This problem stems partially from venues permitting customers, of varying group size, to freely choose seats, causing a sub-optimal seating allocation. To solve this operational problem we formulate and study a capacity based revenue management control problem that explicitly accounts for group size and customer choice. We formulate the problem as a discrete-time Markov Decision Process with the objective to maximize total expected profit. Each period, and for a given group size, the manager decides on the sub-set of remaining seats to make available. Given the offered set, customers select particular seats or choose not to purchase any. We provide an algorithm to determine the optimal solution and obtain insights into structural properties. Due to the curse of dimensionality we provide and analyze via simulation various heuristics. Based on transactional sales data from a large annual North American sporting event we empirically illustrate how the MDP parameters can be estimated.

■ TD-53

Tuesday, 14:30-16:00 - 4D UPV 1.4

International Aspects of OR II

Stream: International Aspects of OR
Chair: *Ulrike Reisach*

1 - Gender diversity in the upper echelons and firm sustainability performance: an examination of Istanbul stock exchange companies
F. Pinar Acar, Gözde Gözüm

Sustainability has become an important determinant of competitive advantage. Firms are expected to demonstrate environmental and social outcomes. Boards of directors and top management teams (TMTs) are the ultimate decision-making units responsible for meeting the needs of stakeholders. This paper investigates female representation and gender diversity on boards and TMTs and firm sustainability performance. The main issue addressed is whether female representation and gender diversity on boards and TMTs impacts the firm's ability to meet sustainability index requirements. Group diversity and critical mass literature provide the theoretical background. Group diversity literature suggests that diversity in attributes such as gender results in greater variety of ideas, perspectives, knowledge, creativity and innovation in turn competitive advantage. Research on critical mass argues that women representation on boards needs to reach a critical mass level before it can affect decision-making process and firm performance.This study hypothesizes that 1)as gender diversity on the board and TMT increases so too does the firm's sustainability performance and 2)the number of females on the upper echelons (board and TMT) has a positive relationship with sustainability performance. To test the hypotheses, binary regression was conducted. The sample consists of top 100 best performing companies in the Istanbul stock exchange. The results provide support for the hypotheses.

2 - Supply chain modelling for Indian railways catering services
Narasimhan Ravichandran

Indian Railways, being one of the largest rail networks in the world, is constantly attempting to improve the passenger amenities. One such initiative is to provide clean food to passengers. The volumes are very large. The Network distribution is also wide. There are several challenges related to sourcing distribution and delivery of this service. In this explanatory study, we present the possible modelling options in the overall context of this service.

3 - A comparison of the operational efficiencies between national and public museums in South Korea
Sukran Kim, Jaewoo Chung

As the number of tourists increases due to fast economic growth, the cultural demands as well as the social expectations on the roles of museums and art galleries have increased in South Korea. When evaluating performance of museum management, the rate of returning visitors out of the total visitors is one of the key indices, which represents the competitiveness of a museum because the higher returning rate guarantees additional profits with lower costs for attracting new visitors. However, many existing studies overlook the importance of the returning rate and use absolute measures only such as number of visitors or exhibitions. The purpose of this paper is to evaluate the operational efficiency of national museums in Korea using both absolute measures and relative measurement of visitor's return ratios. The authors of this paper analyze the operational efficiency of 13 museums in total based on a DEA (data envelopment analysis) model. The results of the study show that four sites operate efficiently whereas 9 others sites are inefficient. The results are compared with those without the returning ratio in the final portion of this paper. It is expected that this study will help museums and art galleries to make better decisions on input resources for achieving better outputs as well as better establishment of operational strategy to accelerate the qualitative growth of the museums.

4 - Regional impact analysis of Chinese OFDI on carbon emission
Wenju Tian

Given the background of new urbanization in China, it is of great practical significance to analyze how to achieve the goal of carbon emission reduction and green development through the "going global" strategy. Therefore, based on the panel data of 30 provinces in China from 2003 to 2014, this paper builds a threshold model based on urbanization rate of OFDI impact on carbon emissions and conducts a test analysis in the whole country, east, middle and west regions respectively. The results show that: (1) OFDI has dual threshold effect based on urbanization rate both in the whole country and in the East, Middle and West regions. There are differences in thresholds in different regions, with the highest threshold in the Eastern region being 59.2% and 85%, followed by 38.71% and 53.21% in the Central region, and the lowest being 28.24% and 35.60% in the Western region. (2) Below the first threshold, an increase in OFDI will cause an increase in regional carbon emissions; an increase in OFDI will inhibit regional carbon emissions when it lies between the first and second thresholds. After the second threshold value, this inhibitory effect will be more obvious.

■ TD-54

Tuesday, 14:30-16:00 - 4D UPV 1.6

Sports Analytics I

Stream: OR in Sports
Chair: *Tomi Seppala*

1 - Application of a hybrid optimization model to improve the performance of the NBA lineups
Rodrigo Infante-Escudero, Roman Rodriguez-Aguilar

The present work deals with a hybrid model of optimization applied to sports. A linear optimization model was made using different alignments of each team of the NBA to select the optimal alignments for each team according to the time of each alignment on the court and the score obtained. Using these optimal alignments, an index of technical efficiency was constructed using stochastic frontiers.

NBA information was used for the last season to use information from active players; in the same way only a minimum playing time was considered for each player to not take into account outliers in score and game time. It is necessary to take into account that if atypical values are not eliminated, the alignment with the highest score would be maintained throughout the game, which due to strategic and health considerations is not feasible in reality.

The optimal alignments generated by the optimization model are an input for the stochastic frontier model that will be the indicator that will allow the performance of the different alignments to be measured over time according to their performance. The developed model can be a precedent for the evaluation and monitoring of the performance of the different line-ups in the NBA and as a reference for an indicator of technical efficiency that can be used by the coaches to improve the performance of the team during the season.

2 - Ranking the solutions of the models in literature on forming the best team for sports clubs by using TOPSIS method
Gercek Budak, Imdat Kara

Forming the best team for sports clubs is one of the greatest challenges for the team coach at before the match stage. This decision is extremely important as it affects the competence of the sport club and accordingly it determines the financial income and sportive success of the sport club. Academic researches on team forming are tremendously increased in the last decade due to the technological improvements on data collection in sports games, increase of the popularity of the sports and reachability to the relevant data. In literature, there are many proposed mathematical models or applications of methodologies on forming the team which give solution for the best team by considering the different aspects of the problem player performance, team harmony and deviations from the coach's strategy. In this study, we handled the final decision on choosing the best team among the solutions obtained by conducting different approaches. We propose to use TOPSIS methodology to support the team coach on the final decision. TOPSIS parameters are obtained according to the team coach's judgements and a real-life application is established on a volleyball team which competes in the first division of Turkish Volleyball League.

3 - Scheduling youth divisions in Argentinian football
Agustina Lopez, Guillermo Durán, Mario Guajardo, Gonzalo Zamorano

This presentation will discuss the mathematical models used to design the 2018 schedules of the six youth divisions of the Argentine football league. There are three older divisions (Under-20, Under-18 and Under-17) and three younger ones (U-16, U-15 and U-14). Each division has 28 teams split into two zones of 14, and each team plays just once against every other team in its zone in a single round-robin plus one interzonal match. The two top teams in each zone play semi-final matches and the two winners meet in the final. The three older divisions use the same schedule while the three younger ones follow the same sequence of games but with the home/away pattern reversed. To create the two schedules, an ILP model was developed that minimizes the number of breaks and incorporated special restrictions requested by the teams. An additional restriction is added to eliminate the major differences in distance travelled over the season between the younger and older division teams of each club. This condition was implemented in the model by first partitioning the teams into geographical clusters and then adding a constraint imposing that each team play the same number of home and away matches against teams in each cluster. The resulting schedules achieved a drastic reduction in the travel mileage differences from levels exceeding 100% in the final year of manual scheduling to less than 30% in all cases. Our schedules are being used for the 2018 season.

4 - The playing styles of the soccer teams in the 2014 FIFA World Cup Brazil based on game data and factor analysis
Tomi Seppala, Tai Nguyen, Tai Nguyen

This study analyzes the soccer team's playing styles in the 2014 FIFA World Cup based on gameplay data. Exploratory factor analysis is used to study performance related variables with the objective is to reveal the underlying playing styles through latent factors. Factor analysis is employed to examine the patterns not directly measured by diminishing a large number of variables into a few underlying factors that allow for better understanding and interpretation of the data. By analyzing a large data set collected for the 32 teams and more than 600 players competing during the 2014 FIFA World Cup in Brazil, the results assert that there are three underlying playing styles among the teams participating in the World Cup: possession-based, individualistic, and practical style. An additional analysis provides further insights into the impact that the background attributes of the players in the team can have on the underlying styles. The results stemming from the research contribute to the current literature by providing a fresh approach in studying the styles of play adopted by soccer teams. As the players are a critical part of the overall team performance that eventually impact the financial and business performance of a sporting club the team managers can use the approach as a starting point in making decisions related to the team. The extracted playing styles could, for example, be used to make an assessment whether a player fits into the team's current playing style.

■ TD-55
Tuesday, 14:30-16:00 - 4D UPV 2.1

OR in Practice - The Human Factor

Stream: Making an Impact I
Chair: *Gerben Groenendijk*

1 - The human factor: being right is one thing, it's another to be acknowledged for it
Nicole Havinga, Bryan Kuiper

Often brilliant optimization results are not viewed as such by various stakeholder during OR implementations. There can be multiple reasons for this. Is the solution of high quality (low cost, high revenue), but are the stakeholders just not used to the solution which is presented to them? Or did we not optimize the actual problem that needed to be solved? Maybe there are conflicts in requirements: the stakeholders may not be aligned on what they find the best solution to their problem.

The challenge in practice is how to tackle the problems mentioned above. This means first of all finding which problem we actually have to solve. It also means that stakeholders have to accept that the solution presented to them could be different than they expect, but could still be of high quality when looking at the goals. Therefore it is essential to this process to define the success criteria. When multiple success criteria are defined, it needs to be identified what the prioritization is, especially when there are conflicting requirements. Quantifying the results and comparing them to a baseline is how we can show the stakeholders that the presented solution solves their problem.

During this session we will open the discussion with some example use cases. We are looking forward to your experience and input.

2 - No walk in the park! Skills for developing routing optimization software in practice
Gerben Groenendijk, Vera van den Dool

"Due to a sudden increase in the number of customers, parcel delivery company X realizes the time has come to apply optimization software for automatically creating efficient delivery routes. To prepare the shift from manual to automated planning, a team of OR specialists working for company X get together to compile a complete and unambiguous list of requirements, a clear definition of the problem that needs to be solved, and a desired outcome, supported by some insightful, illustrative examples. A full problem definition is presented to the optimization software consultancy.

If the situation described above was at all realistic, our job at ORTEC would be a lot simpler than it is. In practice, developing supportive optimization software for a wide range of customers operating in a fast-moving, competitive, and unpredictable market is no walk in the park. Most steps leading to the problem definition have gaps and difficulties that ORTEC first needs to resolve. This workshop is aimed at anyone interested in applying OR in practice. In an interactive way we will share our best practices, address challenges faced, and skills required when bringing OR into practice with help of real-life vehicle routing problems. "

■ TD-56
Tuesday, 14:30-16:00 - 4D UPV 2.2

Advances in Renewable and Energy Systems

Stream: Optimization in Renewable Energy Systems
Chair: *Gordon Dash*
Chair: *Nina Kajiji*

1 - Cross border pollution and taxes
Salvador Sandoval

This work develops a Cournot's oligopoly model, of partial equilibrium, under reciprocal dumping restraints between two countries. The domestic companies allocate a part of their production to the local consumption and the rest to the export market. Firms generate pollution in their productive processes, but they possess technology to reduce it. We use an instrument of environment policy, pollution tax, in order to control emissions. We calculate the optimal pollution tax; so governments can implement strategical and rational environmental policies to maximize the general welfare function that includes consumers, firms and the social cost of polluting. We suppose that cross border pollution exists: the countries involved in the reciprocal dumping export a part of their pollutants to another country, and the remaining emissions are assimilated in the producing country. In this case, governments implement a pollution tax to the companies in order to compensate for the damage caused by the pollution. The pollution quantities the companies yield in each country are distributed in direct proportion to the quantities produced of the good for local consumption and the export market. From the results of the model we can mention the following: 1) if the marginal cost of polluting is high or if imports are very high, a positive tax is imposed, and 2) if the marginal cost of reducing pollution is greater than the marginal cost to pollute, then companies do not reduce their emissions.

2 - Carbon capture, utilization and storage in the context of Turkish energy market
Danial EsmaeiliAliabadi

Combusting fossil fuel is the conventional approach to initiate a set of chemical reactions which releases stored energy as heat and other possibly dangerous byproducts. Among all fossil fuels, coal, with nearly 40% of world's power production, is considered as the dirtiest source of energy that when combusted, releases numerous harmful pollutants such as Nitrogen oxides (NOx), Sulfur dioxide (SO2) and Carbon dioxide (CO2). Climate scientists believe that CO2 with about 60% of the total greenhouse gas (GHG) emissions is the major contributor to global warming. Turkey has huge domestic coal reserves and Turkey is determined to utilize this potential entirely for energy generation purposes. This policy contradicts the Kyoto protocol and

Paris climate accord, which Turkey is part of, to battle the global climate change. Carbon Capture, Utilization, and Storage (CCUS) is the set of methods and technologies that removes CO2 from the emissions and prevents them from leaking into the atmosphere. In this study, we focus on the application of aqueous Monoethanolamine (MEA) scrubbing method as a well-proven carbon capture (CC) technology on the coal-fired power plants. We investigate the economic and environmental impacts of MEA scrubbing technology in the context of Turkish energy market. A mixed-integer nonlinear programming model has been developed that considers regulations, economic factors, and emissions.

3 - Reduction of transmission-grid constraints for computationally efficient N-1 secure dispatch

Richard Weinhold, Robert Mieth

The current challenges of the European electricity market are mainly challenges of grid utilization and stability. Therefore, it becomes more and more necessary to explicitly incorporate feasible representations of the physical transmission grid into economic analyses. In common energy-economic models, grid representation is done using the dc load flow (DCLF) approach as a linearization of the otherwise prohibitively complex physical load flow equations. This allows for a both adequately precise and computational sensible market optimization with grid restrictions. With the same argument the N-1 criterion is usually approximated by enforcing either an absolute or relative error margin on the transmission lines at all times. However, this approximation is not suitable for analysis of market-strategies closely related to the physical state of the line, such as optimal redispatch and flow based market coupling. With increasing shares of renewables and the need for highly efficient grid utilization, such strategies are a crucial part of the current market development. This paper presents a methodology for a true N-1 representation by reducing the grid matrix to the minimal set of constraining lines. This allows the calculation of a security constrained dispatch while being computational efficient. The methodology is realized by an implementation in Python as of a newly developed open source market model that specifically incorporates grid and market interdependencies.

4 - Undetectable cyber-physical attacks on power grids under the AC model

Mauro Escobar, Daniel Bienstock

We describe an algorithm to compute undetectable cyber-physical attacks on power grids under the AC power flow model. In normal conditions, voltage at nodes and current of transmission lines are periodically reported from sensors across the network to a control center, with this information, a power flow estimation can be performed. In our attack model, the adversary's actions affect a small zone of the grid: he can modify the demands of the nodes within this zone, hide its status (voltage and current) from the control center, and report different values to deceive the network scheduler. An overload is created in the attacked area and it is not noticed by the control center of the system. Consequently, the compromised line could eventually trip and thereafter cause cascading failures. We have been able to construct these attacks on large networks in the MATPOWER case library, formulating it as an non-linear optimization program (given the physics behind the AC power flow model). Thanks to IPOPT, we can describe real and reported status of the grid, hiding overloaded lines by more than 20% of its capacity.

■ TD-57

Tuesday, 14:30-16:00 - 4D UPV 2.3

Software for Optimization Modeling I

Stream: Software for Optimization
Chair: *Robert Fourer*

1 - Recent advances for building and deploying analytical solutions using aimms

Ovidiu Listes

We present recent developments in the AIMMS software platform which facilitate a fast and flexible building of analytical decision applications as well as their deployment in enterprise wide systems with client-server architectures and advanced user interfaces.

2 - Model deployment in GAMS

Frederik Proske

In most cases, using GAMS in the typical fashion - i.e. defining and solving models and evaluating the results within the given interfaces ? presents a sufficient way to deploy optimization models. The underlying field of mathematical optimization, in which the focus is not so much on visualization as on the problem structure itself, has remained a kind of niche market to this day.

In the large and very extensive segment of business analytics, however, intuitive deployment and visualization are essential. Since these two areas are increasingly overlapping and in the context of the ever-increasing use of the Internet, interest in alternative deployment methods is also growing in the field of mathematical optimization. In this talk we will show how deployment options of GAMS models can look like.

As an example, we present a web interface which is based on an R package called ?Shiny?. We will show how a model that was written entirely in GAMS can be deployed with this WebUI on either a local machine or a remote server (e.g. to leverage parallel computing) in just a few steps.

While data manipulation, scenario management and graphical evaluation of the optimization results can then be performed from within the WebUI, the model itself is not changed. Therefore, the Operations Research analyst can keep focusing on the structure of the optimization problem while planners have a powerful tool to plan and visualize the results.

3 - Optimizing in the cloud - deploying optimization models on the cloud with web services REST APIs

Bjarni Kristjansson

Over the past decade the IT has been moving steadfastly towards utilizing software on clouds using Web Services REST API's. The old traditional way of deploying software on standalone computers is slowly but surely going away. In this presentation we will demonstrate the soon-to-be-released MPL REST Server, which allows optimization models to be easily deployed on the cloud. By delivering optimization through a standard REST API, which accepts data in either JSON or XML formats, the optimization becomes purely data-driven. Client applications can now be implemented relatively easily on different client platforms such as mobile/tablets or web sites, using just standard HTML/CSS with Javascript, or any other preferred programming language. Google and Amazon have been among of the leading software vendors in the area of Web Services and publish several REST API's which can be quite useful for deploying optimization applications. On the server side, optimization models can easily access online data using for example the Google Sheets API and Amazon DynamoDB. On the client side, libraries such as the Google Maps API and the Google Visualization API can be used to provide rich user experience. We will be demonstrating mobile web applications which utilize the MPL REST Server and the Google/Amazon REST API's for deploying optimization models.

4 - Developing optimization applications through algebraic modeling in AMPL: featuring Python and R APIs for a quick and easy integration with other applications.

FIlipe Brandão, Robert Fourer

Using a high-level algebraic representation that describes optimization models in the same ways that people think about them, AMPL can provide the head start you need to successfully implement large-scale optimization projects. AMPL API is an interface that allows developers to access the features of AMPL from within a programming language; Methods for directly assigning data to AMPL parameters and sets are provided, which can be used instead of the normal AMPL data reading procedures. AMPL API has been written with usability in mind, and it is easy to access its functionalities from C++, Java, C#, MATLAB, Python, and R. In this talk, we feature the Python and R APIs for AMPL, which allow a quick and easy integration with other applications.

■ TD-58

Tuesday, 14:30-16:00 - 4D UPV 2.4

Machine Learning and Data Analysis I

Stream: Emerging Applications of Data Analysis
Chair: *Alexander Aduenko*

1 - LSTM network time series predicts high-risk tenants
Wolfgang Garn, Yin Hu, Paul Nicholson, Bevan Jones, Hongying Tang

In the United Kingdom, local councils and housing associations provide social housing at secure, low-rent housing options to those most in need. Occasionally tenants have difficulties in paying their rent on time and fall into arrears. The lost revenue can cause financial burden and stress to tenants. An efficient arrear management scheme is to target those who are more at risk of falling into long-term arrears so that interventions can avoid lost revenue. In our research, a Long Short-Term Memory Network (LSTM) based time series prediction model is implemented to differentiate the high-risk tenants from temporary ones. The model measures the arrear risk for each individual tenant and differentiates between short-term and long-term arrears risk. Furthermore it predicts the trajectory of arrears for each individual tenant. The arrears analysis investigates factors that provide assistance to tenants to trigger preventions before their debt becomes unmanageable. A five-years rent arrears dataset is used to train and evaluate the proposed model. The root mean squared error (RMSE) punishes large errors by measuring differences between actually observed and predicted arrears. The novel model benefits the sector by allowing a decrease in lost revenue; an increase in efficiency; and protects tenants from unmanageable debt.

2 - A novel training algorithm to build decision trees for anomaly detection
Sarah Itani, Fabian Lecron, Philippe Fortemps

Anomaly detection is a widespread problem in the sphere of data science. One-Class Classification (OCC) is an approach that addresses this issue for various applications, e.g. fraud detection, medical diagnosis, monitoring. Actually, OCC training algorithms are run on a set of training instances included in the same class, with potentially some additional few outliers. Thus a OCC methodology allows to handle problems associated with poor data availability. One-Class Support Vector Machine (OCSVM) is one of the most popular OCC methods. Though high-performing, this predictive technique can hardly satisfy some specific needs which are required in diagnosis aid for example. Indeed, in this context, predictions should be explained and justified, thus interpretability constitutes an important modeling goal. In the present work, we propose a one-class learning algorithm to implement decision trees. These models are originally dedicated to multi-class prediction; we propose an adaptation to the one-class mode. The original aspect of our proposal is related to the division mechanism, which is here based on the information of density, without the necessity of generating physically outliers as the representatives of a second class. It appears that our proposal, which is readable and interpretable, performs favorably in comparison to the most common OCC methods (e.g. OCSVM) and shows robustness towards high dimensional data.

3 - Content-based image retrieval and analysis with use of scalable morphological models
Ivan Reyer, Ksenia Aminova

An approach to content-based image retrieval and analysis is considered. A continuous model of a segmented image consisting of a set of nonoverlapping polygonal figures is constructed. Each polygon from the set approximates a homogeneous raster region within the image, with polygons of two neighbour regions having common fragments of boundary. To obtain the set of polygons a modified algorithm for approximation of a binary image with polygons of minimal perimeter is used. The model also includes marked skeletons of polygons describing changes of skeletal representation at increase of the approximation accuracy value. Thus, a polygonal figure generates a family of variously detailed boundary-skeleton shape models. Obtained image models are compared by shape and color of polygons. To estimate the shape similarity, integral morphological features (the change of boundary convexities' number at increase of the approximation accuracy value, medial width function, approximated Maragos spectrum etc.) are compared. The applications of the presented approach to retrieval and analysis of images and video sequences are described.

4 - Model generation for machine intelligence
Vadim Strijov, Oleg Bakhteev

To solve an applied problem, a data scientist constructs a model, optimises its parameters and puts the model into operation. After a while, the model looses quality due to changes of environment. We propose to dismiss the data scientist from this procedure, and to replace him with a mechanism of model reproduction. This mechanism is called learning to learn, or meta-learning. It defines a strategy for automatic generation of local and universal models. This talk discusses the principles of model generation and selection. It gives an overview of deep neural networks, which construct models. It proposes a routine to forecast the structure of models. It is illustrated by problems of human behaviour analysis using sensors of wearable devices.

■ TD-59

Tuesday, 14:30-16:00 - 4D UPV 2.5

Operation and Planning Problems in Electric Energy Systems with Renewable Resources

Stream: Technical and Financial Aspects of Energy Problems
Chair: *Luis Baringo*

1 - Risk-based operational model of a distribution company in the presence of electric vehicles and renewable energy resources
Miadreza Shafie-khah, S. M. Bagher Sadati, Jamal Moshtagh, João P. S. Catalão

In this paper, a risk-based model is proposed to study the impact of renewable energy resources and electric vehicles on the optimal operation of a distribution company. Due to the uncertainty of electric vehicles and renewable energy resources, the conditional value-at-risk (CVaR) method is employed to limit the risk of expected profit of the distribution company. The model is applied on the 15-bus distribution system, and the results show the usefulness of the proposed model to manage the distribution company's risk.

2 - Planning and operating the future European power system
Ruth Dominguez, Miguel Carrión, Giorgia Oggioni

The objectives of this work are twofold: first, to efficiently plan the capacity expansion of a power system allowing a high penetration of renewable generation; second, to design a market structure that ensures the technical and economic viability of the resulting power system. To tackle this, we propose a multi-stage investment model in generating and storage capacity considering uncertain sources, such as the demand growth or the capital costs of the generating facilities, involved in the decision-making process. This model is used to determine the optimal investment decisions to achieve the objectives of the European

Commission in terms of renewable generation for the electricity supply for 2030. In addition, the operation of the resulting power system is analysed considering an electricity market in which energy and reserves are simultaneously dispatched regarding the variability of the renewable production. Real input data from the European power system are used to develop the case study.

3 - Sample average approximation for risk-averse problems: a virtual power plant scheduling application
Ricardo Pinto de Lima, Antonio Conejo, Loïc Giraldi, Olivier Maître, Ibrahim Hoteit, Omar Knio

In this presentation, we address the solution of risk-averse stochastic programming problems for the self-scheduling of a virtual power plant (VPP) using a Monte Carlo Sample Average Approximation (MCSAA) methodology. The decision-making problem of the VPP involves a self-scheduling and market involvement problem under uncertainty in the wind speed and electricity prices. The MCSAA methodology is integrated with an L-Shaped solution method, which can solve risk-neutral and specific risk-averse problems. This methodology provides a framework to understand and quantify the impact of the sample size on the variability of the results. The results include an analysis of the computational performance of the methodology, estimators for the bounds of the true optimal solutions of the problems, and an assessment of the quality of the solutions obtained.

4 - Robust self scheduling of a virtual power plant in energy and reserve electricity markets
Ana Baringo, Luis Baringo, José Manuel Arroyo

This work considers the self-scheduling problem of a virtual power plant trading in both energy and reserve electricity markets. The virtual power plant comprises conventional generation, wind power generation, and a flexible demand that participate in those markets as a single entity in order to optimize the use of energy resources. As a distinctive feature, the proposed model explicitly accounts for the uncertainty associated with the virtual power plant being called upon by the system operator to deploy reserves. This uncertainty and the uncertainty in available wind power generation levels are modeled using intervals and confidence bounds, respectively, while uncertain market prices are modeled using scenarios. Therefore, the proposed model is formulated as a stochastic adaptive robust optimization problem, which is solved using an effective column-and-constraint generation algorithm involving the iterative solution of a subproblem and a master problem. Results from a case study are provided to illustrate the performance of the proposed approach.

Tuesday, 18:00-19:00

■ TE-01

Tuesday, 18:00-19:00 - Opera House

IFORS Distinguished Lecture: Air Transportation Optimization

Stream: Plenaries
Chair: *Michael Trick*

1 - Air Transportation Optimization
Cynthia Barnhart

There is a long history of applying operations research techniques to problems in airline and air transportation system planning and operations. Over time, these techniques have become more sophisticated, with models and algorithms enhanced to account for multiple sources of uncertainty, competitive effects, passenger choice, and dynamic decision making, to name a few. The impacts have been significant, as demonstrated through numerous applications to air transportation problems across the globe. In this talk, I will briefly review this history, provide examples that illustrate the evolution of modeling and solution approaches, quantify some of the impacts, and highlight research opportunities in the field.

Wednesday, 8:30-10:00

■ WA-01

Wednesday, 8:30-10:00 - UPV Nexus

IFORS Tutorial Lecture

Stream: IFORS Tutorial Lecture
Chair: *Michael Trick*

1 - Solving Hard Shortest Path Problems with the Pulse Framework
Andres Medaglia

Many challenging applications in the field of transportation and logistics often involve the solution of underlying large-scale network problems with shortest path structures. The pulse framework implements ideas and strategies that have been available in the playground of network optimization for years, but when used collectively under a single framework they become stronger and are able to solve a wide array of hard shortest path problems. Initially, we proposed the pulse algorithm as an exact method for solving shortest paths with side constraints. Later, we identified other shortest path variants where the same principle behind the pulse algorithm applied. In this tutorial, we present the pulse algorithm as a framework based on the idea of performing an implicit enumeration of the entire solution space supported by pruning strategies that efficiently discard a vast number of solutions. We focus on the key aspects that have made possible the effective solution of several shortest path variants. We also illustrate the use of the pulse algorithm as a building block to solve hard combinatorial problems beyond the shortest path domain.

■ WA-02

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S101

DEA and Energy

Stream: DEA: Applications
Chair: *Helena Brozova*

1 - A combined multi-criteria decision making method for efficiency assessment of marine renewable energies
Negar Akbari

Many European countries benefit from significant marine renewable energy sources and offshore wind, tidal and wave energy have attracted increased attention in the recent years as viable candidates for clean power generation. In this seminar, a decision making model is presented that aims to assess the efficiency of marine renewable energy technologies and to suggest improvements via the combined application of Data Envelopment Analysis (DEA) and Goal Programming (GP). The DEA method is used to assess the efficiency of these technologies given a set of inputs and outputs commonly shared by these technologies; a fuzzy goal programming method is then applied to suggest improvements for the inefficient units based on decision makers' defined targets. This process will be conducted in an iterative manner, through which inefficient units will be recognized and improved continuously. Limited decision making models have been developed in the literature for evaluating the efficiency of marine renewables and suggesting appropriate measures for improvement. This study will contribute to the literature on the application of combined multi-criteria decision making methods in the marine renewable energy sector for helping decision (policy) makers in this domain.

2 - Measuring the allocation efficiency of power generation portfolio under nuclear-free homeland energy policy
Li-Ming Chou, Chang Dong-Shang, Chun-Cheng Chen, Yi-Chun Chen

The energy policy of Nuclear-Free Homeland has been initiated in Taiwan, which projected the portfolio goal of power generation at 2025 will account for natural gas 50%, coal 30% and renewable energy power 20%. During the transitional period towards the Nuclear-Free Homeland, exploring the alternative portfolio of power generation is an important research issue for the sustainability of energy and environment because the power supply capacity of nuclear power plants accounts for about 12.5% of the total installed capacity. In this study, the decision-making units of possible portfolio of power generation are proposed in accordance with the government's construction plan of installed capacity. Then the allocation efficiency of power generation portfolio is measured by data envelopment analysis. The informatics of the power generation portfolio on the efficient frontier contributes to the decision making. The undesirable outputs of carbon emission are incorporated into model to measure the technical and allocation efficiency. Moreover, the effect of electricity price adjustment and demand growth of electrical power on the efficient frontier of the power generation portfolio will be further analyzed by scenario simulation for addressing policy and managerial implications.

3 - Determining preferred responses in crisis situations
Helena Brozova, Michal Škoda

This article deals with a quantitative support of decision-making in crisis management with the aim to rank necessary measures based on their importance to eliminate the consequences of a crisis situation. The decision support is primarily designed to meet the needs of gas distribution dispatching centres but it could be also used in other sectors. With regard to the limited information that the employee of dispatching centre has available immediately after the crisis, the entire system is designed to work with vague input data. The used model is created as the multip-criteria decision making model with fuzzy evaluation. The initial step of the process starts with the common evaluation of the severity of all possible threats of the expected crisis situations using fuzzy scale. For each threat the ranked list of necessary responses with their importance is also created. When the crisis situation occurs, each threat severity resulting from the current crisis situation is evaluated with fuzzy scale. The second step consists of the synthesis of common and current evaluation of the threats importance from both. In the third step, the importance of individual responses is calculated based on the severity of the threats and the importance of the response for each threat. The vector of importance for all threats is received for each response. In the fourth step all these vectors with corresponding measures are lexicographically ordered and the final action plan is obtained.

■ WA-03

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S103

Production and Operations Management

Stream: Production and Operations Management
Chair: *Milena Bieniek*

1 - A dynamic multi-commodity lot-sizing problem with supplier selection, storage selection and discounts for the process industry
Thomas Kirschstein, Frank Meisel

In this talk a sourcing problem of a production facility from the process industry is presented. The production facility sources raw materials from a set of suppliers that offer different discount schemes. For storing raw materials, heterogeneous storage facilities can be used varying with respect to associated costs and capacities. We formulate the corresponding planning problem of selecting suppliers and storage locations as well as determining order quantities and transport flows under the discount schemes offered by the suppliers as a mixed-integer program.

For solving large problem instances, a heuristic based on the kernel search is proposed and evaluated in a real world case study. The case study reveals that supplier selection and storage selection are highly interdependent decisions. By integrating both perspectives, significant savings can be generated. It turns out that typically a sole optimal supplier exists for each raw material. However, the selection of the optimal suppliers depends on both the prices offered by the suppliers as well as the associated logistical costs for transportation and stock-holding.

2 - Joint optimal pricing and lot-sizing decisions for an advance sales system under stochastic conditions
Maryam Ghoreishi, Christian Larsen

In this paper, we investigate the effect of stochastic inputs on problem of joint optimal pricing and lot-sizing decisions for deteriorating items where the inventory cycle is divided into advance and spot sales periods. During the advance sales period, customers can make reservations while customers with reservations can cancel their order. However, during the spot sales period customers receive the order as soon as the order is placed, but they cannot make any reservation or cancelation during that period. We assume that the inter-arrival times during the advance sales and spot sales period are exponentially distributed where the arrival rate is decreasing function of price. Moreover, we assume that the number of cancelled reservations is binomially distributed. In addition, we assume that deterioration process follows an Exponential distribution. We investigate two cases. First, we consider two-state case where we find the optimal price during the spot sales period, the optimal price during the advance sales period, the optimal lot-size and maximum advance sales amount. Next, we develop a generalized case where we extend two-state case also to allow dynamic pricing during the spot sales period. We apply the Markov decision theory in order to find the optimal solutions. In addition, for the generalized case, we apply the policy iteration algorithm in order to find the optimal prices, the optimal lot-size and maximum advance sales amount.

3 - When is (inventory-driven) dynamic bundling profitable?
Wee Meng Yeo

In practice, some firms may tie the sale of high-value item with its low-value counterpart. This prevalent form of sales restriction is applied when inventory level of the critical item becomes sufficiently low, otherwise it is lifted. We examine within a Markovian framework for (inventory-driven) dynamic bundling where retail firms enforce the purchase of high-value items in packages in a two-item setting to maximise profits. Under order-up-to policies, we provide sufficient conditions to explain when static bundling strategies such as pure component or mixed bundling can be most profitable, while in other cases, they are dominated by dynamic bundling.

4 - Consumer returns policies in consignment contracts with inventory control and price-dependent additive demand
Milena Bieniek

We study a consignment contracts with inventory control with consumer returns behaviour. Consignment is the shifting of the inventory ownership to the supplier. We consider an additive, price-dependent and uncertain customer demand. We compare two kind of consignment regimes. In the first one called the vendor managed inventory program the supplier decides the consignment price charged to the retailer for each unit sold, the refund price for each returned item and the service level. The retailer chooses the retail price. The vendor gets paid based on net sold units, the return units and the salvages unsold units. In the second program called the retailer managed inventory the retailer choses service level. In our model the objective is the maximization of the centralized and the decentralized channel profits. We give the optimal solutions for both kinds of programs. The conclusions for the additive demand seems to be quite different than the previously obtained in the existing research conclusions for the multiplicative demand case.

■ WA-04

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S104

Advances in Risk Management

Stream: New Challenges in Investment Strategies, Risk and Financial Modelling
Chair: *Roy Cerqueti*

1 - Dependency and systemic risk in banking and insurance
Rosanna Grassi, Gian Paolo Clemente, Asmerilda Hitaj

Systemic risk is strongly related to the interconnectedness among individual institutions. Academic research into systemic risk traditionally focuses on the banking sector, but less attention has gained the analysis of systemic risk in insurance sector. Increasing interaction between banks and insurers and financial conglomeration easily explain how mutual and cross company exposures to extreme risks can determine the potential impact of a financial crisis simultaneously on banks and insurers. Our aim is to analyze the systemic interdependencies within and across the European banking and insurance sectors during times. We construct the network structure of financial institution, by including stock return series of all listed international banks and insurers. An undirected and complete network is considered, where weights are calibrated taking into account the dependency between each couple of stock returns over a chosen time window. In particular, by studying the characteristics of these networks on different time periods, we aim to analyze downside risk interdependencies within and between European insurers and banks. Furthermore, we design the structure of the network in a manner so that we are able to disentangle the role of systemically important banks and insurers within the network itself and their new regulations.

2 - Green bonds funds: efficiency and concentration risk
Anna Maria D'Arcangelis, Giulia Rotundo

The growth of the Green Bond market encouraged many Institutional investors to diversify the portfolios by moving towards sustainable investments. While the traditional financial intermediaries (banks) show to be not so keen to insert this kind of investment in their balance sheets, other institutional investors like asset management companies were quite sensitive to enlarge their offer to the market segment of sustainable investments and also on the more specific theme of green-bonds investment. This is the rationale for our exclusive focus to mutual funds and passive vehicles (ETFs). The analysis starts from the results in the literature that state the existence of a premium for green bonds and it is targeted to verify both the dynamics of the returns of a sample of the green bond funds and their efficiency. Thus our initial analysis is aimed at the comparison of green bonds funds with their benchmarks, and also with the conventional fixed income benchmarks/indices and green-ETF, as passive competitors in the segment. A further objective is to investigate the issue referred to the existence of a typical concentration risk for green bond funds, due to the limited amount of choices in the investible universe. This issue is particularly important, as it could put at risk the fulfilment of the typical goals of active management.

3 - Non stationarity of high order return distribution moments and their irrational fractional Brownian motion modelling
Gurjeet Dhesi, Muhammad Bilal Shakeel, Thamila Madji, Marcel Ausloos

This paper reports results on the forecast of the numerical value of the fat tail(s) exponent, kurtosis, and skewness of asset price distributions obtained from stock market indices, moreover simulated using the Irrational Fractional Brownian Motion (IFBM) model. An auto regressive analysis advances the understanding of the modelling and forecasting the returns distributions moments, whence provides some logical argument for the detailed shape of returns distributions and accurate measurement of Value at Risk. The methodology uses a moving time interval width procedure, going beyond a standard consideration about the evolution of IFBM parameters for a time interval divided into 2 years wide windows. In so doing, we search whether there is non stationarity effect due to the width of windows, investigating what is going on from small to large windows. Thus, we are looking for some "convergence", - somewhat washing out outliers. We have also examined whether statistical characteristics measured and simulated values depend on the time origin. The various forecasting values are discussed.

4 - Systemic risk assessment through adjacency clustering coefficient
Roy Cerqueti, Rosanna Grassi, Gian Paolo Clemente

This paper proposes a novel measure of systemic risk in the context of financial networks. At this aim, we provide a definition of systemic risk based on the community structure around the nodes of the network. Specifically, we introduce the concept of adjacency clustering coefficient of a node i as an opportunely weighted mean of the clustering coefficients of the nodes which are adjacent to i. Then, we define the adjacency clustering coefficient of a network as the mean of the adjacency clustering coefficients of its nodes and explore its properties in terms of systemic risk assessment. Empirical experiments on the time-varying global banking network provide insights on how systemic risk has changed over the last years, also in the light of the recent financial crisis.

■ WA-05

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S105

Inventory and Location Routing Problems

Stream: Vehicle Routing and Logistics Optimization I
Chair: *Emilio Jose Alarcon Ortega*

1 - An effective matheuristic for the multi-vehicle inventory routing problem
Oguz Solyali, Claudia Archetti, Haldun Sural

We consider an inventory routing problem in which a supplier distributes a single product to multiple retailers using a homogeneous fleet of capacitated vehicles over a discrete and finite time horizon. The aim is to decide on shipment quantities to retailers and vehicle routes in each time period such that the sum of routing costs and inventory holding costs at the supplier and retailers are minimized. We propose an optimization-based heuristic that relies on solving restricted formulations of the problem. The computational experiments on benchmark instances reveal that the proposed heuristic yields favorable results compared to the existing heuristics in the literature.

2 - A two-echelon inventory-routing problem for the last mile delivery of perishable products
Sonja Rohmer, G.D.H. (Frits) Claassen, Gilbert Laporte

This research presents a two-echelon inventory-routing problem with delivery patterns for the last mile delivery of perishable products. A supplier delivers products to an intermediary depot, where storage may occur and from which they are delivered by smaller vehicles to the customer locations. Holding costs incur for storage at the depot. Customer delivery patterns specify the availability of a customer. The objective is to minimise total transportation and holding costs. The problem is relevant to the last-mile delivery of highly perishable products such as fresh food or flowers. We formulate the problem as a mixed integer linear program and solve it by means of an adaptive large neighbourhood search metaheuristic in combination with the solution of a reduced version of the formulation. Three variants of the heuristic are compared on a variety of randomly generated instances. Given the two-stage structure of the problem, computational results show the importance of taking the cost structure into account when choosing the most suitable solution approach.

3 - A heuristic approach based on biased randomization for location routing problem
Abdullah Almouhanna, Banafsheh Khosravi, Djamila Ouelhadj, Angel A. Juan

A biased randomization of the classical heuristics for Vehicle Routing Problem has been shown to have successful results in the literature. We propose a Multi-Level Biased Randomized (MLBRH) heuristic for the capacitated LRP. This approach consists of three levels; the initial level, the global level, and the local level. In the initial level, an iterative approach is employed to choose the best solution with regard to the minimum location and routing costs for different combinations of depots. In the global level, a Biased Randomized Extended Clark and Wright Heuristic (BRECWH) is developed to improve the result of the Multi Depot Vehicle Routing Problem from the initial level. Finally, in the local level, we adapt a Biased Randomized Clark and Wright Heuristic (BRCWH) from the literature to solve the VRP for each depot which is resulted from the global level. In both global and local levels, the biased randomization is employed by a pseudo-geometric distribution which generates a probability of selection for each pair of routes in the savings lists of the devised classical and extended Clark and Wright heuristics. The computational results, implemented on 46 instances from two well-known benchmark data sets, show that the proposed approach is promising for further developments in terms of quality and computation time.

4 - A matheuristic for the consistent inventory routing
Emilio Jose Alarcon Ortega, Michael Schilde, Karl Doerner

We present a model and a solution methodology for beverage inventory routing systems. Customers have special characteristics and requirements including the need for consistency in delivery times and the existence of time-windows. We also allow split deliveries in the formulation to cover the case of temporary high demands caused by special events such as sports events or music festivals. We present a mathematical model for the consistent inventory routing problem with time-windows and split deliveries. We propose a matheuristic based on the concept of Adaptive Large Neighborhood Search (ALNS). First, we construct an initial solution using an adapted cheapest insertion followed by two local search steps. A 2-opt algorithm deals with bad routing sequences and a second stage eliminates single-customer-routes. We then apply ALNS to the obtained solution. We introduce several destroy and repair operators that target certain aspects of the specific problem in order to obtain good routing and inventory plans. Moreover, for good solutions found during the search, we solve a mathematical sub-problem based on the problem formulation. This way we obtain optimal delivery quantities as well as optimal waiting times in the schedules if necessary. We present computational results obtained by applying our exact method as well as the metaheuristic to a set of instances adapted from a benchmark set and compare the impact of the different operators and characteristics of the problem.

■ WA-06

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S106

Stochastic Modeling and Simulation in Engineering, Management and Science II

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Chair: *José Niño-Mora*

1 - Optimal policy for economic production lot-sizing model with preventive maintenance
Minjae Park

In this study we investigate an optimal manufacturing quantity for economic production lot-sizing model with a random defective rate and preventive maintenance service for manufacturing machine. We study the properties of optimal economic manufacturing quantity to minimize an expected cost when a random defective rate for product is considered. If a manufacturing machine produces some proportion of defective items which is larger than the lot tolerance percent defective, then a machine shifts from an in-control condition to out-of-control condition and it should have a maintenance service to decrease the possibility to produce imperfect-quality products. It is considered that time to condition shift is a random variable and follows a general distribution. A mathematical model is developed to find optimal manufacturing quantity and to investigate other optimal decision variables. Numerical examples are given for the applicability of the methodology derived in the paper.

2 - Modelling of a buffer stock by a random walk with two barriers

Basak Gever, Zulfiye Hanalioglu, Tahir Khaniyev

In industries, buffer stock management is significant as it affects the production performance. Therefore, in this study, a stock with 2a capacity where located between two machines which are working at the same speed, is considered. Under the assumption that the speeds of loading and dumping are the same and machines are halted when the buffer stock is completely full, the level of buffer is investigated by random walk with two barriers. The jumps of the random walk are expressed by random variables which have bilateral exponential distribution function. In this study, the variation on the level of the stock until the first time the stock becomes completely full or empty, is denoted by the random variable N. The aim of this study is to investigate the numerical and functional characteristics of the random variable N by using basic identity for random walk. In order to achieve this aim, the explicit and open form of the probability generating function of the random variable N is found. Then, using this formula, the explicit and approximate expressions for the expected value, variance, standard deviation, coefficient of variation, skewness and kurtosis coefficients of the random variable N are obtained.

3 - A global optimization method for a quadratic reverse convex programming problem by listing FJ points

Syuuji Yamada

In this talk, we propose a global optimization method for a quadratic reverse convex programming problem (QRC) whose feasible set is expressed as the area excluded the interior of a convex set from another convex set. It is known that many global optimization problems can be transformed into such a problem. Iterative solution methods for solving (QRC) have been proposed by many other researchers. One of the difficulty for solving (QRC) is that all locally optimal solutions do not always satisfy KKT conditions. In order to overcome this drawback, we introduce a procedure for listing FJ points of (QRC). By utilizing such a procedure, we can calculate all FJ points contained in the intersection of the boundaries of convex sets defining the feasible set. Further, we propose a new algorithm for finding a globally optimal solution of (QRC).

4 - Numerical instability in average reward Markov decision processes

José Niño-Mora

When tackling a large-scale not analytically solvable Markov decision process model, standard approaches aim to obtain a heuristic or optimal policy from the approximate or exact numerical solution of the model's dynamic programming optimality equations. Yet, we show that, in a wide range of relevant long-run average reward discrete (finite or countably infinite) state unichain models, where such equations are formulated in terms of the average gain and bias, their numerical solution is fundamentally hindered by an inherent instability phenomenon preventing accurate computation of the bias for large states. We illustrate the phenomenon through examples, elucidate its root cause, outline its implications, including for the one-step policy iteration method and for assessing the accuracy of simulation estimates, and discuss possible approaches to partially overcome such an instability difficulty.

■ WA-07

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S107

Timetabling and Passengers

Stream: Public Transportation II
Chair: *Marie Schmidt*
Chair: *Evelien van der Hurk*

1 - Solution methods for integrated timetabling and passenger routing

Philine Schiewe, Anita Schöbel

Periodic timetabling is an important yet computationally challenging problem in public transportation planning. Although the objective is to minimize passengers' travel time, their routing is often handled separately leading to timetables which are suboptimal for the passengers. Integrating the routing decisions into the optimization process of finding a timetable is therefore important for finding passenger-friendly timetables but also significantly increases the computation time. Here, we consider an integer programming model for integrating timetabling and passenger routing and focus on finding good solutions faster than by solving the integrated IP formulation. We develop an exact preprocessing method for reducing the problem size as well as heuristics which provide upper and lower bounds on the objective with considerably less computation time. The heuristics are experimentally analyzed on a small benchmark example and are shown to work on an instance of the German long-distance railway network. The exact preprocessing method as well as the heuristics are not specific to the presented IP formulation but can also be transferred to other solution methods.

2 - Demand and supply interaction for the train timetabling problem

Naut Bulten, Rommert Dekker, Shadi Sharif Azadeh

A train timetable is defined as a set of arrival and departure times of each train from each of its stopping stations and it is the output of the Train Timetabling Problem (TTP). Typically, the TTP models use the simplifying assumption that the passengers always take their shortest paths and eliminate the demand from the problem.

In most of the existing literature, modelers assume the passengers to be exogenous in the form of an origin-destination (OD) matrix. The timetable, then, can be constructed either with constraints on the satisfaction of demand, with penalties in the objective function for unsatisfied demand, or both.

In this research, we assume neither demand nor supply to be exogenous and model the TTP such that demand is dependent on the timetable. By doing this, the OD matrix is not given but depends on the solution. This gives not only a more realistic view, but also allows the TOC to increase revenue through maximizing passenger satisfaction (and thus demand). We model the TTP as a mixed integer programming problem and solve it using a tailored heuristic for large scale network.

3 - Synchronizing transfers through integrated timetabling and vehicle scheduling - an iterative matheuristic approach with public transit traffic assignment

Joao Fonseca, Tobias Zündorf, Evelien van der Hurk, Allan Larsen

Transfer times add inconvenience to journeys and thus synchronizing departures and arrival times of relevant lines improves the service for passengers. As the timetable changes passengers may also change their travel itineraries. Additionally, introducing small timetable modifications may also affect the operational costs, as the timetable defines a set of feasible vehicle schedules. We address the Integrated Timetabling and Vehicle Scheduling Problem (IT-VSP) with Public Transit Traffic Assignment (PTTA). The IT-VSP is formulated as a MILP that minimizes transfer costs with a budget on operational costs. Given an initial non-cyclical timetable, time-dependent service times and passenger demands, the transfer time cost is minimized by allowing modifications to the timetable that respect a set of headway constraints. Timetable modifications consist of shifts in departure time and addition of dwell time at intermediate stops. We propose to solve the problem iterating between solving a matheuristic for the IT-VSP and re-computing the PTTA. The matheuristic solves the IT-VSP MILP allowing timetable modifications for a subset of timetabled trips only, while solving the full vehicle scheduling problem. Results for the Greater Copenhagen area indicate that our approach finds better solutions faster than a commercial solver and that allowing the addition of dwell time creates a larger potential for reducing transfer costs. We also show that the integration with the PTTA model generat

4 - Timetabling with integrated passenger distribution

Johann Hartleb, Marie Schmidt, Markus Friedrich, Dennis Huisman

We present two models to integrate passengers' behavior into the optimization process for finding timetables. For fixed timetables, traffic assignment models usually distribute travel demand on a set of connections. However, state-of-the art timetabling formulations assume a pre-fixed routing for each passenger, independent of the offered connections. Since these two procedures highly depend on each other, two integrated formulations are proposed. The first integrated formulation is based on a linearized multinomial logit distribution, a commonly used traffic assignment model, and the second formulation is based on a linear simulation framework for choice models, which can be used to model the passenger distribution in the network. Given a choice set of routes in a public transportation network with fixed lines, a timetable and passenger distribution are computed simultaneously, ensuring good connections for the passengers on multiple routes with each model. We compare timetables generated by these two approaches and a state-of-the art timetabling method with respect to different evaluation methods for timetables, among them travel time on shortest paths and travel time according to a logit distribution. Furthermore, we evaluate the resulting timetables also by more comprehensive evaluation functions considering other factors than travel time only.

■ WA-08

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S108

OR in the Physical Internet

Stream: OR in the Physical Internet
Chair: *António Ramos*

1 - Operations research in the physical internet: literature review and opportunities for research

Manuel Lopes, Teresa Pereira, Pedro Lopes

The new Physical Internet paradigm for supply chain management is presented as a valid alternative to achieve economically, environmentally and socially efficient and sustainable transportation and distribution of goods. This new approach to the supply chain management entails a major shift in logistics systems, with implications throughout the supply chain, which has direct impact on the way operational reseach problems are currently addressed. Many of the problems studied by Operational Research will have to be revisited to allow its applicability in this new Physical Internet paradigm. Aware of this new reality, this paper presents a state-of-the-art survey on Operational Research problems in the Physical Internet. The review considers papers published between 2009 and 2018 and it is intended to be a starting point on the classification of the OR problems within the Physical Internet paradigm, aiming to identify opportunity areas for future research.

2 - Simulation-based optimization approach for PI-networks

Christian Haider, Stefanie Kritzinger, Alexander Kinast, Erik Pitzer, Michael Affenzeller

Physical Internet (PI) aims to connect single logistics network together, to create an open and global transportation network. Within the opening and globalization, the networks complexity rises through the consideration of many restrictions. Due to the high complexity of such networks special methods have to be developed to solve this kind of complex problems. One already known approach to solve such a task, is simulation-based optimization. Simulation-based optimization combines the two phase's optimization and simulation with each other, whereas the optimization is used to generate valid solution candidates, which are evaluated through the simulation. Due to the intricacy of the networks, metaheuristics are used for the optimization process. Based on the already known problem representation a new problem representation of vehicle routing for PI-networks containing a new date encoding was developed. For the creation of solution candidates, a genetic algorithm is used and therefore some new manipulation methods, which are suitable for the new data-encoding, have been implemented. Since a PI-network is a complex system with many nodes of different types, the simulation has to evaluate the candidates from the optimization step in a reasonable time. Therefore, a new algorithm for the simulation step was developed. This new approach lacks a bit of intelligence, but is more time efficient than a conventional simulation.

3 - Physical internet: a study of the containers layer in the NOLI reference model

Moustafa Nakechbandi, Jean-Yves Colin, Hervé Mathieu

The goal of a Physical Internet is to be a sharable, more efficient, logistics network. The NOLI Reference Model for a Physical Internet is a Reference Model, inspired by the OSI Reference Model for data networks and Internet. A reference model divides the complexity of the whole problem into easier sub-problems. As the OSI model, the NOLI model includes 7 layers (Colin 2017). These layers are, from layer 1 at the bottom, to layer 7 at the top: the Physical Handling Layer, the Link Layer, the Network Layer, the Transport Layer, the Order Layer, the Container Layer and the Product Layer. A first model, named OLI, was proposed in 2009 by Montreuil et al (Montreuil 2009). It also included 7 layers. Its Layers are somewhat different from the ones in the NOLI model. In this presentation, we study more precisely some functionalities of Layer 6, the Container Layer. We present its goal and location in the NOLI model, some of the software and material services it must provide, and the relationship it has with Layer 7 above, and Layer 5 below it. It also includes some algorithms to manage the handling of the imbalance in specific containers (Colin 2015). We compare it with the TCP/IP, the OSI and the OLI Reference Models.

References 1. Colin et al. IPIC 2017, A Proposal for an Open Logistics Interconnection Reference Model for a Physical Internet. 2. Montreuil et al. 2009, Physical Internet Manifesto. 3. Colin et al. ICALT 2015, Management of mobiles resources.

4 - Operational research problems in the physical internet

António Ramos, Elsa Silva, José Fernando Oliveira

One of the problems of today's supply chains is that they are economically, environmentally and socially inefficient and unsustainable. The low occupancy rates of trucks and containers at departure and the percentage of empty returns and the precarious family and social life and health of the drivers, because of long periods away from home, are just a few examples. The new Physical Internet paradigm for supply chain management represents a real and viable alternative to meet the challenges posed. Physical Internet relies on collaborative management models and the extension of the normalized containerization paradigm to all levels of cargo movement and handling to provide a fast, productive, reliable and sustainable supply chain. This approach introduces at a strategic, tactical and operational level new challenges to supply chains, which were not conceived to support the Physical Internet paradigm but rather customized to requirements of a particular company. These new collaborative networks and infrastructures have operational constraints very different from the classic ones that arise from the traditional supply chain, strongly influencing OR problems such as the three-dimensional loading capacitated vehicle routing problem, the container loading problem or the hub location problem. Considering these premises, our contribution is to identify research gaps and opportunities for future research in the OR field under the new Physical Internet paradigm.

■ WA-09

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S109

Graphs, Data and Optimization

Stream: European Working Group: Data Science Meets Optimization
Chair: *Pieter Leyman*

1 - A scale-independent structural definition of community detection in graphs
Alexander Braekevelt, Pieter Leyman, Patrick De Causmaecker

Finding groups of connected individuals or communities in graphs has received considerable attention in literature. In an attempt to quantify the intuitive concept of "strongly connected individuals with few outgoing connections", many definitions have been proposed. Most of these, however, provide little insight in the quality and properties of the resulting subgraphs in general graphs. Applications in OR might require more rigorous definitions. We propose to analyze different characteristics from literature, derived from clique relaxations, and determine a better definition of connectedness. An important aspect in this regard is the scalability of the definition, which we explicitly take into account. We subsequently discuss our algorithm, based on the Moody & White approach for finding vertex connected sets, to detect the defined types of communities, given a minimum and maximum value. Hence, the proposed technique is able to identify groups of nodes which satisfy predefined properties. In terms of data, we use both existing (real-world) data and fictitious data generated ourselves. Finally, we also analyze the impact of data parameters on algorithm performance, and consider the link with instance difficulty. Possible applications include social media network analysis (e.g. Facebook, Twitter), bioinformatics and real-world vehicle routing.

2 - Network structure and dynamics of European stock markets
José G. Dias

The analysis of co-movement and contagion between stock markets has been based mostly on the computation of correlation-based measures on raw data. A disadvantage of using this type of measures is that they are sensitive to extreme observations and do not take time dependency into account. This paper introduces a new method that filters time dependence and data outliers by using hidden Markov models prior to the computation of association measures. Then, networks analysis is performed to understand cross-relations between stock markets. The application to European stock markets illustrates the improved understanding of dynamics using different measures of association and dynamic visualization techniques, in particular rolling measures of association, hierarchical trees, and minimum spanning trees (MST).

3 - Supporting evaluation of algorithms during pace challenges
Jan Badura, Maciej Antczak, Artur Laskowski, Szymon Wasik

The goal of the Parameterized Algorithms and Computational Experiments (PACE) Challenge is to investigate the applicability of algorithmic ideas studied and developed in the subfields of multivariate, fine-grained, parameterized, or fixed-parameter tractable algorithms. The 2017 and 2018 editions of PACE were hosted using Optil.io platform. Up to this point, the organizers run solutions submitted by users only once, at the end of the contest, using manually executed scripts. Optil.io platform provided them with automatic, continuous evaluation method. Contestants could submit their algorithms to the platform and have them assessed almost instantly using 200 instances. 100 of them were public ones, for which participants could see their results in real time and compare those results with others. Another 100 instances were private. Results of evaluation using these instances were visible only to organizers, and after the challenge deadline, they were used to determine the winner. For each instance algorithm could use up to 30 minutes of processor time, thus requiring to perform 100 hours of computation per submission. Thanks to the parallelization, contestants could check their results on public instances after just around 90 minutes. Uploading problems from both editions to Optil.io platform was possible with a minimal additional effort from the organizers, and after minimal pitfalls, at the beginning of 2017 edition, the evaluation worked seamlessly.

4 - A self-adaptive evolutionary algorithm for the intermittent traveling salesman problem with different temperature profiles
Pieter Leyman, Patrick De Causmaecker

We study the intermittent traveling salesman problem (ITSP), which extends the traditional TSP by including temperature restrictions for each node. These restrictions limit the allowable consecutive visiting time for each node, which leads to each node possibly requiring multiple visits. We extend previous work by considering different types of temperature profiles, which determine the temperature increase and decrease rates. We propose an evolutionary algorithm (EA) and show the contribution of each of the EA's individual components. Especially the analysis of different solution representations, which is often overlooked in literature, is of great importance. The effect of including the EA's parameters in the solution representation, allowing for self-adaptive parameter control is studied as well, and compared with adaptive rules which adjust parameter values based on solution quality. Additionally, the consequence of introducing a learning component in the EA's mutation operator, is investigated. Based on the test results, we draw conclusions regarding the contribution of each of the proposed algorithm components, and show the impact of the different temperature profiles.

■ WA-10

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S110

Urban and Territorial Planning in MCDA

Stream: Multiple Criteria Decision Aiding
Chair: *Isabella Lami*
Chair: *Marta Bottero*

1 - An integrated multi-criteria spatial decision support system for urban energy scenarios
Sara Torabi Moghadam, Patrizia Lombardi

Reducing energy consumption in the built environment sector, towards low-carbon cities requires a supportive planning process. In this regard, the use of appropriate tools and methods for addressing complex interactions of Urban Integrated Energy Planning (UIEP) processes is needed. However, the choice among UIEP scenarios is extensively based on multi-actors and multi-criteria aspects. The research, therefore, deals with the integration of participative decisional processes into UIEP by organizing different focus groups involving relevant stakeholders. This study aims at developing a new Multi-Criteria Spatial Decision Support System (MC-SDSS) tool to support UIEP in real-time processes. The developed MC-SDSS is an interactive energetic plug-in of GIS environment using CommunityViz. The architecture design of the tool consists of four major parts: (i) creation of GIS-database (ii) modelling of Energy Interactive Impact Assessment (iii) modelling of Suitability Analysis (iv) defining of energy retrofitting scenarios using many presentation features including maps, alerts and charts. The new MC-SDSS is applied to a case-study, a medium-sized city of the metropolitan area of Turin (IT), in order to facilitate the dynamic decisional process for stakeholders who can ask "what-if" questions and visualize "if-then" scenarios. Accordingly, two set of retrofitting decision scenarios, expert-oriented and stakeholder-oriented, are developed through a participative workshop.

2 - Dominance-based rough set analysis for understanding the drivers of urban development agreements
Marta DellOvo, Alessandra Oppio, Francesca Torrieri, Milosz Kadzinski, Grzegorz Miebs

The rise of neoliberalism in the context of urban development has encouraged the cooperation between public and private parties. This cooperation is structured by contracts, generally called Urban Development Agreements (DAs). Being part of the urban regeneration strategies, these projects aim at achieving a durable improvement of an area according to sustainability principles. Thus, within the negotiation between private and public, multiple and conflicting instances have to be faced case by case. Despite the uniqueness of each DA, it is possible to define a set of pertinent characteristics that play a crucial role in determining the fairness and appropriateness of the public-private partnership. Given this context, the work proposes the Dominance Rough Set Approach (DRSA) for exploring the relationship between condition attributes or criteria and decision with the aim of supporting negotiations on the basis of specific features of the DA under evaluation. Specifically, DRSA has been applied on a sample of DAs recently concluded in the Lombardy Region, and tested on the other sample of DAs under the negotiation phase. The analysis has accounted for the characteristics referring to the following five contexts: urban, institutional, negotiation, development, and economic. The inferred decision rules provide useful knowledge for supporting complex decision processes such as DAs.

3 - A multicriteria framework based on the Choquet integral and the analytic hierarchy process for evaluating scenarios of adaptive reuse
Francesca Abastante, Salvatore Corrente, Salvatore Greco, Isabella Lami, Elena Sezenna

The research aims to test an assessment framework based on the Choquet integral and Analytic Hierarchy Process (AHP). The Choquet integral is a well-known MCDA method taking into account interactions between criteria but it shows two main problems: the need to determine a capacity that assigns a weight not only to single criteria but also to subsets of criteria; the need to express on the same scale evaluations of different criteria. To handle the first problem we adopt the Non Additive Robust Ordinal Regression (NAROR) that simultaneously considers the capacities compatible with the indirect preference information provided by the Decision Maker (DM). With respect to the second problem, we apply the AHP. The proposed methodology is here applied to a current topic: the adaptive reuse of the abandoned thermoelectric power plants due to inefficiency. According to this problem, the main Italian distributor of electricity (ENEL) launched the "Futur-e Project" in order to provide new sustainable activities. In the context of this project, the case study here presented concerns the simulation of a process aimed at selecting the most appropriate development scenario for the former thermoelectric power plant of Bari (Italy) considering different point of views. In this perspective, the framework proposed can result very useful, in particular because of the presence of a number of interacting criteria and alternatives, as the situation of several urban and territorial problems.

4 - GAHP II Sorting method: an application to the vineyard landscape of Langhe, Roero and Monferrato (Italy)
Vanessa Assumma, Marta Bottero, Alessio Ishizaka

The economic assessment of landscape represents a complex task where different monetary and non-monetary aspects and values have to be considered. Integrated approaches are therefore needed in order to properly take into account all the relevant dimensions for the evaluation and to provide a framework able to support decision-making processes in the context of landscape planning and management. The present contribution illustrates the development of a multicriteria evaluation model to sort different municipalities in the Piedmont Region (Italy) with reference to their attractiveness in terms of Landscape Economic Value. This evaluation considers the case of the vineyard landscape of Langhe, Roero and Monferrato, that has been recently included in the World Heritage List of UNESCO (2014). The evaluation model has been based on a system of landscape economic indicators that represents the main economic characteristics of the 101 municipalities belonging to the UNESCO site. Municipalities are sorted with the AHP II method (Ishizaka et al. 2012) which is a new classification method based on AHP that requires less pairwise comparisons with respect to the traditional AHP sorting method. In particular, the present work proposes a further extension of the AHP Sort II method, namely the GAHP II Sorting method, which allows the opinion of different experts to be included in the evaluation, thus providing a multi-stakeholders view of the decision problem.

■ WA-11

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S111

Novel Applications of Analytics

Stream: Business Analytics
Chair: *Wouter Verbeke*

1 - The beneficial effect of ensemble learning in predicting student drop-out in online learning environment
Trung Hoai Minh Phan, Kristof Coussement, Dries Benoit, Arno De Caigny, Annelies Raes

Online learning has been an educational revolution in the recent years especially after the successful introduction of the Massive Open Online Course (MOOC). Despite having many advantages of high flexibility, unlimited participation and low access fee, online learning has been suffered from student retention. Therefore, to maximize online learning experience, it is crucial to build a student drop-out prediction model as accurate as possible. This study focuses on one special type of online learning data: the MOOCs with monthly subscription plan, where the student decides to pay the subscription fee at the beginning of each month to be able to access to unlimited MOOCs on the learning platform. In order to predict the student drop-out (subscription plan cancellation), 6 groups of features have been constructed to capture the student's learning activities, i.e. student's information, learning motivation, learning difficulty, student interaction, goal orientation and student cluster. Moreover, a benchmarking section between standard statistical models and the most recent Logit Leaf Model (LLM) has been implemented to select the best accuracy model. Finally, insights into the impact of each feature group on the student drop-out is given as a suggestion for student retention strategy for this online learning platform.

2 - Higher order mining for incremental root cause analysis
Eduardo e Oliveira, Vera Miguéis, José Borges

Root Cause Analysis (RCA) aims at identifying the true origin of a problem. It is an intricate problem, especially in complex manufacturing systems, which produce large amounts of data. Data Mining (DM) techniques have been proposed as a solution for tackling RCA in complex systems. However, these techniques usually focus on the analysis of data from discrete periods of time. The analysis of the datasets corresponding to each period is usually developed separately, and there is not a concern for managing the root causes knowledge in the long term. We propose an approach that focuses on this concern, by developing a technique for incremental RCA using Higher Order Mining (HOM). In the proposed solution, we mine the rules extracted using C5.0 algorithm from several samples. These rules describe the possible root causes of certain problems. By mining the rules, the proposed approach is able to identify the most prevalent variables and propositions related to those problems, therefore identifying the true root causes. This solution allows rules to be analyzed incrementally, actively managing the knowledge on root causes, and providing continuous learning of the problems analyzed. The proposed solution is validated through a case study developed in the context of semiconductor manufacturing.

3 - Motivating creativity with a carrot and a stick - creativity-weighted productivity, relative performance information, and perceived competition
Peter Rötzel, Burkhard Pedell

Creativity remains one of the key success factors for many organizations, but firms struggle to use adequate controls to motivate creativity-weighted productivity of employees. While prior literature presents competing perspectives regarding the effect of rewards on individual creativity, the grand challenge of motivating creativity-weighted productivity is still unsolved. This study links the competing perspective of whether creativity can be increased by monetary incentives and investigates how relative performance information (RPI) and creativity-weighted pay scheme affect employee creative productivity. Our results show that a combination of RPI and creativity-weighted pay increases employee creative productivity and prevents a "crowding-out effect". The current study presents and tests a general model for understanding the advantages and disadvantages of RPI and creativity-weighted pay on the quality and quantity of employee creative productivity. Our findings implicate that RPI induces motivation, but we find that the effect regarding total productivity is magnified when the RPI is public rather than private. However, it is also shown that creativity-weighted pay interacts with the use of RPI and leads to a significant increase of both quantity and quality of creative productivity. By isolating the RPI and creativity-weighted pay effects, our study provides insights into the costs and benefits of RPI in a creative productivity environment.

4 - Towards accurate and scalable metrics for predicting user engagement on tablets by combining multimodal biosensor data with behavioral interaction patterns
Klaas Nelissen, Seppe vanden Broucke, Bart Baesens, Monique Snoeck

The goal of this work is to investigate to what extent biosensors (eye tracker, heart rate sensor, and skin conductance wrist monitor) can be used to predict whether a user was engaged while reading a news article on a tablet.

This is useful because while biosensors offer the most accurate measurements, they are not scalable as they require a lab setting. Swipe interaction patterns are usable on a large scale, but offer no possibility of objectively knowing if a user is engaged.

Making the link between biosensors and behavioral interaction patterns enables bridging the gap between accuracy and scalability when measuring user engagement.

We report on the specific swipe interaction patterns which correlate most with the physiological signals that indicate engagement.

We have done qualitative experiments where about 60 subscribers of 2 different newspaper brands wear sensors and indicate engagement with articles in a newspaper tablet app, while we also logged every (swipe) interaction with the tablet.

With one of the newspapers, we also modified a section of the regular newspaper so it contained shocking articles, which allows us to investigate the physiological reaction and corresponding swipe interactions that occur with unexpected content.

The contribution of this work lies in the fact that it is the first to combine multimodal biosensor data with behavioral interaction patterns for measuring user engagement in the application domain of digital news reading.

■ WA-12

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S112

Operational Problems in Maritime Terminals

Stream: Maritime Transportation
Chair: *Juan Correcher*

1 - A machine scheduling approach to the berth allocation problem under channel restrictions
Christian Bierwirth

Shipping channels are often a constraint to port capacity due to the signicant capital cost and environmental impact of channel dredging. Capacity impacts of channel operations are most significant in tidally restricted ports, where deep draft vessels are only able to move through the channel during narrow windows around high-tide in order to maintain sufficient under-keel clearance. Channels are often narrow which constrains the capability of vessels passing in opposing directions. There has been much research to-date around berth allocation and sequencing, but in channel constrained ports the value of existing approaches can be limited. In this paper we present an approach to optimise the scheduling of channel movements and furthermore, to integrate the channel scheduling and berth allocation/sequencing problems. A MIP formulation is presented for this problem, based on a no-wait bidirectional flow-shop with parallel machines and time window constraints. Benchmark problems from the literature for berth allocation/sequencing have been modified to incorporate a range of channel configurations and used as test cases for the proposed model.

2 - A new branch and benders cut scheme and heuristic column generation for the discrete berth allocation problem minimizing the makespan
Giorgi Tadumadze, Simon Emde, Heiko Diefenbach

The berth allocation problem aims to optimally schedule arriving ships at seaport container terminals by assigning them to time slots and berthing areas along the quay. The present work addresses the discrete berth allocation problem with given time windows for the ships with the goal of minimizing the makespan. We propose a novel exact algorithm based on Benders decomposition as well as a heuristic based on column generation. In a series of computational tests both on benchmark instances from the literature as well as on newly generated ones, our exact method is shown to solve most problems within a few minutes to optimality, while our heuristic can solve particularly tricky instances with tight time windows well in acceptable time. We also derive some insight into how resources like quay cranes should be distributed among berths.

3 - Optimization of daily berth allocation planning
Ozge Kubilay, Serap Akcan

In this study, ships were examined at the port. The purpose of this study was to schedule the ships to maximize the total profit based on four main constraints. First, landing places of the port have different sizes and according to these sizes, they can be suitable for a ship or not. Suitability constraint controls the ships' suitability and provides to match the arriving ships with suitable landing places. The second constraint is that of time scheduling which considers arrival times, due times, starting times and also over-times. The other two costraints are precedence relation and over-time constraints. A mathematical model is proposed for finding the optimal solution and has been validated with a numerical case.

4 - A mixed integer linear formulation for the berth allocation problem in terminals with irregular layouts
Juan Correcher, Ramon Alvarez-Valdes, Thomas Van den Bossche, Greet Vanden Berghe

The Berth Allocation Problem (BAP) is the optimization problem in which port terminal planners are required to assign a berth and a berthing time to all the vessels whose arrival at the terminal is expected in the near future, with the objective of minimizing the total assignment cost. The BAP was first addressed by the end of the 1990s and since then academic researchers have increasingly considered new constraints and real-word characteristics. Until now, however, scientific studies have lacked in taking into account many spatial safety rules that berth planners usually apply in practice.

In this work we study the novel BAP faced in terminals with irregular layouts which give rise to adjacency, oppositional and blocking relations between berths. These relations may prevent vessels from berthing or departing under given conditions and thus require a new problem formulation in which all these constraints are included.

We propose a mixed integer linear program (MILP) and evaluate its implementation through extensive computational experiments on realistic instance sets. We also perform a comprehensive study to determine how various factors influence the difficulty of the problem. The results show that the proposed MILP is able to solve optimally instances with up to 40 vessels arriving at the terminal within a week. The number of instances solved optimally decreases with increasing number of vessels or safety restrictions, and increases with increasing number of berths.

■ WA-13

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S201

Operational and Cyber Risk Modeling

Stream: Financial Modeling, Risk Management and Managerial Accounting
Chair: *Pilar Gargallo*

1 - A new methodology for modelling operational risk using skew t-copulas and Bayesian inference
Betty Johanna Garzon Rozo, Jonathan Crook, Fernando Moreira

We present a general methodology based on skew t-copulas and Bayesian inference for modelling extreme multivariate dependent losses and the regulatory capital for operational risk. Current approaches fail to model both asymmetric dependence and accurate extreme upper tail dependence (e.g. 99.9% percentile), which is critical information for risk managers. This paper addresses this gap. The method is applied to SAS' Operational Risk Global Data to model operational risk at big U.S. banks. We compare the impact of established multivariate copulas and the multivariate skew t-copula for estimating total regulatory capital. We show that the skew t-copula can be used effectively in high dimensions and yields asymmetric and in principle more accurate measures of tail dependence in the very extreme tails (i.e. 99.9% percentile). Our methodology suggests a smaller capital charge, a reduction of up to 56% with respect to the standard Basel model compared with less flexible methods.

2 - Semi-closed simulated stock market: the impact of the traders' backgrounds
Valerio Ficcadenti, Gurjeet Dhesi, Mohammad Emambocus, Muhammad Bilal Shakeel, Babar Syed

This project aims to investigate the impact of cultural and academic backgrounds on the trading and investment strategies implemented by the traders. It is done by designing an on-line trading room that takes into consideration the components of a semi-closed simulated stock market (pricing mechanism, stock allocation and news generation) and the financial literacy of the users. The trading room is designed such as to register and capture the interactions of the different aspects within a 'semi-closed' system with respect to different users' backgrounds in an experimental environment. It also consents to explore the realm of randomly generated news to the responses of participants for determining rationality of behaviours in according with user markets' understanding. The time can be compressed within the experiments and it permits to run multiple simulation in one day, increasing the data availability. The users' information about their studies or social condition (i.e. actual jobs) are provided at the on-line registration. Indeed, when the simulations start, the user will provide their field of his studies and / or his jobs position. Through this experimental environment, we study the traders' behaviours taking into consideration different samples that compares and contrasts different users' backgrounds and social conditions. Secondly, we explore how the modified pricing equation jointly with different news generation dynamics affect the users' responses.

3 - A novel approach for determining cybersecurity insurance pricing
Thomas Lee

In the contemporary world, we are surrounded by a complex network of interconnected sensors. These allow us to share, collate, transmit, and store vast amounts of data. It is no surprised that Cyber security issues rank among the top technology challenges organizations face today. Cyber risk has become increasingly important as the severity and frequency of cyber incidents is steadily on the rise. Cyber risk management is thus a necessity for businesses to ensure firms' stability and operability. In this paper, we develop a model using cyber insurance to manage potential loss when safeguards are breached and the system fails. We utilize stochastic modeling techniques and adapt actuarial mathematics from life insurance analytics to aid the cyber risk professional in visualizing the current as well as future security state of their cyber network and provide the necessary steps to enhance the security of their enterprise network from external threats. Our model takes into consideration the attacker skill level, number of attacks and the level of security defense. Our analysis provides an explicit mechanism to evaluate the actuarial present value of expected losses and variance of losses from malicious attacks, and to evaluate changes in those losses that would result from enhancing system's security. We develop a suitable insurance premium to cover cyber risk and provide a basis for evaluating the benefits of improving system security.

4 - Measuring the leadership relationships between Spanish mutual funds: a dynamic Bayesian approach
Pilar Gargallo, Laura Andreu, Manuel Salvador, José Luis Sarto

This paper proposes a dynamic Bayesian framework to analyze the leadership relationships between Spanish mutual funds. To this end, a state-space model based on the Capital Asset Pricing Model (CAPM) is used to estimate the evolution of mutual funds' market exposure over time. From these estimations a dynamic exploration of the network topology of leadership relationships is carried out by using several measures of connectedness and systemic risk proposed in the literature.

■ WA-14

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S202

ETHOR I Ethics and Societal Complexity I

Stream: OR and Ethics
Chair: *Dorien DeTombe*

1 - Big data driven government policy a complex societal problem
Antoinette Muntjewerff

The Dutch government designs policy on the basis of large quantities of data. The Central Bureau of Statistics (CBS) is the main government agency that takes care of collecting, storing and analyzing data for government policy. New data techniques make it possible to collect increasingly large amounts of data, to link datasets in different ways and to analyze data faster and more varied. Based on these analyzes the design of more effective and more efficient government policy is possible. The government is increasingly aware of the possibilities offered by big data for government policy . A new division has been set up within the CBS that focuses on big data statistics, the Center for Big Data Statistics (CBDS). The government also asked the Scientific Council for Government Policy (WRR) for a report on big data and security . The WRR notes that big data can provide an important contribution to designing effective government policy, however large-scale collection, re-use of data and automated data analysis with profiles also entails risks related to privacy, discrimination and "chilling" effects. Therefor it is important to identify both the advantages and the disadvantages of using big data for government policy. In this paper we state that Big Data driven government policy is a complex societal problem. We handle the problem of Big Data driven government policy following the methodological requirements from the field of Societal Complexity using COMPRAM .

2 - The essence of ethics and societal complexity
Cathal Brugha

Ethics is associated with ethos, and contains the concepts of 'right' and 'community'. The essence of decision-making asks two questions: The first is what should we do? Is it sufficient to plan, or should we actually get things done? The second is on where should we focus? Should we relate to people? Or is it sufficient to deal with things, power, and rules? Together these form many sets of four fundamental constructs. Getting things and bringing people into a decision are about planning. Making things and giving to people is about getting things done. Rule, care, respond and serve is another. Also faith, hope, love and right / righteousness, which are antidotes to fear, anxiety, resentment, and guilt. Also capacity, capability, contribution and community. Ethics theory generally incorrectly confines itself to the subjective aspects, such as rule, care and respond; also to faith, hope and love; and to capacity, capability, contribution. Ethics should be about giving, being right, not taking on guilt; but instead serving community, according to its own objective norms.

3 - Earthquake preparedness: optimal deployment of emergency treatment sites
Simona Cohen Kadosh, Zilla Sinuany-Stern, Yuval Bitan

The official framework of the earthquake preparation policy in Israel presumes that care for all casualties is of main interest and as so defines the necessity of deploying Emergency Treatment Site (ETS) as part of disaster logistics preparedness. These ETS's will provide medical first aid during the first 72 hours to moderate and light condition casualties. Modeling the ETS's deployment and finding their optimal locations and quantities by minimizing distance, is our main interest. While authorities define only one kind of ETS, equipped and located in advance, defined here as static ETS, our optimization model suggests adding new mobile ETS that operates under command of static ETS. These mobile ETS's will be equipped only after an event occurs. The model is based on network hierarchical location problem with "soft" constraints, where a set of destruction points and sets of candidate static and mobile points are given. The destruction sites are based on prediction at specific area, while the candidate points are according to the relevant authorities' instructions. The research scenario assumes that a mobile ETS will be connected only to one destruction site and one static ETS within defined maximal distance and capacity constraints while static ETS can serve several sites. The planned facilities can help minimize uncertainty of policy makers at disaster logistics during the first hours, saving more lives. A small numerical example is presented.

■ WA-15

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S203

New Applications in Vehicle Routing II

Stream: Vehicle Routing and Logistics Optimization II
Chair: *Mustafa Yilmaz*

1 - A vehicle routing problem with periodic replanning
M' Luisa Carpente, Julian Costa, Manuel Fontenla, Ignacio García-Jurado, Silvia Lorenzo-Freire, Guido Novoa-Flores

In this work we focus on the problem of managing the fleet of trucks of the company GESUGA (located in Galicia, Spain). One of the daily problems encountered by this company is that of effectively designing the next day's collection routes, taking into account the requests that have remained unmet during this day. The other problem is that these routes are replanted properly during the next day, trying to incorporate some of the new demands into the previously designed routes. Linear programming models, simulation techniques, and metaheuristics associated with the VRPTW (Vehicle Routing Problem with Time Windows) have been combined to solve this problem.

2 - Periodic vehicle routing problem with flexible visit frequencies
Ahmet Camcı, Ozgur Ozpeynirci, Arya Sevgen

We study an extension of periodic vehicle routing problem in which customer visit frequencies is a decision variable. We define a demand function increasing with respect to the frequency. Therefore, the new problem becomes revenue maximization where a high frequency increases sales and therefore revenue on the other hand increasing the transportation costs as well. We develop a heuristic algorithm based on variable neighborhood search and simulated annealing for the problem. We conduct computational tests on the modified versions of the widely used test instances of periodic vehicle routing problem.

3 - The r-interdiction multi-depot vehicle routing problem
Mir Ehsan Hesam Sadati, Deniz Aksen, Necati Aras

The protection of critical facilities in the last 15 years has attracted much attention from the OR community. Critical facilities involve physical assets such as bridges, railways, terminals, power plants, hospitals, police stations, and transportation hubs among others. In this study, a bilevel optimization problem for the determination of the most critical depots in a multi-depot vehicle routing problem is introduced for the first time. We refer to this problem as the r-interdiction multi-depot vehicle routing problem (RI-MDVRP) with customer selection. This problem is modelled as attacker-defender game (Stackelberg game) where the attacker is decision maker for the upper level problem (ULP) and the defender is decision maker for the lower level problem (LLP). In ULP, attacker decides to interdict r-depots with certainty to cause maximize disruption in the network and in the LLP, the defender has to re-optimize the vehicle routes and satisfy all customers' demand after the attack either using the operational depots or through outsourcing to a third party service provider. The ULP is solved through exhaustive enumeration, which is viable when the cardinality of interdictions does not exceed five among nine depots. For the LLP we implement a Tabu Search heuristic adapted to the selective multi-depot VRP. Finally, computational results on RI-MDVRP instances are obtained by constructing the instances from standard 33 MDVRP test ins

4 - A mathematical model for time-dependent hierarchical Chinese postman problem
Mustafa Yilmaz, Merve Kayacı Çodur

The Hierarchical Chinese Postman Problem (HCPP), a variant of the Chinese Postman Problem (CPP), is an arc routing problem. HCPP is NP-hard problem and several methods have been developed to solve this problem. Many studies in literature have taken the minimum distance covered between nodes into consideration. Clearly, all of these studies ignore time-dependent travel speeds between two locations. Travel speeds (and time) in almost all metropolitan areas change drastically during the day due to a variety of different factors, such as weather condition, peak traffic hours and accidents, along with the distance. Spending minimum time to travel streets is of great importance to ensure traffic flow and road safety, particularly in many practical implementation areas of HCPP, such as snow ploughing in winter, garbage collection and routing security patrol vehicles. This study introduces a new problem called the Time-Dependent Hierarchical Chinese Postman Problem (TD-HCPP) that aims to minimize the total traveled time, while obeying precedence relationships between edges. This problem differs from most arc routing problems because the duration of traversing a street changes depending on the time of day. The problem is formulated as a mixed integer linear programming. The proposed model was tested on modified benchmark instances and randomly generated problem instances.

■ WA-16

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S115

Discrete and Global Optimization II

Stream: Discrete and Global Optimization
Chair: *Jan van Vuuren*

1 - Optimization in Sanger sequencing
Silvia Lorenzo-Freire, M' Luisa Carpente, Ana Cerdeira-Pena, Ángeles Saavedra Places

In this framework, we are interested in solving the MIP problem associated with the organization of the DNA samples in the plates to carry out the PCR (polymerase chain reaction) process. This is not an easy task, since many aspects should be taken into account to get the optimal organization of the DNA samples.

Since processing each plate in the laboratory is quite slow and expensive, the main objective of our optimization problem is to order the DNA samples minimizing the number of plates and taking into account the restrictions imposed by the characteristics of the termocycler. However, it is not always possible to obtain the optimal solution of this problem in a reasonable computational time. Then, we have also developed an heuristic algorithm based on the simulated annealing procedure that provides good solutions in short computational times. This algorithm is being successfully used in the laboratory.

2 - The Euclidean combinatorial configuration: properties and applications in optimization
Oksana Pichugina, Sergey Yakovlev

The Euclidean combinatorial configurations sets (ES) are extracted from a class of finite point configurations. Their connection with Berge's combinatorial configurations sets and the Euclidean combinatorial sets is established. An ES classification, based on the analysis of geometric features and the specifics of the formation, is given. A concept of a basic ES (BES) is introduced, and properties of BES of permutations, signed permutations, partial permutations, and their polytopes are studied. Approaches to ES modeling by the continuous functional representation method are presented. They are based on analysis of geometric peculiarities and structural properties of an EC, as well as its induced multiset and base set. The approaches are divided into two groups: representing a BCS as an intersection or touching of surfaces, combining an H-representation of the BCS's polytope and equality of its circumscribed surface. The derived BCS continuous representations make possible applying nonlinear methods to optimization on the corresponding ES and combining them with standard discrete optimization techniques. Continuous optimization approaches are especially promising for two-level, vertex located, and spherically located BCS due to a possibility of convexification of the objective function and additional constraints. Therefore, we focus on detecting and exploring such sets and propose original approaches to optimization over them that are based on the sets' specifics.

3 - On the problem of kite location in airborne wind energy farms
Fernando A. C. C. Fontes, Dalila Fontes, Luis Tiago Paiva, Luís Roque

In standard wind farms with several turbines mounted on towers, the problem of selecting the best location of each tower is a well-studied one. This is a complex problem depending on the characteristics of the local wind and on the terrain topography. In practice, the separation between generator towers is typically 5 to 9 rotor diameters in the predominant wind directions and 3 to 5 in the direction orthogonal to the predominant winds. Here, we consider an airborne wind energy system based on a farm of power kites to generate electricity. The problem of selecting the best layout in a wind farm of power kites is essentially unexplored. The flight envelope of each kite and its tether is conic shaped. Therefore, this problem has two additional dimensions to be explored in order to make a better use the wind available: namely, one more space dimension and the time dimension (two kites can use the same position, if not at the same time). The formulation considers maximizing the total energy produced by a set of power kites while taking into account the dynamics of the kite systems, the robustness to collisions, the predominant wind characteristics, the wind variations, the terrain characteristics, and the wake effects. We report results of our first attempt to this challenging optimization problem using a heurist solution method.

4 - Scheduling Markovian PERT networks to maximize the net present value: new results
Ben Hermans, Roel Leus

We study the problem of scheduling a project so as to maximize its expected net present value when task durations are exponentially distributed. Based on the structural properties of an optimal solution we show that, even if preemption is allowed, it is not necessary to do so. Next to its managerial importance, this result also allows for a new algorithm which improves on the current state of the art with several orders of magnitude. The key difference with previous algorithms is that the derived structural properties allow to reduce the dynamic program's state space significantly.

■ WA-17

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S205

Robust and Distributionally Robust Optimization

Stream: Stochastic and Robust Optimization
Chair: *Francesca Maggioni*

1 - Distributionally robust optimization with confidence bands for probability density functions
Guanglin Xu

We consider a stochastic program where the distribution is not completely known and only a set of historical data or some information of the shape, e.g., the modes, of the distribution is available. We apply a data-driven approach to construct an ambiguity set consisting of all the probability density functions that could have generated the available data. Our decision-making problem then hedges against the worst-case scenario distribution over the ambiguity set. The resultant distributionally robust optimization is computationally intractable due to the fact that it has both infinitely many constraints and infinitely many decision variables. To this end, we reformulate the problem into a semi-infinite program and propose an effective stochastic gradient method to solve it. The numerical results illustrate the strength of our approach.

2 - Data-driven distributionally robust optimization with Wasserstein metric, moment conditions and robust contraints
Adrián Esteban-Pérez, Juan Miguel Morales

We consider optimization problems where the information on the uncertain parameters reduces to a finite data sample. Using the Wasserstein metric, a ball in the space of probability distributions centered at the empirical distribution is constructed. The goal is to solve a minimization problem subject to the worst-case distribution within this Wasserstein ball. Moreover, we consider moment constraints in order to add a priori information about the random phenomena. In addition, we not only consider moment constraints but also take into account robust classical constraints. These constraints serve to hedge decisions against realizations of random variables for which we do not have distributional information other than their support set. With these assumptions we need to solve a data-driven distributionally robust optimization problem with several types of constraints. We show that strong duality holds under mild assumptions, and the distributionally robust optimization problems over Wasserstein balls with moment constraints and robust classical constraints can in fact be reformulated as tractable finite programs. Finally, a taxonomy of the tractable finite programs is shown under different assumptions about the objective function, the constraints and the support set of the random variables.

3 - The single-source capacitated facility location problem under demand uncertainty: robust optimization and branch-and-price algorithm framework
Jaehyeon Ryu, Sungsoo Park

We consider the single source capacitated facility location problem, where there exists uncertainty in customer demands. We propose a Dantzig-Wolfe decomposition of the problem in which demand uncertainty is isolated from the master problem, and treated separately in the subproblem. The problem is solved by a branch-and-price algorithm. The computational experiments show that our approach outperforms the branch-and-cut algorithm applied to the ordinary robust formulation of the problem. We also present the results of simulation studies which show the trade-off between the robustness of the solutions and additional costs incurred.

■ WA-18

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S206

The Founders of OR and the Development of Soft OR & Problem Structuring Methods - Special Discussion Session

Stream: Soft OR, Problem Structuring Methods
Chair: *Robert Dyson*

1 - The founders of OR and the development of Soft OR & PSMs
Frances O'Brien, Robert Dyson

Soft OR and PSMs (SORPS) have, particularly in recent years, been associated mainly with OR in the UK and Europe. There have been attempts to break into the US market and in particular into the prestigious US OR-related journals, with little success. This paper identifies six characteristics of SORPS and explores the extent to which the work of the Founders of OR relates to the characteristics. It also explores the influences of the Founders on some of the classic SORPS methods and suggests lessons for the OR community.

■ WA-19

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S207

Spare Parts and Maintenance Management

Stream: Supply Chain Management I
Chair: *Joachim Arts*

1 - Stocking and expediting in two-echelon spare parts inventory systems under system availability constraints
Melvin Drent, Joachim Arts

We consider a two-echelon spare parts inventory system consisting of one central warehouse and multiple local warehouses. Each warehouse keeps multiple types of repairable parts to maintain several types of capital goods. The local warehouses face Poisson demand and are replenished by the central warehouse. We assume that unsatisfied demand is backordered at all warehouses. Furthermore, we assume deterministic lead times for the replenishments of the local warehouses. The repair shop at the central warehouse has two repair options for each repairable part: a regular and an expedited repair option. Both repair options have stochastic lead times. Irrespective of the repair option, each repairable part uses a certain resource for its repair. Assuming a dual-index policy at the central warehouse and base stock control at the local warehouses, an exact evaluation procedure for a given control policy is formulated. To find an optimal control policy, we look at the minimization of total investment costs under constraints on both the aggregate mean number of backorders per capital good type and the aggregate mean fraction of repairs that are expedited per repair resource. For this non-linear non-convex integer programming problem, we develop a greedy heuristic and an algorithm based on decomposition and column generation. Both solution approaches perform very well with average optimality gaps of 1.56 and 0.23 percent, respectively, across a large test bed of industrial size.

2 - Operational level planning of a multi-item two-echelon spare parts inventory system
Engin Topan, Matthieu van der Heijden

In this paper, we study operational planning of spare parts supply in a multi-item two-echelon distribution network. We consider decision problems concerning a broad range of reactive and proactive operational interventions commonly observed in practice. These particularly include demand fulfillment, emergency supply, stock allocation and rebalancing in the supply network. Our objective is to integrate these decisions and to determine the optimal interventions to minimize the total downtime and ordering costs. A case data of a leading manufacturer of photolithography systems is used to test the performance of our integrated approach. We demonstrate that by using our integrated approach, the manufacturer can reduce total downtime considerably. We also show that our approach is efficient enough to solve practical size problems.

3 - Practical repair shop priorities
Ece Zeliha Demirci, Joachim Arts, Geert-Jan van Houtum

We consider a single location with one repair shop and one warehouse, where several repairable spare parts are kept to maintain service of an installed base of machines. We investigate the dynamic scheduling problem of a repair shop that needs to choose which type of component to repair next in order to minimize the sum of backorders over all component types. We derive a closed-form formulation for Whittle's index as a function of steady state probabilities. We test the performance of Whittle's index policy and heuristic developed based on fluid optimization formulation of the problem through numerical simulations.

4 - Spare parts provisioning for manufacturing systems
Gudrun Kiesmuller, Florian Sachs

Manufacturing systems consist of several machines often connected with material flow systems. If machines are subject to failures and breakdowns, then often buffers are installed to decouple the machines and to avoid a production stop of the whole system. In this paper, we additionally allow stock keeping of spare parts in order to enable fast repairs. As a consequence machine availability as well as the isolated production rate is increased, which results in a larger throughput. We model the system as a Markov Chain to enable the computation of the steady state probabilities and all relevant performance measures. Further, we investigate the interrelation between spare parts provisioning and buffer size and we show how the optimal system design can be determined. The optimal system design depends on the cost for spare parts and the cost for buffer places, which requires the joint optimization of buffer places and spare parts stock. If the same parts are responsible for the failures in all machines, then spare part provisioning is getting more attractive due to the pooling effect.

■ WA-20

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S301

Decision Support Systems: AI Techniques

Stream: Decision Analysis and Decision Support Systems
Chair: *Pascale Zaraté*

1 - Sketching for near-real time process mining
Vasco Santos, Bruno Oliveira, Orlando Belo

Process Mining is an active field of research that has developed immensely in the last years. The primary focus is the correct analysis of transaction or processing logs to better represent or understand an organizations' process flows. Most process mining techniques have been developed for well-defined workflows thus making the results easier to analyze. Adding to this complexity the necessity for near real time analysis and process mining becomes an questionable approach. Analyzing huge data logs for real time decisions is impractical with current methodologies and techniques. Whenever a result is attained it is probably outdated or no longer valid, specially taking into consideration that during the process mining analysis, many other events were already registered and not taken into consideration. This challenge is the basis for this work. Several approaches can be tested, like distributed process mining, obtained through partitioning logs and merging the process mining results, or differential and incremental process mining, taking advantage of previous process mining results, or sketching, searching and analyzing the most relevant log patterns since there is no real time computational power to analyze the entire log. In this work we will focus primarily in the last approach, sketching, without disregarding the other alternatives.

2 - OLAP signatures elicitation

Orlando Belo, Ricardo Silva

Discovering usage patterns in analytical processing systems (OLAP) is something we must take into account every time we are involved with the optimization of an OLAP system, in particular with regard to the computational resource involved - time and memory. In most of these systems, querying actions are recorded in event files, which hold pertinent information about what users are exploring. This information is quite valuable for optimizing OLAP system services, since it allows for establishing usage patterns and knowing users' behavior and the resources they use in OLAP sessions. Obtaining these patterns allows for a very effective characterization of OLAP users, which can be materialized using OLAP signatures - a mechanism capable of characterizing OLAP users based on their past behavior. The knowledge of an OLAP signature is quite sufficient to recognize automatically an OLAP user, as well as the type of queries and features that he can use. In this paper, we present an innovative method for defining OLAP signatures and making a priori the selection and materialization of multidimensional data views for supporting future OLAP sessions. The application of the method allows for reducing the computational resources involved with, maximizing system performance and reducing storage of multidimensional data structures.

3 - Service-oriented approach for ETL development using patterns

Bruno Oliveira, Vasco Santos, Orlando Belo

The ETL workflows are currently developed using frameworks that provides a set of useful tools and orientations to develop complete ETL packages based on a monolithic approach. In the last few years, we have been working with the pattern concept for ETL development: a set of reusable composite tasks that can be configured for the generation of specific instances that can be executed in existing ETL commercial tools. These components are described as independent tasks that can be changed without affecting the ETL structure, enhancing ETL reusability and simplicity. We are basically designing a single application with a set of individual components. The microservices architectural style is based on the development of applications as a suite of small independent services that can be replaced, upgraded and developed to enhance reusability and improve systems implementation and maintenance. Considering these principles fit well the purpose of the approach we are developing, we aim to study the use of microservices architectural style for ETL development using the ETL patterns we developed so far.

4 - A proposed multicriteria analysis decision support tool for university students healthy life index: a pilot application for a faculty performance comparison

Aslı Özmen

Sustaining a healthy life, eating habits and regular physical activity plays an important role. However nowadays, unbalanced diet and still adopt a lifestyle has prepared ground many important diseases including obesity. In this concept it is important prevent young people in their early time. The aim of the study is to developed a decision support tool to figure out the healthy living conditions of the students who study at AIBU (Abant Izzet Baysal University). Tool includes four main criteria set; education life, physical activity levels, nutritional habits and social life opportunities also the sub-criteria. Criteria set developed using literature and expert opinions. The contribution of the study is to show the findings on the physical activity and nutrition habits of students and decision support tool that includes multicriteria decision-making methods integrated with empirical data and it can be used as an alternative decision support tool in the decision-making process.

■ WA-21

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S303

(Semi-)Infinite Programming

Stream: Nonlinear Programming: Theory
Chair: *Maria Dolores Fajardo*
Chair: *Margarita Rodríguez Álvarez*

1 - Stability of the duality gap in linear semi-infinite programming

Miguel Goberna

We present recent stability results on the duality gap function g that measures the difference between the optimal values of the dual problem and of the primal problem in linear semi-infinite programming. In [1] we analyze the behavior of g when the data defining these problems may be perturbed, considering seven different scenarios. In particular we show that, under mild conditions, the duality gap of the perturbed problems is zero around the given data. We also give conditions guaranteeing that those data providing a finite duality gap are limits of sequences of data providing zero duality gap for sufficiently small perturbations, which is a generic result. [1] Goberna, M.A., Ridolfi. A., Vera de Serio, V.N., Stability of the duality gap in linear optimization, Set-Valued and Variational Analysis 25, 617-636, 2017.

2 - A new data qualification in convex multiobjective semi-infinite programming

Margarita Rodríguez Álvarez

Given a semi-infinite multiobjective convex problem, we introduce a data qualification that enables to characterize optimality in terms of Lagrange multipliers. We show that this condition characterizes the weak efficient solutions through the weak Karush-Kuhn-Tucker (KKT) condition, and identifies the proper efficient solutions through the strong KKT condition. We also address the question in relation to a gap function.

3 - Exact stable relaxations in robust SOS-convex polynomial optimization

José Vicente-Pérez, Vaithilingam Jeyakumar

In this talk we examine necessary and sufficient conditions for exact stable relaxations of a class of convex polynomial optimization problems in the face of data uncertainty in the constraints. We consider a robust SOS-convex polynomial optimization problem where the constraint data is affinely parameterized and the uncertainty sets are assumed to be bounded spectrahedra. The class of SOS-convex polynomials is a numerically tractable subclass of convex polynomials and, in particular, contains convex quadratic functions and convex separable polynomials. We also show that the relaxation problem can equivalently be reformulated as a semidefinite linear program.

4 - Converse and total duality for evenly convex optimization problems

Maria Dolores Fajardo

By means of a conjugation scheme based on generalized convex conjugation theory, instead of Fenchel conjugation, we build an alternative dual problem for a general optimization one defined on a separated locally convex topological space, using the perturbational approach. Sufficient conditions for converse and total duality involving the evenly convexity of the perturbation function are stablished.

■ WA-22

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S304

Applications of Multiobjective Optimization

Stream: Multiobjective Optimization
Chair: *António Gaspar-Cunha*

1 - Maximum entropy estimation of nutrient importance
Ante Ivancic, Argyris Kanellopoulos, Jacqueline Bloemhof

Diet healthiness optimization models are commonly based on linear and goal programming, with the goal of minimizing deviations between e.g. observed nutrient intake values and their respective recommended targets. Deviations are computed through a loss function (e.g. absolute, quadratic), parameterized by a set of (non-zero) coefficients, or weights. Weights are a way of representing the relative importance of nutrient deviations. Almost all diet models employ a unit weighting scheme which, if rescaled, is equal to a uniform probability distribution. However, such distribution is unlikely to be universally optimal, given how greatly nutrient importance varies across different consumer subpopulations. Nevertheless, nutrition experts resort to it, since they do not know how to impose a different one in a structured manner. Therefore, we propose the principle of maximum entropy (MaxEnt), a method for inferring the least biased set of weights, i.e. the simplest solution that is consistent with experts' opinions. We show the plausibility of such method, given that it unifies the Occam's razor principle (formalized through the Kolmogorov complexity), and Bayes' theorem, for which we argue to be the crucial components for inferring nutrient importance weights. Furthermore, we show how a non-uniform distribution emerges as a result of pairwise comparisons of diets, during which diet preferences are expressed through natural language.

2 - A multi-objective global score for the beam angle selection problem
Guillermo Cabrera-Guerrero, Enrique Cabrera

In radiation therapy for cancer treatment several optimisation problems must be solved to find a clinically acceptable treatment plan. One first problem is the beam angle selection (BAS) problem. Usually, to decide between two beam angles configurations (BAC), the best possible plan that can be delivered by each BAC must be computed. The problem of computing the optimal plan for a pre-defined BAC is the fluence map optimisation problem (FMO).

To solve the FMO problem, an optimisation model must be defined. Unfortunately, FMO models proposed in the literature have little clinical meaning and, therefore, treatment planners still making decisions looking at measures other than the FMO objective function(s) values.

Recently, a new concept has been proposed to solve the BAS problem: the global score (GS). The GS aims to drive the search based on measures that are commonly used in clinical practice. Since these measures are very hard to optimise, the GS is computed after an FMO objective function is optimised. Although appealing, the GS has, in our opinion, one main drawback: it still compressing all the criteria into one single value, usually using a weighted sum of all the criteria.

In this study we propose to extend the GS concept to a multi-objective GS which provides a set of efficient treatment plans decision makers can choose from. The proposed multi-objective model is solved using a simple Pareto Local Search algorithm.

3 - A multi- objective model for hospital supplies using modified evolutionary computation
Soumyajyoti Datta, Rohit Kapoor

In hospital, after personnel, inventory of the medical supplies incurs the second highest cost accounting for about 35-40% of the total expense.The medical supplies refer to the complete set of items that need to be maintained so that the care delivery can be accomplished effectively and efficiently.Inventory control of the supplies is unique due to perishable nature, high stock out costs and associated risks, high prices with erratic supplies and specific suppliers. Recently, the hospitals operate in chains and there is also existence of rotation of the supplies across the various members to counterbalance the variations of demand and diversify the inventory maintenance cost across the chain members. The current paper captures the context through a multi-objective optimization model and provides as well as compares the non dominated pareto fronts derived from the quality solutions at reasonable computational cost through the advanced evolutionary algorithms such as NSGA-II and MOPSO. The solutions have been evaluated in regard to convergence, uniformity in the distribution and spread of the pareto fronts. The robustness has been validated through a diverse combination of test instances.

4 - Multi-objective optimization of blow moulded containers through the evolution of neural networks
António Gaspar-Cunha, Roman Denysiuk

In polymer industry, injection blow moulding is an important industrial process for manufacturing hollow plastic parts. There is a growing interest to optimize the use of raw polymeric materials. Generally, the polymer used in these containers is optimized by dividing it into different sections and minimizing the wall thickness in each section. The definition of discrete sections is limited by the shape of the container and can lead to sub optimal solutions. This study suggests determining the optimal thickness distribution for blow moulded containers as a function of geometry. The methodology relies on the use of neural networks and finite element analysis. Neural networks are stochastically evolved considering multiple objectives related to the optimization of material usage, such as cost and quality. Numerical simulations based on finite element analysis are used to evaluate the performance of the container with a thickness profile determined by feeding the coordinates of mesh elements in finite element model into the neural network. The proposed methodology is applied to the design of an industrial bottle. The obtained results reveal its validity and usefulness. The ability to identify the most critical regions and to distribute the material accordingly was observed. The methodology is general and can be applied to optimize blow moulded containers with different geometries and provides potential to account for varying mechanical properties along the wall of container.

■ WA-23

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S305

Lot Sizing II - Heuristics

Stream: Lot Sizing, Lot Scheduling and Production Planning
Chair: *Bernardo Almada-Lobo*

1 - A two-phase approach for the parallel machine capacitated lot-sizing and scheduling problem with shared resources
Jesica de Armas, Manuel Laguna

We address a Capacitated Lot-sizing and Scheduling Problem that involves multiple single-level items to be processed on parallel machines over a planning horizon. The objective is to determine, for each time period, the assignment of products to machines, their production quantities, and sequencing, in order to maximize total production, while meeting inventory requirements for products. This problem is studied in the context of the manufacturing of insulation for pipes. It considers constraints such as the availability of shared resources, sequence-dependent changeover times, product-machine production rates, inventory limits, due dates for make-to-order products, and planned/unplanned machine downtimes. We did not find any work addressing this particular version of the problem in the literature. Our solution approach consists of two phases. In the first one, a mixed-integer programming model is formulated and solved. This charges the maximum changeover time when production changes from one product to the next. The second phase searches for changeover time savings by reordering the products. The savings are turned into production time, resulting in additional throughput. An enhanced model that addresses one of the shortcomings of the base model is also proposed. Additionally, we develop a procedure to determine safety stock levels and use Monte Carlo simulation to assess the risk associated with inventory shortages due to the uncertainty in the production rates.

2 - Sandwich approximation algorithms for lot-sizing problems
Wilco van den Heuvel, Guillaume Goisque, Christophe Rapine, Albert Wagelmans

We consider single-item lot-sizing problems which are (NP-)hard because of the shape of the objective function, typically non-concave. Examples are lot-sizing problems with (i) batch procurement, (ii) certain types of quantity discounts, and (iii) transportation by multiple vehicle types. We propose polynomial-time approximation algorithms based on a 'sandwich' technique, in which the objective function of the original problem is bounded from below by an easier objective function and from above by the same easier function but multiplied with a constant. In fact, finding the tightest sandwich function is an optimization problem on its own, of which the result determines the obtained approximation ratio, typically depending on the problem parameters. One of the strengths of the approach is that we can obtain multiple solutions within the performance bound by an approach based on parametric analysis. Finally, we have implemented such a sandwich approximation algorithm for a multi-level lot-sizing problem with batch procurement. We are able to find solutions within a few percent from optimality in a fraction of a second for reasonably sized instances.

3 - Fast heuristic for creating (online) production plans for the capacitated lot-sizing problem
Christian Almeder

Fast construction heuristics for the capacitated lot-sizing problem, like the Dixon-Silver heuristic or the ABC-heuristic, creating production plans stepwise period by period. This is not suitable in a dynamic environment where customer orders arrive not necessarily in a chronological order. To respond fast to customer requests according demands have to be included in the plan immediately. We propose a rule-based construction heuristic for adding new demands to an existing plan. The rules are designed to obtain cost-minimal plans while minimized the necessary changes to the existing plan. This heuristic can be used as an online planning tool as well as to generate high quality production plans by applying a suitable ordering of the customer demand requests. Although its flexibility the heuristic generates plans with same or better quality than the above mentioned well-known heuristics.

4 - Matheuristcs for capacity planning at the glass container industry
Bernardo Almada-Lobo, Flaviana Moreira de Souza, Márcio Silva Arantes, Cláudio Fabiano Motta Toledo

A mathematical model and two mathematical programming-based genetic algorithms are developed for a capacity planning problem appearing at the two-stage glass container industry. The first continuous stage melts down different raw materials to produce the molten glass, which is then molded into final products in the second discrete stage. The solution approaches determine the best configuration of the molding machines when a new furnace must be installed, while dealing with a lotsizing and scheduling problem that appears at the first stage.

■ WA-24

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S306

Dynamical Models in Sustainable Development III

Stream: Dynamical Models in Sustainable Development
Chair: *Ingunn Gunnarsdottir*
Chair: *Pierre Kunsch*

1 - Dynamic modeling of the impact of energy transition on economy and environment
Chun-Cheng Chen, Chung-Shu Liu, Chih-Tung Hsiao, Chang Dong-Shang

Kyoto Protocol and Paris Climate Agreement illustrate that many countries in the world have reached a consensus to curb greenhouse gas emissions in order to reduce the impact of economic activity on the environment and natural resources. Although Taiwan is not a participant in the Kyoto Protocol and Paris Climate Agreement, it still actively promotes various greenhouse gas reduction measures. Taiwan's thermal power accounted for about seventy percent of total electricity. Most of it is generated from fossil fuels, which are imported from foreign countries. As a result, the power generation sector is one of the major sources of greenhouse gases. Presently on the electricity supply, a revision of power generation portfolio is taking place across Taiwan, underscored by the long-term power source development schemes of Taiwan Power Company which was released in June 2017. However, electricity is the basis for industrial development and one of the major energy sources to contribute to the economic growth. The soaring price of energy and price volatility would hurt the development of industry and economic growth in Taiwan. This study uses the system dynamics methodology to explore the process of construction and renovation of electric power sources, analyze its structure, and simulate the impact of energy policy on the economy and environment under different power generation portfolio scenarios for Taiwan's power supply.

2 - Evaluation and optimization of photovoltaic panel resources via a novel radiation - to - electrical power model
Omer Nezih Gerek, Ümmühan Başaran Filik, Tansu Filik

Solar power remains to be a major input for renewable energy systems. In a typical energy plant, electricity is generated by installing certain amount of photovoltaic (PV) panels with interconnections, inverters and battery units. The classical way of determining the amount of PV panels is through solar potential analysis of the region, analysis of the panel conversion factor, and the energy demand profile. Normally, the solar potential is evaluated and the radiation-to-electricity conversion factor is applied for determining the necessary number of PV panels for a given demand profile. In modern approaches, the ambient temperature is also considered to better model the conversion. In this study, it was observed that PV panels show an I/O lag with an input of solar radiation and an output of electricity. Typically, morning hours have lower energy yield than afternoon hours at the same solar radiation intensity, implying an overall hysteresis behavior. This is attributed to the temperature dependency of solar cells. Using actual solar radiation readings and real electricity conversion values from our experimental renewable energy plant in Anadolu University, the above effects are observed and mathematically modelled. By instantaneous matching of energy demand to our new model output, optimal number of PV panels are determined for fixed and sun-tracking systems. It was observed that the above optimization is necessary for minimal loss of energy load at lowest installation cost.

3 - Evaluation of photovoltaic storage systems under uncertainty applying stochastic dynamic programming
Dogan Keles, Joris Dehler

The rising share of intermittent renewable energy production in European and international energy systems increasingly pose a threat to system stability and the price level in energy markets. However, the effects of renewable energy production onto electricity markets also give rise to new business opportunities. The expected increase in price difference over the course of a day increases the market potential for storage applications and combinations with renewable energy production. The value of storage depends critically on the operation of the storage system. We evaluate photovoltaic (PV) storage systems under uncertainty, as renewable production and electricity prices are fundamentally uncertain. The operation problem is formulated as a Markov decision process (MDP). Uncertainties of renewable energy production are integrated into an electricity price model using ARIMA-type approaches and regime switching. Due to stationarity and heteroskedasticity of the underlying processes, an appropriate stochastic modeling procedure is developed. The MDP is solved using stochastic dynamic programming (SDP) and recombining trees (RT) to reduce complexity. We evaluate the sensitivity of the SDP towards price cluster choice in the RT. The program is applied in the German electricity and balancing energy market to show the potential increase in storage value with higher price differences and evaluate a possible imposition of the feed-in levy onto energy directly stored from the grid.

4 - Sustainable energy future in Iceland
Ingunn Gunnarsdottir, Brynhildur Davidsdottir

In an increasingly energy intensive world with depleting fossil fuels and raised environmental awareness, it is important to strive towards sustainable energy development. Nonetheless, there is no universally accepted definition of what a sustainable energy future is. Without a clear idea of what a sustainable energy future should entail, it is difficult to determine how it can be reached. Through stakeholder engagement, the elements of and actions towards a sustainable energy future in Iceland are identified and the decision-making structure is analyzed. Iceland is presented as a case study and its energy system is analyzed. Informed stakeholders of the system were engaged through individual semi-structured interviews, the public's voice was captured through focus groups, and results were verified through a Delphi survey. The common thread from all stakeholders was a lack of a comprehensive long-term energy policy. This even further adds value and immediacy to this research. The creation of such an energy policy can be a complex decision-making problem that requires the consideration of different objectives. With a comprehensive strategy, it is possible to optimize actions such as electrifying transportation and increasing energy security. The importance of stakeholder engagement has become increasingly apparent. An emphasis was placed on developing a robust way of involving stakeholders and analyzing their input to ensure the re-applicability of methods being developed.

■ WA-25

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S307

Vehicle Routing Problems

Stream: Combinatorial Optimization II
Chair: *Luciana Buriol*

1 - Spontaneous postman problems
Peter Recht

In this lecture we address "'Spontaneous Postman Problems"'. In this type of routing problems the postman selects subsequent streets of his tour by a willy-nilly strategy. In such a way it differs from well known "'classical"' postman-problems, where the postman's transversal of streets is performed according to some routing plan. This problem appears in real world tour planning, if the selection of subsequent traversals is done careless. Such a choice can be observed in the display of tours in a museum or tours in trade fair. The spontaneous character of such a choice leads to the basic question how to partition a street network into different districts in such a way, that one can guarantee, that each district is served if the postman is "'spontaneous"'. The structural problems of the network that arise within this framework are closely related to the investigation of local traces and maximum edge-disjoint cycle packings in graphs.

2 - An adaptive large neighborhood search algorithm for the blood sample transportation problem
Garazi Zabalo Manrique de Lara, Paolo Detti, Giorgio Di Benedetto

The biological sample transportation problem is a pickup and delivery problem arising from the transportation of blood and biological samples from clinics or dedicated centers to hospital laboratories. In this work a real-world problem is addressed, concerning the reorganization of the transportation of biological sample tubes from sampling points to the main hospital in Bologna, Italy. During morning hours, blood and other biological samples are collected in different centers and have to be transported to the main hospital, within a certain amount of time, for their analysis. Samples are transported by a fleet of vehicles, located in geographically distributed depots. Each sample has a limited lifetime (i.e., a deadline). If a sample cannot arrive to the hospital before the deadline either is discarded or can be stabilized to get some extra lifetime in geographically distributed dedicated centers called Spoke Centers. From a modeling point of view, the Spoke Centers can be considered as transfer points, where the sample may be "transferred" from one vehicle to another, after the stabilization process is finished. The objective is of minimizing the total traveled distance while fulfilling the ride time requirements. An Adaptive Large Neighborhood Search Algorithm is proposed for the problem. Computational experiments on different set of instances lead to improvements on the current practice and improve the vehicle distribution arrival to the hospital.

3 - Synchronization of unmanned vehicles and vans for parcel delivery
Olivier Gallay, Marc-Antoine Coindreau, Nicolas Zufferey

The potential use of light unmanned vehicles (typically drones or robots) to transport goods is currently gaining larger interest in both the industrial and academic communities. Directly inspired by an industrial application currently under development at a large European mobility provider, we evaluate in this contribution how vans and unmanned vehicles can be combined in the context of parcel delivery. In particular, we consider the situation where drones or robots are embedded into the delivery vans themselves. When it is efficient to do so, these light unmanned ressources can leave the vehicle with parcels to be delivered at customer locations, and thereafter come back to the van to be refilled and recharged. While drones and robots are cost efficient and more agile but suffer from low range as well as room space for parcel storage, vans are relatively more expensive and induce a larger ecological footprint but offer on the other hand larger autonomy and capacity. In a static day-ahead context, our dedicated metaheuristic generates solutions that allow to take advantage of the specific characterisitics of each of these transport modes. As a result, we show that, while autonomy and capacity issues prevent from implementing a delivery fleet consisting only of unmanned vehicles, synchronizing them efficiently with vans offers room for substantial cost savings in comparison to a classical fleet including vans only.

4 - Using relax-and-fix algorithm for solving an improved formulation of a maritime inventory routing problem
Luciana Buriol, Marcelo Friske

In this work, we propose a Relax-and-Fix algorithm for solving a class of Maritime Inventory Routing Problem. The problem consists of routing and scheduling a heterogeneous fleet of vessels to supply a set of ports, keeping inventory at production and consumption ports between lower and upper limits. Instead of using a conventional time-space network formulation that can be very weak, a fixed-charge network flow is used for modeling the problem to provide better bounds. Also, valid inequalities are incorporated into the model in order to enable the Relax-and-Fix algorithm to obtain solutions in short processing times. Three MIP-based local search procedures were developed for improving the solutions obtained by the Relax-and-Fix. Tests were performed on instances of the literature, showing that the solution approach, although simple, can be useful for solving the problem.

■ WA-26

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S308

Delays and Robustness in Railway Scheduling

Stream: Public Transportation I
Chair: *Rob Goverde*

1 - Railway delay management with passenger rerouting in face of train capacity constraints

Eva König, Cornelia Schoen

Delay management for railways is concerned with the question if a train should wait for a delayed feeder train or depart on time. The answer should not only depend of the delay, but there are other factors to consider, for example capacity restrictions. We present an optimization model for delay management in railway networks that accounts for capacity constraints on the number of passengers that a train can effectively carry. While limited capacities of tracks and stations have been considered in delay management models, passenger train capacity has been neglected in the literature so far, implicitly assuming an infinite train capacity. However, even in open systems where no seat reservation is required and passengers may stand during the journey if all seats are occupied, physical space is naturally limited and the number of standing seats constrained for passenger safety reasons. Our model allows the rerouting of passengers missing their connection due to delays or capacity constraints which means instead of waiting one cycle time passengers may reach their destination on alternative trains and routes. In this talk, we present the model formulation, solution procedures for MINLPs and results from a numerical experiment analyzing the impact of train capacity restrictions on delay management decisions.

2 - Train delay prediction and its perspective for railway operations

Marie Milliet de Faverges

We present in this study a methodology to improve robustness of railway operations with long-term delay prediction. Delay risks are estimated a few days before operations and these predictions could be used to make tactical decision. In this case, predictions will be used to reduce delay propagation and online rescheduling in main train station.

Many studies have shown that arrival delays follow an exponential law, in particular the Weibull distribution. We have verified the hypothesis on our data and we choose to model them with the Weibull distribution and to estimate the punctuality risk with generalized linear models. They model data with any exponential distribution, and an individual delay probability distribution is obtained for each train as outcome.

The platforming problem consists in affecting platform to arriving trains and routing these trains through station with arrival and departure paths. It can be implemented with mixed integer programs. Since most of secondary delays are accumulated at station due to shared infrastructure or bad synchronization, it is of an utmost importance to find an efficient and robust solution to this routing issue. Knowing the actual delay probability of each train enable to identify potential conflicts in paths or tracks allocations. From an Operations research perspective, it is possible to adjust penalty corresponding to these risky allocations or change constraints.

3 - Multi-objective timetable design for rail transport services

Narayan Rangaraj, Aayush Aggarwal

While constructing a rail timetable, slack and buffer headway are two major decision parameters which affect the robustness of the timetable. Slack increases the planned traversal time of the trains which degrades the quality of service. Large headway reduces the capacity utilization of the system, which hurts the demand carrying capacity of the system. To construct a robust timetable that can absorb stochastic disturbances, one needs to give either slack or buffer headway or both in the timetable. We have analyzed the effect of adding slack and buffer headway on other parameters like throughput, capacity and punctuality in a homogeneous railway system. We have proposed a relationship between slack, buffer headway and punctuality. It is seen that a given level of punctuality can be achieved by different combinations of slack and buffer and hence, we have introduced a new term called Equi-punctuality curves. These curves establish the trade-off between slack and buffer headway to achieve a given level of punctuality against stochastic delays. These Equi-punctuality curves may be used to find the optimum value of buffer headway and slack, for example, if there is a limit on minimum timetabled speed, then the required headway and corresponding capacity of the railway network can be determined to achieve a given level of punctuality. The ideas are explored in different environments in Indian Railways, including commuter services.

4 - Integrated timetable rescheduling and passenger routing by dynamic event-activity networks

Yongqiu Zhu, Rob Goverde

Railway disruptions occur on a daily basis and usually last for hours. To mitigate the resulting passenger inconvenience, we propose a Mixed Integer Linear Programming model to generate the rescheduling timetable during railway disruptions, with the objective of minimizing the travel times perceived by passengers. The model consists of three modules: 1) the timetable rescheduling that adjusts the time-distance train paths by delaying, re-ordering, cancelling, flexible stopping and flexible short-turning trains; 2) the passenger assignment that is formulated as a multi-commodity problem to assign passengers to the appropriate trains; 3) the dynamic event-activity network to handle the interactions between the rescheduled timetable and passengers. This network is dynamically constructed from the rescheduled timetable, based on which passengers make their route choices. The basic idea of the model is dynamically building an event-activity network by rescheduling the timetable until all passengers are assigned to trains and the minimal passenger perceived travel times are achieved. The model has been implemented and tested in part of the Dutch railway network. An optimal passenger-oriented disruption timetable can be generated within 10 minutes, considering a one-hour open track blockage and thousands of passengers. In the future, a heuristic algorithm can be adopted for the problem to speed up the computation.

■ WA-27

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S309

Extensions of the Newsvendor Problem

Stream: Production, Service and Supply Chain Management

Chair: *Yasemin Merzifonluoglu*

1 - Robust multi-market newsvendor problem with market selection and uncertain demand data

Mohammad Abdel-Aal, Shokri Selim

Traditional approaches to supply chain planning consider planning problems under the assumption that all demand sources should be satisfied. However, in the real world, firms have limited resources, therefore, planning approaches must take the capacity of these resources into consideration and select the optimal set of demands to satisfy. This study investigates the impact of the lack of demand information on the performance of inventory and demand selection problems. We study the Selective Newsvendor Problem (SNVP) where the decision maker selects the optimal set of markets to serve and decides on the optimal order quantity to procure. We focus on the case when the demand distribution at some markets is only partially specified. The demand uncertainty is characterized by an uncertainty set. We study robust SNVP under box uncertainty set. The robust counterpart model under this uncertainty set is obtained and efficient solution algorithm is proposed. The computational results and discussion are provided and useful insights for the SNVP robust counterpart reformulation are extracted.

2 - Newsvendor models with supply uncertainty and a backup supplier

Dimitrios Pandelis, Ioannis Papachristos

We analyze newsvendor models with a primary unreliable supplier and a backup reliable and more expensive supplier. At first the retailer places an order to the primary supplier and reserves capacity from the backup supplier. After the delivered quantity from the primary supplier becomes known, the retailer may exercise the option to buy any amount up to the reserved capacity. We assume that the primary supplier is subject to random capacity and we consider the cases when the option to buy from the backup supplier is exercised before or after the demand becomes known. For both cases we obtain the optimal order and reservation quantities.

3 - Analyzing supply chain contracts for behavioral newsvendor under information asymmetry
Abhishek Chakraborty, Sumit Sarkar

In the past decade there is growing body of literature in the domain of newsvendor problems analyzed through Prospect Theory. A newsvendor who is behavioral tends to deviate in terms of placing an order with respect to the optimal order being placed by an expected profit maximizer newsvendor. If the supplier is aware about the behavioral nature of the newsvendor, she can choose an appropriate contract. However, if there is information asymmetry on the part of assessing the type of newsvendor (profit maximizer, loss averse etc.), then contracting gets affected. In our work we would like to capture the contract design issue from the supplier's perspective when there is information asymmetry regarding the type of newsvendor.

4 - Integrated demand and procurement portfolio management with spot market volatility and option contracts
Yasemin Merzifonluoglu

The newsvendor problem aims to optimally choose a level of order quantity to respond to a known demand distribution with the objective of maximizing expected return. In practice, the decision maker is often challenged with more complex settings involving multiple decisions and uncertainties. For instance, firms may benefit from choosing the set of customer orders to satisfy. It may also be worthwhile for many firms to select a supply portfolio instead of relying on a single procurement mode. This paper provides novel optimization models and solution techniques that can help businesses to achieve the maximum performance from a given production system by optimally selecting customer demands, procurement quantity, spot market purchase and option contract usage. We specifically focus on the special case of normally distributed random variables, and provide an exact solution method. When the primary procurement quantity is not a decision variable, the problem becomes a version of a Stochastic Knapsack Problem. For this case, we present an efficient heuristic solution algorithm based on properties of an optimal solution and empirically show that it provides high-quality solutions. We also provide a broad numerical study to examine the sensitivity of integrated procurement and demand selection strategies to key problem parameters.

■ WA-28

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S310

Iterated Greedy

Stream: Memory-based Heuristics
Chair: *Ruben Ruiz*

1 - Bicriteria M-machine no-wait flowshop scheduling problem
Harun Aydilek, Asiye Aydilek, Ali Allahverdi

We consider the m-machine no-wait flowshop scheduling problem to minimize total tardiness with a constraint on makespan such that setup times are considered as separate. We establish dominance relations and propose an algorithm which is a hybrid of an insertion algorithm and simulated annealing algorithm. We adapt several well performing existing algorithms in the literature. We compare the performance of the proposed algorithm with those of the adapted algorithms. We conduct extensive computational experiments to compare the performances of the algorithms. The computational experiments indicate that the error of the best existing algorithm is at least twice of that of the proposed algorithm. Therefore, the proposed algorithm is suggested for the considered problem.

2 - Heuristic approaches to makespan and flowtime minimization in a two-level hybrid flow shop with no-wait constraint
Andreas Hipp, Caroline Raue, Rainer Leisten

Hybrid flow shop (HFS) problems have become popular to represent real world applications. A lot of different types of HFS with several constraints have been examined, but the ways of solving these models are often very complicated and cannot be used in real cases. For this reason, we deal with a two-level permutation HFS which is known to be np-hard. We include no-wait constraint which is common for several production systems e.g. in steel industry. Finally, according to the classification of Graham et al. (1979) we apply HF2((P2(1))1(2))|no-wait, prmu| with makespan and flowtime objectives. Due to the importance of efficient solutions in practical production applications, we propose a computational study including several heuristic approaches for problem sizes up to 200 jobs. Suitable dispatching rules (e.g. Shortest Processing Time) are compared with constructive heuristics. We divide our procedure into two parts. First, we combine two sequencing approaches with machine assignment strategies. In the second step, a computational test using benchmarks provided by SOA research group is conducted. All heuristics in use are ranked based on different performance criteria followed by a one sided hypothesis test of paired samples. We can show that dispatching rules can achieve equivalent or even better results compared to constructive heuristics.

3 - Iterated local search algorithm for the quadratic assignment problem
İslam Altın, Aydin Sipahioglu

Quadratic Assignment Problem (QAP) is one of the best known combinatorial optimization problem. The objective of QAP is assigning of each facility to a location so as to minimize total cost. Since QAP is an NP-Hard problem, it is hard to obtain optimal solution in a reasonable computation time. Therefore, heuristic methods are used to solve QAP, generally. In this study, a solution approach combining Iterated Local Search (ILS) algorithm and simulated annealing is applied to solve QAP. In this approach, ILS algorithm prevents getting stuck into local optimal solution by perturbing current solution as well as Simulated Annealing algorithm is used as a local search method. Besides, it is offered different neighborhood search methods.In order to test performance of the proposed approach, test instances taken from QAPLIB are used. It is shown that the proposed algorithm can obtain really good solutions which maximum deviation from the optimal solution is less than 1% for medium and large scale problems, in a reasonable computation time.

4 - Keep it simple, stupid. Iterated greedy methods for scheduling problems
Ruben Ruiz

There is a certainly worrying trend in the scheduling literature of proposing complex bio-inspired metaheuristics to solve different machine scheduling problems. One can basically find from fireflies and leaping frogs to harmonies, galaxies, soccer players, zombies and flying elephants (this is not an exaggeration). In this talk, we point out at the many fallacies and biased experiments that are misleading authors and readers towards more and more complex methods. Basically, "new" methods are tested in newer and faster computers, with faster compilers and in more efficient platforms. Obviously, the new results are often better than the old results. This better performance is often wrongly attributed to the proposed wild operators and intricated methods while in reality is just the effect of testing well-known ideas in newer hardware. We will show that simple destructive-constructive greedy methods and local search are all one needs to obtain state-of-the-art results in several flowshop scheduling problems.

■ WA-29

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S311

Cutting and Packing I

Stream: Cutting and Packing

Chair: *Julia Bennell*

1 - Research gaps and future research directions in cutting and packing
Julia Bennell, José Fernando Oliveira, Gerhard Wäscher

Cutting and packing is an established research topic in OR and has an active research community within EURO. The typology of cutting and packing problems published in EJOR in 2007 has provided a clear framework to describe and categorise problems. While some problem types may be considered well solved, there are still many opportunities for further research in cutting and packing. The paper will describe the research opportunities in terms of gaps in the literature, new avenues to improve the research in active problem types and problem extensions that look at extending the scope of cutting and packing research into connecting domains. The authors will set out a research agenda that includes challenges in developing theoretical models and application focused solutions.

2 - Challenge ROADEF / EURO 2018 - cutting optimization
Quentin Viaud, Eric Bourreau

The French Operational Research and Decision Support Society (ROADEF) organizes jointly with the European Operational Research Society (EURO) the ROADEF/EURO challenge 2018 dedicated to glass cutting problem in collaboration with Saint-Gobain Glass France, one of the world's leading glass manufacturers. Flat glass is mostly produced through a process called the "float process ". At the end of this process, an infinite glass ribbon is cut into large glass sheets (bins). To facilitate the storage, bins are stacked after cutting from the ribbon. These bins are most of the time cut into smaller rectangular pieces (items) adapted to customer needs. These items are cut according to a cutting pattern which satisfies a certain amount of constraints related to the customer (production plan, ...) or to the physics of glass (guillotine cut, cut length limitation). Bins are not perfect and may contain defects inherent to the float process. The goal of this challenge is, for a given sequence of bins and their defects, as well as a given item batch to cut, to propose an algorithm to minimize the glass losses of the cutting process. During this presentation, we will describe the problem, its context and constraints and also answer questions from the audience. A more detailed subject, realistic instances and solution checker can be found at challenge.roadef.org. An overall amount of 45.000 EUR will be distributed to the best contributions. Registration is possible until September 2018.

3 - Improving a semi-discrete lines representation for the 2D irregular strip packing problem
Wojciech Kuberski, Dirk Roose, Tony Wauters

The 2D irregular strip packing problem deals with placing a number of irregular pieces on a rectangular sheet of material, where the size in one dimension is fixed, while the size in the other dimension is minimized. We propose two improvements to the semi-discrete lines representation introduced in (Akunuru et al. 2013), where polygonal pieces are represented by a set of equidistant vertical line segments. Since this representation is used for collision checking, the polygon defined by these line segments must fully contain the original polygon. An important parameter of the representation is the resolution, i.e. the distance between the discretizing lines. We present a refinement of the algorithm in (Akunuru et al. 2013) in order to correctly handle edges, for which the projection on the horizontal axis is smaller than the resolution and thus may fall between the discretizing lines. Using the semi-discrete lines representation, the strip packing problem can be solved by heuristics or by constrained linear programming. The resolution influences the accuracy of the solution and the computational cost. We propose a method to determine an appropriate resolution, using features from the dataset without creating the semi-discrete representation. This method is validated using the datasets from ESICUP.

4 - An archaeological irregular packing problem
Antonio Martinez Sykora, Julia Bennell, Carlos Lamas-Fernandez, Marta Cabo Nodar

Abstract. The paper explores the use of cutting and packing methodologies in a new and innovative way to support archaeological research. Pre-hispanic cultures in Mexico used codices to register different aspects of their everyday life including their lands and crops. Each family register the number of pieces of land that they owned together with some measures of its dimension in a codex. These codices have been deciphered and using the methodologies presented by Williams et al (2008) we have accurate information about the length of each side of the pieces of land and the area they covered. Using the given dimensions, each terrain can be reconstructed as polygons. In addition, the dimensions and location of the settlements are known. This description equates to a two dimensional pack-ing problem with an irregular bin and irregular pieces that can be rotated. While irregular shape packing has been an active research area for many years, the work focuses on pack-ing a single strip for cutting material for manufacturing. However, while the problem at hand is quite different, we draw on the techniques arising from this research area in both geometry and algorithm design; see Bennell and Oliveira (2008, 2009) for reviews. In the presentation we will present the problem and some specific complexities that lead to the so-lution methodology needing to generate a range of different solutions. We present a formu-lation of the problem and use some simple heuristics to find a set of so

■ WA-30

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S312

Operations and Game Theory

Stream: Game Theory and Operations Management
Chair: *Bo Chen*

1 - Algebraic geometry in operational research games
Tri-Dung Nguyen

Algebraic geometry has recently been emerged as an alternative approach for solving integer (non)-linear programs by studying the algebraic structure of the underlying lattice and generating sets. Although algebraic geometry is, in general, still not as competitive as mainstream IP solvers such as CPLEX, there are certain classes of problems where using algebraic geometry is more effective. This includes the problem of finding the Shapley value of a class of integer maximization games where an exponentially large number of IPs must be solved. A major obstacle in using algebraic geometry for integer programming is the computational bottleneck of finding the Groebner and the Graver bases. In the second part, we present a recent progress in refining the project-and-lift method, which is the current state-of-the-art algorithm for finding the Graver basis, such that the algebraic geometry method can handle larger IPs.

2 - Discounting, diversity, and investment
Wei Wei, Sebastian Ebert, Xunyu Zhou

Within the classical real option setting, we show that disagreement or uncertainty about what discount rate to use leads to delayed investment and more risk-taking. We connect with the behavioral economics literature and present the most comprehensive analysis of the impact of time preferences on investment decisions to date. Contrary to existing results, we show that time-inconsistency arising from behavioral time preferences leads to delayed rather than premature investment. We also find that, for these non-standard time preferences, the option value from investment may be zero.

3 - Computational analysis of market designs for smart grid implementation
Julia Grübel, Veronika Grimm, Sebastian Martin, Gregor Zöttl

Our work provides a computational framework that allows to analyze market interaction of different agents in smart grids. With the framework, we study different policies for the implementation and operation of photo-voltaic (PV) generation in low-voltage networks. Based on recent contributions of Madani et al. (2015), Coffrin et al. (2016), and Braun (2007), we propose a convex reformulation of network constraints that take into account active and reactive power, voltage magnitude and angles, and a model for the inverters connecting PV generators to the grid. Furthermore, we consider the option of network expansion. The resulting formulation is a mixed-integer linear problem. The convex problem structure ensures a unique market equilibrium and allows us to compare the impact of market designs on market outcomes. As an application, we study several policies for PV integration, i.e., from complete control over inverter investment and operation by the network operator to one based on incentives/penalties. In addition, we calculate the optimal system setup. Previous contributions already have analyzed incentives of market participants in the presence of network constraints, however, based on more simplified network representations, mainly suited to proxy power flows in high-voltage networks. In this work, we explicitly analyze interaction of market participants in low-voltage networks, where voltage and current levels, reactive power flows and losses are of central importance.

4 - Nash equilibrium uniqueness for two-player non-cooperative continuous games
Maria Carmela Ceparano, Francesco Caruso, Jacqueline Morgan

We address the issue of uniqueness of Nash equilibrium of a two-player non-cooperative game when the strategy spaces are (not necessarily finite dimensional) Hilbert spaces. As well-known, a unique Nash equilibrium exists if the best replies correspondences are single-valued and one of the two possible compositions of the best reply functions is a contraction. In this presentation sufficient conditions are given on the data of the game for the existence of one and only one Nash equilibrium when no one of the two possible compositions of the best reply functions is a contraction. For weighted potential games these conditions do not necessarily require the strict concavity of the potential function or the existence of a maximum point for such a function.

■ WA-31

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S313

Behavioural Operations and Games I

Stream: Behavioural OR
Chair: *Aysegul Engin*

1 - Performance of selected contract designs for the newsvendor problem considering behavioral economic aspects of bargaining: experimental evidence
Maximilian Vincent Reimer

The competitiveness of entire industries depends on efficiently concluding contracts along their supply chains. For the Newsvendor Problem a number of contracts promise to efficiently coordinate the actors. However, the well-documented biases for the individual decision (order quantity), as well as for the contract choice, challenge their practical effectiveness. In many previous experiments, another important reason for losses is ignored: one contract participant is replaced by an algorithm. This can lead to a systematic overestimation of contract efficiency, as the ability to maximize profits and intent to cooperate will be literally non-humane. In the experiment presented, an extension of the wholesale price contract is examined in a human-to-human negotiation, whereby explicit contract rejections are made possible. The available contract options include ones that are designed on the basis of established bargaining solutions. Thus, it becomes possible to examine a variety of allocations away from the Nash equilibrium (the favorite of many algorithms). Firstly, the experiment reveals the real performance of different contract designs. Interestingly, contracts based on known bargaining solutions are shown to have a strong appeal. Explanations (based on incentivized beliefs and random choice errors) for the observed behavior are presented. Practical implications can be derived, which can stand up to more realistic behavior of the negotiators while improving performance.

2 - Analysis of the hockey stick phenomenon using game theory and economical experiments
Natalia Correa, Sergio Ramirez

The rush of companies to achieve established goals entails the loss of regularization in deliveries during the sales cycle, which affects the supply chain process synchronization, impacting service efficiency and efficacy as reflected in the accumulation of orders at the end of the month. This effect is known as The Hockey Stick Phenomenon (HSP). Two causes of this phenomenon are of particular interest to this study: information asymmetry and discounts at the end of the month to achieve goals. Our study aims to understand the HSP in a theoretical and practical way by using game theory and economic experiments. Based on Singer's investigation (2008), we developed a model to simulate the negotiation relationship between the supplier and the retailer. Using he Z-Tree platform and undergraduate and postgraduate students, we carried out an experiment with three treatments twice. Our findings indicated that increase discounts at the beginning of the month and decrease discounts at the end of the month could be a strategy to mitigate the HSP. A subsequent ongoing study has migrated to an O-Tree platform, in which five different treatments will be applied twice, in order to identify which factors produce a collaborative relationship between supplier and retailer.

3 - The curse of knowledge in decentralized supply chains
Daniel Sanchez-Loor, Wei-Shiun Chang

Companies in a supply chain face information asymmetries. Current literature assumes that a leader with better information anticipates a follower's response only using the information available to the follower. However, the curse of knowledge suggests that the leader cannot exclude her additional information and overestimates the follower's information. We conduct a pilot experiment in which manufacturers have precise information about demand and set a wholesale price, whereas retailers observe an uncertain demand and order a quantity. Manufacturers show a tendency to move away from their optimal pricing influenced by their additional information.

4 - Optimistic overconfidence in bidding behavior with differently represented cost feedback in electronic reverse auctions
Aysegul Engin

This paper focuses on how individuals' bidding behaviors are influenced by the feedback from the auction platform under different forms of information representation. We assume that individuals perceive this information stochastically, since they have only incomplete information about other bidders. Facing such uncertainties may lead to various decision biases. In this paper, we particularly consider optimistic overconfidence, which is defined as individuals' overestimation of the likelihood for occurrence of a favorable outcome. In an auction context, optimistic overconfidence may lead to overestimating the probability of winning an auction, and thus to more aggressive bidding behavior (i.e. more severe deviation form one's true costs). We conduct an experiment in full factorial design with explicit stochastic information feedback in two different representation forms. Results with respect to information representation indicate that if the individuals are presented with a representation format that fits to their characteristics, processing gets easier, leading to less bias. Additionally, overconfident individuals overestimate their winning chances, if they have objectively low chances of winning the auction. If the chances of winning the auction is objectively high, there is no significant difference among the individuals with respect to their reported probability of winning the auction.

■ WA-32

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S314

Transportation and Uncertainty

Stream: Routing, Logistics, Location and Transportation
Chair: *Camilo Quiroga*

1 - Exact models and optimal policies for shipment consolidation: a stochastic dynamic programming approach
Sila Cetinkaya, Liqing Zhang

We consider a periodic-review shipment scheduling problem where a consolidation depot is responsible for delivering orders to multiple customers located in close proximity to each other. By employing a temporal shipment consolidation strategy, the orders received at different times can be combined into a single, large shipment, and, hence, the dispatch quantity in each period is determined based on the consolidated load observed at the end of that period. We formulate the model via a stochastic dynamic programming approach and examine the optimal shipment consolidation policies under different transportation options including private carriage and common carriage. We characterize the structure of the optimal policies and examine the optimality of threshold-type policies. Assuming the practically relevant "clearing property", we also investigate the optimality of other meaningful policies and provide sufficient conditions under which they are optimal. We present numerical results illustrating the performance of the proposed policies.

2 - Optimizing the parking price of a car park by queueing models
Yossi Hadad, Baruch Keren

Parking slots, especially in the big cities, are in shortage. The main aim of this research is to set an appropriate price for parking. Underpriced parking causes high arrival rates, long parking time, high occupancy rates with low turnover, low income, and harm to surrounding businesses. Overpriced parking causes low arrival rates and occupancy, low income from the park and harm to business activities in the area. This research proposes models for managing the demands for parking slots by setting the optimal parking price. The optimal parking price here is the price that maximizes the revenue for the park owner or for setting a given level of occupancy of the park slots. The research uses a queuing model and the concept of price elasticity for parking to calculate the optimal parking price. The proposed model is applicable for practitioners that have to set the right price for parking.

3 - The capacity choices of the U.S. domestic airline market and passengers demand forecasting
Nahid Jafari

This research examines the strategies followed by the U.S. domestic airlines in 21st century to achieve their highest revenue in regard with their capacity choices. During this period, although the airlines experienced higher load factors and inflated airfares, in addition to the fluctuation of fuel expenses, they were having profit losses. The analysis is conducted on 16 major airlines on primary factors such as the load factor, market supply (seats) and demand (passengers), unemployment rate, fuel expenses, flight frequency, and aircraft size. To investigate the flight load factor dependency on the airline capacity choice, we use the Durbin-Wu-Hausman test, to verify this endogeneity. Next, we deploy the Long Short-Term Memory network to forecast the U.S. domestic airline passengers.

4 - An optimization model for aircraft routing under uncertain operational times
Camilo Quiroga

The variability in operational times in the preparation and execution stages of a flight has a significant impact on aircraft scheduling and routing, causing delays and influencing the performance of aerial operations. The present work analyzes aircraft routing from the perspective of the Fleet Assignment to different flights, considering the stochastic behavior of operational times and modification in departures and arrivals for an itinerary in adaily operation. The modification of different schedules is subject to proposed time windows, for a flight to be delayed or anticipated, guaranteeing greater flexibility and operation robustness. To solve the Aircraft Routing Problem, a stabilized column generation problem is used, applying a set of specialized auxiliary shortest path models, based on linear programming. Finally, using a Monte Carlo simulation, the On - Time Performance of the fleet assignment is evaluated in specific scenarios considering the weather effect.

■ WA-33

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S315

Data Mining Applications in Life Sciences

Stream: Data Mining and Statistics
Chair: *Pinar Karadayi Atas*
Chair: *Gerhard-Wilhelm Weber*

1 - Epileptic seizures prediction through the analysis of EEG synchronization
Paolo Detti, Garazi Zabalo Manrique de Lara, Renato Bruni, Marco Pranzo

Epilepsy is a neurological disorder arising from anomalies of the electrical activity in the brain, affecting about 65 millions individuals worldwide. This work proposes a patient-specific approach for short-term prediction (i.e., within few minutes) of epileptic seizures. We use noninvasive EEG data, since the aim is exploring the possibility of developing a noninvasive monitoring/control device for the prediction of seizures. Our approach is based on finding synchronization patterns in the EEG that allow to distinguish in real time preictal from interictal states. This is obtained by considering bivariate measures of synchronization, i.e., measures involving couples of EEG channels. In practice, we develop easily computable functions over a graph model to capture the variations in the above synchronization. Then, an automatic classification of the time series generated by the above functions aims at identifying the preictal state. We compare in this task two state-of-the-art classification algorithms and a threshold-based classifier developed ad hoc. Results on publicly available scalp EEG database show that this simple and computationally viable processing is able to highlight the changes in the synchronization corresponding to the preictal state.

2 - Value of patient history for predictive models: a case study using French PMSI database
Hugo De Oliveira, Martin Prodel, Vincent Augusto

The PMSI is the hospital part of the French health insurance database. This medico-administrative database contains quantified and standardized information, without physiological data or vital signs. Its structure is complex, with several tables for stays information, diagnosis or medical procedures. The goal of this study is to evaluate the impact of using patients' history for predictive analysis. The case study is the prediction of re-hospitalizations after a stroke episode in 2015. Historical data of the patients correspond to all the hospital stays before the inclusion, since 2010. A multi-steps transformation has been designed and applied on data to construct a "1 row = 1 patient" database (from the standard 1 row = 1 stay) for classical Machine Learning algorithms. After data cleaning and preprocessing, the final dataset contained 89 000 patients and 3750 features. Predictions were performed considering 30, 60 and 90 days as a time window for re-hospitalization after the discharge of the inclusion stay, as well as with and without history. A Decision Tree classifier with automatic hyperparameter tuning was used to perform predictions. 90% of data was used for model validation and performances were measured using a F1-score for the 10% left. Results show that adding patients' history always leads to a performance improvement. This study encourages the use of patient history for the development of predictive tools using medico-administrative database.

3 - An AHP model for estimating student desertion in higher education institutions
Luis Quezada, Hernan Silva, Astrid Oddershede, Pedro Palominos

This paper presents a multi-criteria decision making method to predict students' desertion in Educational Institutions. The Analytic Hierarchy Process (AHP) is used to estimate the probability of desertion of each individual. The probability is estimated by combining the priorities estimated for the factors affecting dropout with the actual values for those factors for each individual. In order to evaluate the proposed model, two methods were applied. First, the prediction of the model was compared with the actual desertion of the students in one academic year. Secondly, the results were compared with the dropout estimated using a Logistic Regression (RL) method. It was concluded that the degree of predictability of the proposed method was high and similar to the degree of predictability obtained using RL. The advantage of using AHP is that it is simple and that it only requires de judgment of experts from the main administration.

■ WA-34

Wednesday, 8:30-10:00 - SOUTH BUILDING UV S113

Networks and flows

Stream: Discrete Optimization, MIP and MINLP
Chair: *Thorsten Schmidt-Dumont*

1 - New partition inequalities for the unsplittable flow problem
Arnaud Knippel, Sonia Vanier

We study some polyhedral aspects of the polytope of the minimum cost unsplittable flow problem (MCUFP). We first extend the classical cover and cut inequalities to introduce valid inequalities for the (MCUFP) polytope. Then we introduce new classes of valid inequalities, and give separation algorithms for a branch-and-cut framework.

2 - An optimal adding edge with short length between two levels of a complete k-ary tree
Kiyoshi Sawada

This study considers addition of relation to a pyramid organization structure such that the communication of information between every member in the organization becomes the most efficient. The pyramid organization structure can be expressed as a rooted tree, if we let nodes and edges in the rooted tree correspond to members and relations between members in the organization respectively. We have proposed a model of adding an edge between two nodes with different depths to a complete K-ary tree of height H for the purpose of revealing an optimal additional relation. This model is expressed as all edges have the same length. However, we should consider that an adding edge differ from those of complete K-ary tree in length. This study proposes a model of adding an edge with short length between two nodes with different depths to a complete K-ary tree (K=2,3,...) of height H (H=2,3,...). The length of an adding edge is L which is less than 1 while those of edges of complete K-ary tree are 1. When a new edge between a node with a depth M and its descendant with a depth N is added, an optimal pair of depth (M,N)* is obtained by maximizing the total shortening distance which is the sum of shortened lengths of shortest paths between every pair of all nodes by adding edges.

3 - Reinforcement learning in conjunction with autonomous vehicles for the control of traffic flow on highways
Thorsten Schmidt-Dumont, Jan van Vuuren

Ramp metering and variable speed limits are the best-known control measures for effective traffic flow on highways. In most approaches towards solving the control problems associated with these control measures, optimal control methods or online feedback control theory have been employed. Feedback control does not, however, guarantee optimality with respect to the metering rate or the speed limit chosen, while optimal control approaches are limited to small networks due to their large computational burden. Reinforcement learning provides an alternative solution approach with a significantly reduced computational burden. Furthermore, the dawn of the autonomous vehicle promises further improvements in the traffic flow which may be achieved over and above those of these established highway traffic control measures.

In this presentation, a decentralised reinforcement learning approach is adopted towards simultaneously solving both the ramp metering and variable speed limit control problems where these are enforced by giving direct instructions to varying percentages of autonomous vehicles present in the traffic flow. A simple, microscopic traffic simulation model is employed as a test bed so as to be able to evaluate the effectiveness of the control policies proposed by the reinforcement learning agents.

■ WA-48

Wednesday, 8:30-10:00 - 4D UPV B.3

Engineering Optimization

Stream: Engineering Optimization
Chair: *Wolfgang Achtziger*

1 - A contribution to general repair models and their application
Frank Beichelt

The majority of maintenance policies for technical systems considered so far are based on maintenance actions, called in what follows repairs, which only comprise replacements ('good as new'-concept) and minimal repairs ('bad as old'-concept). By definition, a minimal repair enables the system to continue its work, but the system has after a minimal repair the same failure rate as immediately before the failure. In many cases, this is a satisfactory approximation to real-life maintenance management. General repairs have an effect on the system to be maintained, which is 'in between' the effects of minimal repairs and replacements. This effect is measured by their respective degree of repair. This talk gives the definition of a degree of repair suitable for application in maintenance engineering. Based on this concept, the talk analyzes a few new maintenance policies and compares them with regard to their cost efficiency.

2 - A GRASP metaheuristic for generating optimal meshes for fluid flow simulation
Víctor Hugo Martínez Reza, Mayra Elizondo, Rubén Ávila Rodriguez

In this paper, we address the problem of optimizing the network of nodes which defines a mesh inside the computational domain. Particularly in the preprocessing stage, to simulate fluid flow, a network of nodes is designed to form geometric configurations, these must be coupled regular polygonal cells without overlap, however, optimizing a network with regular polygonal cells requires: to minimize the equiangular skewness of the cells and to avoid the overlaps. Given the nature of problem of network generation, we treat it as a problem of packaging articles inside a container for small instances, however, for large instances we propose a metaheuristic to optimize the network. In this article, we present the metaheuristic algorithm, GRASP, to optimize the network of nodes forming 161700 triangular cells without overlaps. We set the Lambda search parameter at 0.6, and the algorithm finds the best coupled triangular cells and with the smallest average equiangular skewness. Thereby we achieve to optimize and to build a mesh with coupled triangular cells and without overlap with the GRASP algorithm.

3 - Optimization of an industrial aluminum parts casting process based on simulated annealing
Antonio Jiménez-Martín, Alfonso Mateos, Guillermo de Lima

In this paper, we aim to optimize an aluminum casting process to create parts for the automotive sector. The company has six aluminum injection molding machines to produce different parts. There are a total of 81 injection molds for 160 different types of parts, including molds for a single part, two or even three different parts. We must account for constraints regarding which molds can be used in each machine, mold changes (up to four a day, which may be non-simultaneous mold or not coincide with worker shift changes), stock of parts, time set aside for machine breakdowns and scheduled machine maintenance processes. The objectives for a two-week planning period are to maximize accumulated demand satisfaction in the two weeks of the different pieces, minimize the delay in parts production with respect to the specified delivery date, minimize energy costs (electricity and gas consumption) and minimize the total number of mold changes performed. A heuristic is used to derive an initial feasible solution. Simulated annealing is then applied to derive the optimal solution. To do this, different neighborhood definitions are created based on the total or partial elimination or introduction of injections or on injection mold changes, whose use dynamically varies throughout the search process.

4 - On optimality conditions for classical formulations of topology optimization problems for discrete/discretized engineering structures
Wolfgang Achtziger

We consider classical problem formulations in the field of topology optimization of discrete or discretized engineering structures. In view of an unperturbed treatment of the problem we work with SAND (simultaneous analysis and design) formulations. This means we consider both, design variables as well as state variables (displacements) linked via elastic equilibrium. This allows a good modeling of stress constraints among other constraints. Due to zero design variables, at an optimal structure the stiffness matrix typically is singular resulting in numerical difficulties. Even worse, standard first order optimality conditions are violated due to missing constraint qualification, and therefore standard solvers typically fail. Nevertheless, for standard objective functions (like weight or compliance) it can be proved that the standard necessary conditions hold. The talk gives insight into the difficulties and presents some background and new results on optimality conditions for this class of design problems. A part of the talk presents joint results with Ch. Schürhoff.

■ WA-49

Wednesday, 8:30-10:00 - 4D UPV B.4

OR in Forestry II

Stream: OR in Agriculture, Forestry and Fisheries
Chair: *Antonio Alonso-Ayuso*

1 - Optimization models of floorboard toplayer assembly
Matthias Kaltenbrunner, Maria Anna Huka, Manfred Gronalt

The goal of the study is to develop a production planning approach for assembling the top layer of floorboards in the parquet industry. The top layer of a floorboard, which has standardized dimensions, is built up of lamellas with different lengths and grades that are aligned in three lanes. The used grades and the arrangement of the lamellas define the quality of the produced floorboard. This leads to a huge number of possible placement patterns that have to be considered in production planning. Hence, we define a MIP model to minimize the total production costs, considering the available raw material, the needed amount of different qualities of demanded top layers, and a minimal production quantity per product. First, we want to present an approach to reduce the number of patterns without constraining the feasible region and second, numerical experiments where different pattern selection strategies are investigated. Third, we develop a decision support system to bring the research to a daily use in the industry.

2 - Stochastic and multicriteria decision making applied to suppression of wildfires
Javier León, Begoña Vitoriano, John Hearne

Several operational research models can be found in the literature dealing with prevention and preparedness to mitigate the effects of wildfires. These models aim to help decision-makers with decisions such as where to perform prescribed burning or resource allocation among others. Most of these models try to integrate different criteria, but often they handle it by adding hard constraints (for instance, on budget or on some environmental metric). However, it is difficult to find models dealing with the response phase, especially considering the inherent multicriteria aspect of the problem.

Once a wildfire has started decision-makers have to choose where and when to attempt to contain it, attending to several criteria and a high level of uncertainty. There are a great number of simulators widely used by fire response services that provide them with an estimation of how will the fire front advance. With that estimation these decision-makers have to decide where and when to send their crews and resources to contain the fire.

In this work we develop a mixed integer linear programming model that will attempt to help the decision-makers with such decisions, including multiple criteria and stochasticity.

3 - Integrating strategic and tactical decision levels in forestry management under uncertainty
Antonio Alonso-Ayuso, Laureano Fernando Escudero, Monique Guignard-Spielberg, Andrés Weintraub

In this work we present a model for the forestry planning problem with two levels of uncertainty and, therefore, two decision levels, namely, strategic and tactical ones. The strategic level (a time horizon of several years) considers uncertainty in the production of timber in the forests. This uncertainty is represented by a multistage stochastic scenario tree, where each time stage to be considered is divided into several periods (quarters, semesters ...). In addition, uncertainty on the timber price and demand is considered at the tactical level whose horizon is given by the stage periods. The tactical uncertainty is represented in a multiperiod two-stage tree rooted with the related strategic node in multistage scenario tree. The strategic nodes have associated decisions on the design of the logistic distribution network of the timber from the forests to the markets, while each tactical node has associated decisions about the amount to be extracted from each stand and the distribution routes to follow to satisfy the demand. Some experimental computational results on a large-sized stochastic mixed 0-1 model are presented based on real data from a Chilean forestry company where, on one hand, the tightness of the model is verified and, on the other hand, the add-value of simultaneously modeling multistage strategic and multiperiod tactical decision making under uncertainty is analyzed.

■ WA-50

Wednesday, 8:30-10:00 - 4D UPV 1.1

OR for Developing Countries IV

Stream: OR for Developing Countries
Chair: *Herman Mawengkang*
Chair: *Begoña Vitoriano*

1 - Factors that affect the user satisfaction of information technology facility service
Roslina Roslina, Devy Mathelinea, Herman Mawengkang

Most of the user satisfaction the research in Information Technology (IT) focus on the result from the data processing of information system . IT facilities service give the hardware and software service to produce information without considering the need of user's specification. This research focused on IT service provider to understand the user's needs before giving the service. The IT service fasility can be considered from the aspect of hardware, software, staff, room and utility that can be gained from IT service fasility. Factor analize has been done to informations gained to know the factors that affect the level of user's satisfaction.from the result of the research it is known that : first, there are three factors that affect the level of user's satisfaction that is, staff service, the utiliy that is gained and the equipment system. second, has been developed a model to measure user's satisfaction to the IT service facility.

2 - Integer programming model for tackling a variant of open vehicle routing problem in evacuation transportation planning system
Dedy Hartama, Herman Mawengkang

The research in evacuation planning has been very much motivated due to the rapidly increased number of disasters world-wide, in Indonesia, particularly. It is the process of shifting the maximum number of evacuees from the disastrous areas to the safe destinations as quickly and efficiently as possible. A number of mathematical models for flow maximization and time minimization has been studied in quite diversified research domains. This paper exploits the notion of a variant of open vehicle routing problem to model the evacuation transportation planning with the objective to minimize the evacuation time. We use a neighborhood search approach for solving the mixed-integer programming model.

3 - Optimization model for logistic planning problem of fish processed product considering location-routing
Intan Syahrini, Devy Mathelinea

Nowadays in the global supply chain system there has been an increased interest in modeling the integration of logistic of production and distribution planning, in order to get more economics advantages. In a distribution network it is important to decide the locations of facilities that impacts not only the profitability of an organization but the ability to serve customers. Generally the location-routing problem is to minimize the overall cost by simultaneously selecting a subset of candidate facilities and constructing a set of delivery routes that satisfy some restrictions. This paper considers a multi-plant and multi-product fish production-distribution planning which produces simultaneously multi fish products from several classes of raw resources. The research under investigation is located at Eastern coast of North Sumatra Province, Indonesia. We use mixed integer programming model to describe the problem. A feasible neighborhood search is proposed to solve the result model

4 - An integer programming model for resource management planning problem in Aceh province, Indonesia
Taufiq Taufiq, Herman Mawengkang

The main natural resources which can be exploited in order to enhance the welfare of people in Aceh province, Indonesia, are from agriculture, plantation and fisheries sectors. These natural resources need to be managed and planned optimally. This paper focuses on the plantation sector. We develop an integer-programming model to tackle the planning problem based on information technology results. The large-scale model is then solved using a direct-search approach.

■ WA-51

Wednesday, 8:30-10:00 - 4D UPV 1.2

Health Care Scheduling

Stream: OR for Health and Care II
Chair: *Eva Schmidt*

1 - Planning of out-of-hours service for pharmacies
Christina Büsing, Timo Gersing, Arie Koster

The supply of pharmaceuticals is one important factor in a functioning health care system. In the German health care system, the chambers of pharmacists are legally obliged to ensure that every citizen can find an open pharmacy at any day and night time within an appropriate distance. To that end, the chambers of pharmacists create an out-of-hours plan for a whole year in which every pharmacy has to take over some 24 hours shifts. These shifts are important for a reliable supply of pharmaceuticals in the case of an emergency but also unprofitable and stressful for the pharmacists.

The out-of-hours service is typically organized locally within small districts as cities or municipalities, leaving a high potential for optimization. In this talk, we present models for a centralized planning in order to improve the coverage of the citizen and simultaneously reduce the load of shifts on the pharmacies.

An out-of-hours plan has to meet several constraints: in addition to the coverage of the whole population we have to consider rest periods between two shifts, a minimum distance between open pharmacies and a fair distribution of the shifts. As a combination of a set cover, scheduling and forbidden set problem, this problem is NP-hard.

To solve the problem, we present several heuristics. Finally, we analyze the obtained out-of-hours plan for the area Nordrhein and compare it with the current out-of-hours plan.

2 - Robust strategic planning for emergency doctors
Manuel Streicher, Sven Krumke, Eva Schmidt

The medical treatment of emergencies is one of the most important problems in health care. A key issue is the problem of strategically planning facilities for emergency doctors. This planning should be done in a way that ensures good medical care for the population while keeping the costs to a minimum. Within the joint project HealthFaCT we model this problem using various concepts of discrete robust optimization. We present a robust model for the problem, the Robust Min-q-Multiset Multicover. The model aims to minimize the number of emergency doctors needed to cover all scenarios of occurring emergencies, where discrete budgeted uncertainty is used to model the demand. Robust Min-q-Multiset Multicover is NP-hard.

We present two solution strategies based on constraint generation and discuss their advantages and disadvantages. Further we give computational results based on real world data.

3 - Next-day operating room scheduling with time-dependent stochastic surgery durations
Enis Kayis, Tugce Karatas, Refik Gullu

Operating rooms are the most critical units of the hospitals responsible for 40% of the revenues and costs. We consider the next-day operating room scheduling problem for a given list of elective surgeries. It is assumed that surgeries have uncertain durations and unlike existing works distributions of surgery durations are assumed to be time-dependent as suggested by recent empirical work on surgery duration estimation. We aim to find the optimal OR sequence and schedule when surgery durations are time-dependent to minimizes the weighted sum of expected waiting time of patients, idle time of operating rooms, and overtime of the hospital staff. We formulate the problem and use sample average approximation to solve the resulting stochastic optimization model. Using these results, we quantify the penalty of ignoring time-dependent surgery durations. Furthermore, we study how the penalty is affected if commonly used heuristics are used in OR scheduling and sequencing.

4 - Resource controlling in the health care sector
Eva Schmidt, Sven Krumke, Manuel Streicher

In the health care sector, the efficient supply of medical care in emergency cases is a very important component and in steady need of optimization. Given a strategic plan for allocating emergency doctors to facilities, it is of great interest to evaluate the quality of such a plan a posteriori.

Every occurring emergency should be reached by an emergency doctor in a reasonable amount of time. This aspect leads to the problem of assigning doctors to emergencies while respecting this given time window and the predefined capacity of each facility. Given the data of emergencies of one shift, the task is to compute a feasible assignment of doctors to emergencies. Then, we can rate the given strategic plan and examine whether the number of doctors in each facility is sufficient to guarantee the medical care of the population.

We analyze the problem and discuss its complexity depending on the total number of available doctors. Furthermore, we present a solution approach using a branch-and-price algorithm.

■ WA-52

Wednesday, 8:30-10:00 - 4D UPV 1.3

E-Fulfillment

Stream: Analytics and Pricing
Chair: *Jan Fabian Ehmke*

1 - Simulation-based optimization of time window allocation for attended deliveries
Magdalena Lang, Catherine Cleophas, Jan Fabian Ehmke

For attended deliveries and services, provider and customer have to agree on a time window. While customers wish for both short time windows and high punctualities, the allocation of time windows significantly affects delivery costs. Given a limited delivery capacity, accepting orders for certain time windows also limits the number of further orders that can be accepted. When forecasting the number of potential orders per time window, revenue management approaches enable efficiently controlling the allocation of time windows to orders. To that end, planners need to assess the effect of an order on further delivery capacity. However, the effect on delivery capacity cannot be determined with certainty at the arrival of the individual order requests, as the travel time per order depends on the overall routing. Vehicle routing methods can approximate travel time and costs, but lack sufficient means to anticipate customer choice between time windows and to control demand effectively. We present a simulation-based framework to learn and approximate the opportunity costs of accepting orders for a time window given the set of accepted and expected orders. Based on simulated order requests, the approach approximates the future effects of control decisions. The results inform the dynamic time window allocation per arriving order request. We present computational results on empirical demand scenarios.

2 - On time window budgets for anticipation in attended home delivery
Sebastian Koch, Robert Klein

As business-to-consumer e-commerce grows, attended home delivery becomes a crucial part of the business model of, e.g., e-grocers and e-tailers. It describes the delivery of goods or services to a customer at an appointed time, which is often called the service time window, in order to avoid failure of delivery. In this talk, we re-consider the problem of integrated demand management and attended home delivery. In the considered business model, customers arrive dynamically and stochastically over a booking horizon and may book delivery for a certain time window. Both the available time windows and the charged delivery fees may depend on the individual customer and may change over time. All bookings must be feasibly delivered during a subsequent delivery day. The goal of the online retailer is to optimize the overall expected profit. Even small instances of the underlying stochastic dynamic program cannot be solved optimally due to the curses of dimensionality and because demand management decisions have to be made in near real time. We develop a novel approximate dynamic programming approach. Thereby, we provide an innovative concept, which we call time window budgets, that helps us to measure and assess the free delivery time within the time windows and thus enables us to anticipate the future value of demand management decisions. In a simulation study, we compare our approach with state-of-the-art benchmarks, showing its profit potential.

3 - A bilevel model with a solution algorithm for the network design and pricing problem
Christine Tawfik, Sabine Limbourg

This work is devoted to jointly examining the intertwined tactical problems of designing freight carrying services and determining their associated prices. We put forward a bilevel model, where a leader is portrayed at the upper level, as a freight transport operator seeking to maximize his profit by setting the services' tariffs and selecting their subsequent operating frequencies, dealing with continuous and discrete variables respectively. At the lower level, the shippers (followers), faced with itineraries composed of the leader's services and an available competition's alternative, react in a costs' minimization fashion. We discuss a heuristic approach to solve the proposed model, addressing its main points of difficulty: the network design and the lower-level optimality. The algorithm is based on the idea of starting with an initial service network that is able to accommodate all the market's demands, then iteratively decrease the frequencies of those services that do not considerably contribute to the leader's revenues. Each iteration is divided in two steps: generating the flows that are compatible with the updated services' frequencies while maximizing the leader's profit, then solving for the services' tariffs that guarantee the flows' optimality for the lower level. Promising results are obtained on real-life data showing the ability of the algorithm of reaching solutions within a small gap from the best reached by CPLEX in a significantly less amount of time.

4 - Flexible time window management for attended home deliveries
Charlotte Köhler, Jan Fabian Ehmke, Ann Campbell, Catherine Cleophas

In the competitive world of online retail, many retailers offer a selection of time windows to fulfill customers' expectations of on-time delivery. Creating a set of suitable and cost-efficient time windows is challenging, because customers have different preferences for certain time windows, and customers prefer short time windows over long windows, which can increase delivery costs significantly. Since demand is not known in the beginning of the booking process, but becomes available incrementally over time, the acceptance of an order request can restrict the ability of accommodating future requests significantly. In this presentation, we consider different ideas of flexible time window management that ensure allocation of short time windows to those customers that do not restrict the flexibility of evolving route plans significantly. We include information about the current route plan (e.g. current utilization and structure) and combine this with realistic customer' choice behavior for different time window options (e.g. place and length) to create customer-individual time window offer sets. We analyze the effectiveness of our ideas in computational experiments given demand structure of real order data from an e-grocer in Berlin, Germany.

■ WA-53

Wednesday, 8:30-10:00 - 4D UPV 1.4

Probabilistic Forecasting

Stream: Stochastic Assessment of Renewable Energy
Chair: *Miguel Carrión*

1 - Optimal switch-over time for non-repairable products with short lifecycles
Ruey Huei Yeh

This paper investigates the optimal switch-over time to a new product with ever-faster technology innovation, which shortens the lifecycle of products. Traditional replacement policies for non-repairable products usually assume that the same product is available to replace the old one whenever it fails. However, due to the rapid development of science and technology, the lifecycle of a product is relatively shortened and the same product may not exist in the market shortly after it is introduced. Consider the case where there will be a new product released before the old one is phased out, and the new product is suitable to substitute the old one. In this case, before the new product is released, the product can only be replaced by the old one whenever the product fails. Similarly, after the old product is phased out, the product can only be replaced at failures by the new one. Between the time that the new product is released and the time that the old product is phased out, a failed product can be replaced either by the old one or switch over to the new product. Assume that the new product with a new purchasing cost and a new reliability function can compatibly substitute the old one. Furthermore, the performance of the product is represented by its life time distribution. Within a finite planning horizon, the objective of this paper is to find the optimal switch-over time from the old product to the new one, such that the total expected cost is minimized.

2 - Benefits in economic terms of short term forecasting of renewable energy
John Boland

I, in conjunction with co-workers, have developed simple mathematical and statistical forecasting tools for solar and wind energy that perform at least as well as complicated machine learning techniques. Additionally they are interpretable in physical terms. However, what I will do in this presentation is discuss the economic benefits of these tools, particularly on the five minute time scale that is important in the Australian National Electricity Market. I will compare my forecasting techniques with smart persistence forecasts. Smart persistence means that the best estimate of the value at time t+1 is the value at time t, taking into consideration the climatology. I will also evaluate the performance of probabilistic forecasts on a half hour basis. To evaluate the economic benefit of each forecasting technique, the Over- and Under-Mean Absolute Error (OMAE and UMAE respectively) can be evaluated.

3 - Forecasting gross inland natural gas consumption in European countries through bagging methods
Erick Meira de Oliveira, Fernando Luiz Cyrino Oliveira

Natural gas has received widespread consideration as a strategic fuel source in almost every European country. Now increasingly deemed as a low carbon and an environmentally friendly energy option, not only is natural gas expected to remain an important fuel source for Europe, but its consumption is also expected to increase, at least in the next few decades. In this context, there has been a long-standing interest in forecasting natural gas demand across different European countries. We contribute to this stream by proposing a combination of Bootstrap aggregating (Bagging) techniques and traditional time series methods to obtain more accurate forecasts of natural gas demands. In addition, we introduce a different bagging procedure that involves generating new series via maximum entropy bootstrap, a novelty in the field of energy demand forecasting. The proposed methodologies are used to forecast 24-steps ahead monthly gross inland consumption data from nine major gas-consuming countries in Europe. A comparative out-of-sample analysis is then conducted using different performance metrics. The obtained results attest that the proposed methodologies can improve forecast accuracy. In many cases the gains are noteworthy when compared with single forecasts on the real data, ie. more than 50% error reduction can be achieved. It is our belief that equally satisfactory results can be obtained on other occasions such as different countries and time series.

4 - Selling price determination of an electricity supplier for electric vehicles
Miguel Carrión, Ruth Dominguez, Rafael Zarate-Miñano

This paper presents a risk-constrained stochastic programming approach to formulate the decision-making problem faced by an electricity retailer that supplies the energy demand of electric vehicles. The retailer participates as a price-taker agent in the day-ahead and balancing markets to procure the energy demand of its clients. In the proposed approach, the owners of the electric vehicles are considered to respond to the price offered by the retailer. Electric vehicles with similar charging profiles are grouped together. We consider that the retailer can control the charging and discharging processes of those electric vehicles that desire to purchase electricity at a competitive price. The uncertainty of pool prices and energy demand of electric vehicles is accounted for. The resulting stochastic programming model is formulated as a mixed-integer linear programming problem. A realistic case study based on the Iberian Peninsula Power System illustrates the proposed methodology.

■ WA-54

Wednesday, 8:30-10:00 - 4D UPV 1.6

Sports Analytics II

Stream: OR in Sports
Chair: *Jiun-Yu Yu*

1 - An accessible lactate threshold assessment tool to support endurance athletes' trainings
Urtats Etxegarai, Eva Portillo, Jon Irazusta, Itziar Cabanes, Jon Larruskain

Lactate threshold is considered an essential physiological variable for endurance sports as an aid for training prescription and performance estimation. However, nowadays there is no reliable way to asses it without specialized equipment or without turning to expensive centres, meaning that it is restricted to few people with access to these resources. Actually, in the literature there is very little research about this topic within the scope of Operational Research. Thus, this work proposes an alternative, cost-efficient, non-invasive and easily accessible way to estimate the lactate threshold and so making it accessible to a wider population. In particular, a new strategy based on feature standardization combined with Recurrent Neural Network was proposed to model the lactate threshold. This work presents a software prototype to be used in cloud that implements this model, as well as its validation against both new athletes and athletes who are at a different fitness level. A further applicability analysis has also been performed to compare the estimated lactate threshold (considering different lactate measurement techniques) with the blood measurement techniques. This analysis together with the validation, shows that our model is a valid accessible tool for lactate threshold assessment.

2 - Advanced voting systems for ranking of candidates
Petra Zýková

This paper deals with advanced voting systems for ranking of candidates. The aims are to find general winner and ranking of candidates. Every voter gives ranking of first p-candidates and also can give penalties to candidates who he/she surely does not want to vote. There are used basic voting systems - plurality rules and Borda's method. There are used advanced voting systems based on the application of data envelopment analysis: DEA/AR model, DEA/AR exclusion model and Llamazares-Peña model. These models are used for application without penalties. Models are illustrated by results of Grand Prix of Formula 1 in season 2016 and a final ranking of drivers in Formula 1 World Drivers' Championship is discussed. Original contribution of the paper consists in formulation of DEA/AR model with penalty and DEA/AR exclusion model with penalty. They are illustrated on Formula 1 World Constructors' Championship data set and the winner is determined.

3 - Sports facility location planning with customers' preference
Jiun-Yu Yu

Most facility location problems do not take customers' preference into account, which is not enough for service facilities. We construct a model to capture the customer preferences with the objective of maximizing the number of customers served. Given the set of open facilities, each customer choose a facility by his/her preference to the facility. As the problem is NP-hard, we design a heuristic algorithm based on maximum flow. The proposed algorithm possesses worst-case performance guarantees for some special cases of our problem. Numerical studies demonstrate the algorithm's average performance and general applicability.

■ WA-55

Wednesday, 8:30-10:00 - 4D UPV 2.1

MIP Solvers in Practice

Stream: Making an Impact II
Chair: *Björn Thalén*

1 - MIP-solvers in practice
Björn Thalén, Joaquim Gromicho, Denise Tönissen, Timo Berthold, Alex Fleischer, Ronald Buitenhek, Frank Haeger

Practitioners who use MIP have a great choice of possible softwares. The huge choice can make it harder to make decisions; and that's where this session should be invaluable.

Bringing together representatives from the 3 top stand alone MIP-solvers, Gurobi, Xpress and CPLEX with representatives from 2 companies and 1 university that are heavy users of one or more of these we try to answer questions like: Why use a 3rd party solver instead of specialised heuristics? What problems have companies experienced in this approach? And of course... which solver is the best in practice?

The rise of so called Mat-heuristic solvers that incorporate a mip-solver as part of the heuristic has seen a large increase in the last years. In this panel discussion we make a deep dive into that world from the usability perspective.

■ WA-56

Wednesday, 8:30-10:00 - 4D UPV 2.2

Emergency Logistics and Healthcare Optimization

Stream: Healthcare Logistics
Chair: *Issam Nouaouri*

1 - An ALNS algorithm for scheduling and routing in home healthcare services
Ahmet Cinar, Sibel Salman, Burcin Bozkaya

In home healthcare services it is customary to visit the patients on a schedule. A Turkish company that sells medical nutrition products provides follow up services to its patients that are fed by tube or orally. Each nurse either visits a set of patients for whom she is responsible at home or calls them by phone on a specific day. In the current system, each nurse decides by herself how to follow the patients up in each month. Thus, the managers cannot control whether the nurses visit the right patients in the right order. Patients can be prioritized depending on factors such as the last visit time, next prescription date and the severity of his/her condition. An important aspect of the priority parameter is that it is updated by time. As time progresses, the priority of an unvisited patient increases. We define an optimization problem that determines which patients to visit on each day of a multi-period planning horizon and in which order to visit them to maximize the total priority of visited patients and to minimize the total routing time. We also develop an Adaptive Large Neighborhood Search (ALNS) algorithm to generate near-optimal feasible solutions in short running times. We measure the quality of the ALNS algorithm by computing the optimality gaps using the upper bounds generated by Lagrangean relaxation. The ALNS algorithm is tested using real-life data and the results of the algorithm are quite promising in terms of solution quality and solution time.

2 - Modeling yellow and red alert durations for ambulance systems
Amir Rastpour, Armann Ingolfsson, Bora Kolfal

In this work, we model ambulance shortage periods, and we study impacts of different corrective actions on system recovery. The focus of the presentation will be the latter. We will discuss a fundamental question for emergency medical service: To quickly restore capacity when utilization increases, is it better to add servers or to expedite servers? We use the theory of absorbing Markov chains to analyze decisions about (1) adding ambulances and (2) expediting service, with respect to two performance measures: (1) the duration of periods during which the number of available ambulances is below a threshold, and (2) the number of lost calls. We prove it is always better to call in an ambulance than to expedite an ambulance if the time until the realization of these two actions has the same distribution. Our methods quantify the impacts of corrective actions and assist EMS dispatchers to make better decisions regarding expediting any number of ambulances versus calling in any number ambulances even if they have different arrival time distributions.

3 - Stochastic modeling and simulation to minimize patient waiting time in an emergency department
Issam Nouaouri, Dorsaf Daldoul, Hanen Bouchriha, Hamid Allaoui

The hospital emergency department (ED) is the primary facility for urgent health issues. Overcrowding and the limited resources affect the waiting time of patients in the ED. In this work, we consider the healthcare services in the ED of a university hospital in Tunisia. The goal is to propose patients scheduling and optimize the human (physicians and nurses) and material resources (beds) required to reduce the average total patient waiting time. We consider six patient queues: (1) triage of patients; (2) general assessment; (3) surgical assessment; (4) the treatment of vital patients; (5) subsequent additional examinations; (6) patients waiting to be assigned to beds in the ED. In this study, we consider the operational level (patients scheduling) and tactical level (sizing human and material resources) by proposing a new approach that includes a stochastic mixed-integer programming model and simulation model. Here, we use the solver ILOG CPLEX Optimization Studio for optimization model and FlexSim software for simulation model. We compare the performance obtained from the proposed approach with what exists currently in the ED under consideration. The results of the experimental study demonstrate that the proposed approach improves the average total patient waiting time.

■ WA-57

Wednesday, 8:30-10:00 - 4D UPV 2.3

Software for Optimization Modeling II

Stream: Software for Optimization
Chair: *Susanne Heipcke*

1 - New modeling options for SAS' optimization
Jared Erickson

In SAS' software, optimization solvers have primarily been accessed from the optimization modeling syntax of the OPTMODEL procedure. SAS' Viya', which provides cloud-enabled, in-memory analytics, also creates new possibilities for optimization modeling. You can now use the powerful algebraic modeling capabilities of the PROC OPTMODEL language to build and solve optimization models in SAS Viya. The runOptmodel action in SAS' Optimization enables you to directly access PROC OPTMODEL's optimization modeling functionality when you program in any of the client languages that SAS Viya supports: SAS, Python, Lua, R, and Java. In addition, you can solve the formulated models in SAS Viya by using the extensive suite of solvers in SAS Optimization for linear programming, mixed integer linear programming, quadratic programming, nonlinear programming, constraint programming, network optimization, and local search optimization. You can use data that are stored in a cloud environment with a model that is submitted from the client without having to move the data. A new Python modeling package, sasoptpy, enables modelers to manipulate data, write the model, and process the solution all within the local Python environment, but use SAS Optimization solvers on a SAS Viya server.

2 - Adding functions to AMPL
David M. Gay

The AMPL modeling system for mathematical programming is demonstrably useful for dealing with a wide variety of mathematical programming problems (e.g., optimization and complementarity problems). While AMPL permits using imported functions, expressed in another language, the AMPL modeling language itself only allows stating algebraic expressions that entail finitely many operations. In some situations, functions expressed directly in AMPL would be useful. In particular, for solvers that allow callback functions (provided by the user) to affect the solver's algorithm, functions expressed directly in AMPL should be useful. This talk presents AMPL extensions that allow stating functions in AMPL, including functions that return tuples of values.

3 - Pyomo: extensible optimization modeling in Python
Carl Laird, Michael Bynum, William Hart, John Siirola, Anya Castillo

Available commercial and open-source optimization modeling packages support generic modeling by separating modeling constructs from instance data through concepts like sets, parameters, and parameterized constraints. However, their model representations are limited to constructs that directly correspond to established solver inputs. In general, this implies that mathematical programs must be expressed as either linear or nonlinear algebraic models; that is, a list of variables, an algebraic objective expression, and a list of algebraic constraints. In contrast, the Pyomo environment is designed to be an open, Python-based environment for building complex, optimization-based strategies. This includes explicit support for expression interrogation, extending the language with additional modeling components, and performing model transformations. In this presentation, we highlight some of the recent developments in the Pyomo project, including problem decomposition and mixed-integer nonlinear programming.

4 - Opening Xpress Mosel
Susanne Heipcke, Yves Colombani

The modelling and solving environment Xpress Mosel has recently been turned into free software. At the same time it has become possible to use alternative Mathematical Programming solvers from within the Mosel language, in addition to the FICO Xpress Solvers. In this contribution we show how other LP/MIP or NLP solvers can be connected to Mosel for use within the Mosel language. The benefits of using high-level modelling languages for the implementation of real world applications (such as speed to deployment and ease of maintenance) are widely recognised by practitioners. The possibility of being able to freely choose from a large set of solvers comes in answer to a recurring request by Mosel users in academia and industry. After giving an overview of the different options how to connect solvers to the Mosel language, namely (a) solver-specific low-level implementations as Mosel modules (examples provided on examples.xpress.fico.com and via Github: https://github.com/fico-xpress/mosel) (b) connecting Mathematical Programming solvers that support the .nl file format via the new 'nlsolv' module this talk will provide a hands-on demo of how to use alternative solvers for an optimization problem formulated as a Mosel model.

■ WA-58
Wednesday, 8:30-10:00 - 4D UPV 2.4

Machine Learning and Data Analysis II

Stream: Emerging Applications of Data Analysis
Chair: *Vadim Strijov*

1 - Cracking open the black box: a neural network based option valuation model
Yi Cao, Jia Zhai

In this paper, we formulate a novel hybrid gated neural network (hGNN) based option valuation model. We start from the no-arbitrage constraints in the option pricing theories, design a multiplicative structure for the hidden neurons to maintain the differentiability of the hidden layer, and select the slope and weights in the input layer to satisfy the no-arbitrage constraints. Finally, we build two small modules as pre- and post-processing modules to improve the input-output mapping capability. A separate neural network is developed for predicting option implied volatilities, which is one of the inputs needed for option pricing models.

Hence our economically meaningful model extends and contributes to the traditional machine learning literature which predominantly focuses on designing complex neural network algorithms to enhance the learning capability for a better mapping performance. It also contributes to the literature on option pricing as it derives analytical expressions for European option Greeks, usually considered the black box in academia and the finance industry.

In the empirical analysis, we apply our hGNN model to daily put and call options written on major stock market indices including the S&P 500, the Nasdaq, the FTSE 100, the DAX 30, and the Hong Kong Hang Seng indices. Our empirical evidence shows that the hGNN model offers accurate option-implied volatility, risk-neutral probability distributions, and option prices.

2 - Narrow big data in streams: exact vs. approximate computing
Michal Cerny

A narrow dataset is formalized by an (n x p)-matrix A, where n stands for the number of data points, p stands for dimension and n is significantly larger than p. We assume the following computational model: the data matrix A is accessed row-by-row in a one-way direction, meaning that once a data point is accessed, it is dropped and is available never again. The memory is restricted to a polynomial in p (but not n). This is a natural computational model for big narrow datasets, since the whole data matrix A cannot be stored in memory, the data points (rows of A) are supplied in a stream and the memory is able to store a single data point or a short sliding window (of polynomial length in p) and perform operations with objects of size polynomial in p, such as (p x p)-matrices. The crucial question is whether usual data-analytic procedures, such as linear regression, can be evaluated in this model exactly (i.e., producing exactly the same results as in the usual all-data-in-hand model), or whether it is necessary to perform a data reduction step (which causes a certain loss of information) prior to the data-analytic procedure of interest. Using Kolmogorov complexity arguments, we can show that e.g. L1-norm estimators in linear regression are not computable exactly in the stream data model, while L2-norm estimation is possible without any loss of information. We also focus on regression diagnostics in the stream data model.

3 - Temporal clustering of time series via threshold autoregressive models
Cem Iyigün, Sipan Aslan, Ceylan Yozgatligil

The primary aim in this study is grouping time series according to the similarity between their data generating mechanisms (DGMs) rather than comparing pattern similarities in the time series trajectories. The approximation to the DGM of each series is accomplished by fitting the linear autoregressive and the non-linear threshold autoregressive models, and outputs of the estimates are used for feature extraction. Threshold autoregressive models are recognized for their ability to represent nonlinear features in time series, such as abrupt changes, time-irreversibility and regime-shifting behavior. The proposed clustering approach is mainly based on feature vectors derived from above-mentioned models estimates. Through the use of the proposed approach, one can determine and monitor the set of co-moving time series variables across the time. The efficiency of the proposed approach is demonstrated through a simulation study and the results are compared with other proposed time series clustering methods.

4 - Multimodel selection for classification problems
Alexander Aduenko, Vadim Strijov

The problem of multimodel selection for classification problems is considered. Multimodels are used when a sample cannot be described by a single model. This happens when features' weights depend on the features' values. In such a case a single generalized linear model cannot describe the relation between features and target variable. Though a multimodel is an interpretable generalization of a single model case, it can contain large number of similar models. This leads to a low forecast quality and lack of interpretability. Several pruning algorithms are constructed based on the suggested method for statistical model comparison. The method is based on introduced similarity function for posterior distributions of models' parameters. Properties of this function are considered and asymptotic distribution of its values for coincident generalized linear models is obtained. The notion of an adequate multimodel is introduced, for which all the constituting models are pairwise statistically distinguishable. Diagonal maximum evidence estimate of features' weights' covariance matrix is used for feature selection. Asymptotic degeneracy of non-diagonal estimate of this matrix is proved. A method is suggested to detect and handle multicollinear features. Several computational experiments show significant improvement in classification quality for real datasets and substantial multimodel size reduction.

■ WA-59

Wednesday, 8:30-10:00 - 4D UPV 2.5

Bidding in Power Markets

Stream: Technical and Financial Aspects of Energy Problems
Chair: *Christoph Graf*

1 - Transmission expansion investment coordination: transition from game-theoretic to mechanism design approach
Sambuddha Chakrabarti, Mohammad Reza Hesamzadeh, Yaser Tohidi

In this paper, we will consider the long term transmission capacity expansion and investment coordination problem in the situation, where there are multiple Transmission Planners (TPs). In such a setting, each of the agents acts to maximize its own utility. However, this is contingent upon what other TPs are planning to do. Here, we first present a game-theoretic approach to solve this problem, along with the simulation results. Subsequently, we point out, that this approach might not always lead to maximizing the overall social surplus of the bigger geographical region, and hence, we propose a mechanism design,that needs to be implemented by the Market Overseer (MO). This mechanism design, we propose, is based on distributed Stochastic Optimization algorithm.

2 - Trading strategies for continuous intraday markets
Gilles Bertrand, Anthony Papavasiliou, Anthony Papavasiliou

The introduction of uncertain renewable energy in power systems has increased the variability in electricity markets. This variability has increased the need for correcting system dispatch closer to real time. An interesting option for making these corrections is to trade in the continuous intraday market, which explains the increase of liquidity in this market recently. For instance the selling volume in the German continuous intraday market has evolved from 1005 TWh in 2010 to 2461 TWh in 2013 and finally to 4070 TWh in 2016.

In this presentation, our contribution is threefold: - First, we model the problem of bidding in the continuous intraday market using Markov decision processes. - Second, we use policy function approximation in order to solve this Markov decision process. The idea is to define a parametric policy. A simple example of parametric policy is to take as parameter a threshold price below wich we buy power and another threshold above wich we sell. - Finally, we optimize the parameters of this policy using reinforcement learning.

3 - Stochastic-dynamic optimization of a joint strategy for day-ahead bidding and intraday trading
David Wozabal, Nils Löhndorf

Power market participants with flexible capacity, such as pumped-hydro storages, face a complex decision problem when trading on spot markets for electricity. As electricity for the same delivery periods trades in multiple markets, bidding decisions must be made jointly, while at the same time open positions can be rebalanced as time moves on. Moreover, as the number of delivery periods is high, participants make multiple decisions simultaneously under uncertainty about future electricity prices.

We consider a hydro storage operating on the German spot market and propose a Markov decision process to model the day-ahead intraday trading problem. All open positions, storage content, as well as the dynamic factors that drive day-ahead and intraday prices are represented as state variables. The state space of the proposed MDP is continuous and high dimensional, so that the resulting optimization problem is computationally intractable and an optimal solution can only be found by approximation. To obtain a quality approximation of the optimal solution, we use approximate dual dynamic programming (ADDP). Based on a case study of a fast pumped-hydro storage unit, we demonstrate that ADDP provides near-optimal solutions for model instances with hourly time resolution and a planning horizon of one week. Our results indicate that the resultin strategy leads to allocation of flexible capacity to the intraday market and that bidding decisions are non-trivial.

4 - Market clearing and best response bidding in the Italian power market
Christoph Graf

The Italian day-ahead market for electricity is split into zonal markets when transmission congestion is present. If transmission constraints are binding, the supply side receives zonal prices while the demand side faces a uniform purchase price. Using actual generation unit level bidding data, we derive a best response bidding model incorporating the Italian market design. i.e., the zonal structure as well as the uniform purchase price. Preliminary results suggest that firms take the probability of facing a congested market into account when bidding into the day-ahead market.

■ WA-60

Wednesday, 8:30-10:00 - 4D UPV B.5

ERC session

Stream: EURO Special Sessions
Chair: *Giovanni Felici*

1 - The European Research Council Grants: an opportunity not to be missed for scientists in Operations Research and Applied Mathematics
Giovanni Felici

Giovanni Felici - Seconded National Expert at ERC Executive Agency, Scientific Project Adviser for the Computer Science Panel Research Scientist at Institute for System Analysis and Informatics, Italian National Research Council

After its first ten years of activity, ERC has confirmed its worldwide recognition as one of the most effective funding agencies for bottom-up, creative high-risk / hi-gain research in all fields of science. ERC current set-up remains unchanged in the forthcoming Framework Program, thus confirming the ERC prominent role in European Research. In this talk we will understand the basic principles on which ERC is based; how Starting, Consolidator, Advanced and the re-launched Synergy ERC grants schemes work; what are the conditions to apply, and where Operations Research and Applied Mathematics stand among ERC funded projects. Some examples of interesting projects will also be discussed. Finally , time will be devoted to the discussion and to address questions from the audience.

Wednesday, 10:30-12:00

■ WB-01

Wednesday, 10:30-12:00 - UPV Nexus

Teaching experiments are condemned to be successful

Stream: Keynotes
Chair: *Ramon Alvarez-Valdes*

1 - Teaching experiments are condemned to be successful
Maria Antónia Carravilla

The stream on Teaching OR/MS is part of the EURO and IFORS conferences since 2010 in Lisbon. The contributions of our community for this stream show that skilled teachers with their enthusiasm and experience are able to create teaching experiments that, as we once heard, are condemned to be successful.

In this talk, we will go through several examples of teaching and learning practices in OR, selected from the ones presented in the Teaching OR/MS stream, from the literature, and from direct contributions. These reported practices may be based on case studies, specific software packages, classroom games and also projects which engage students and help to develop the competencies that are needed to apply the OR/MS methods in practice. There are also some experiments on assessment for large groups of students and on gamification. We believe that experiments like these ones, adapted to the specific program, and to the number and concrete characteristics of the students, may form the building blocks for rather successful OR/MS courses.

■ WB-02

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S101

DEA, Logistics, Transportation

Stream: DEA: Applications
Chair: *Julián Benavides*

1 - Towards automatic suggestions of aircraft trajectory change for mitigating high traffic complexity based on an air traffic control difficulty index
Sakae Nagaoka, Hiroko Hirabayashi, Mark Brown

Air traffic controllers handle air traffic to maintain safe separation and provide orderly traffic flow. The capacity of airspace depends on factors associated with air traffic control difficulty such as workload and traffic complexity. To design airspace and operational scenarios for air traffic management (ATM) systems, a method for estimating the difficulty using aircraft trajectory data is desired. We proposed a difficulty index which can be derived from information such as a geometrical distance in four-dimensional space. Through simulations for evaluating the difficulty values of simulation scenarios based on the proposed method, we found that the air traffic controllers' reactions to a given traffic condition slightly differ from person to person. We try to find an optimum strategy of trajectory changes for mitigating a detected high traffic complexity based on the difficulty values at a given time in a few simulated scenarios under several assumptions. This is a preliminary study to move forward towards the development of an automatic decision support tool on trajectory changes needed to mitigate high traffic complexity. This presentation briefly describes its approach and some results.

2 - Decision-making in a multi-choice environment: a study of shipping carriers in US
Shalabh Singh, Sonia Singh, Ankit Khandelwal

This research paper studies the multi-choice scenario faced by a decision maker while shipping packets to geographically dispersed locations. A varying range of carriers with multiple time and cost options give rise to multi-choice parameters. In order to equip the decision maker for facing such a situation, a multi-choice bi-objective transportation problem with fuzzy as well as crisp parameters has been modeled. Firstly, a fuzzy transportation problem covering time critical services from a single shipping carrier has been solved with the objective of minimizing total shipment cost along with the makespan. Further, multi-carrier options have been explored for cases where the data is not too dynamic for non-time critical services, and the problem has become crisp as a result. The algorithms presented in both the cases have been validated using instances from UPS, FedEx and USPS as the choice of shipping carriers, in ten major cities of the United States. The results obtained from the analysis have been found to be very encouraging, satisfactory and implementable.

3 - Peak workload and performance of parcel delivery companies

Amir Shabani, Gabor Maroti, Wout Dullaert, Sander de Leuw

Performance of parcel delivery companies (PDC) during peak periods has received little attention in the literature. Significant order upsurges imply higher turnover rates and revenues for PDCs but they can also negatively impact inbound and outbound operations, e.g., capacity issues and transportation delays, thereby decreasing service level and customer happiness.

Operations of 17 depots of a large PDC in the Netherlands are considered during four weeks of December in which three demand-affecting events, namely Sinterklaas, Christmas and New Year's Eve take place. We notice that the performance of each considered PDC is not entirely independent in each week, meaning that performance results of a week affect the performance of the next week. Moreover, to have a clear picture of PDCs' performance, both inbound logistics and outbound operations should simultaneously be considered, which implies network structure of the PDCs.

This paper proposes a novel network dynamic data envelopment analysis approach to evaluate PDCs during peak workload periods. To increase the applicability of the proposed model in general, and its utility for supply chain managers in specific, our proposed approach evaluates PDCs by a set of common weights. Empirical findings reveal that none of the PDCs was efficient during four weeks of December in both sorting and distribution process. The analysis has resulted in managerial recommendations to improve performance during peak workload period.

4 - A mobile tool for operational decision support in aircraft dispatch

Hemmo Koornneef, Wim Verhagen, Ricky Curran

During the daily operation of aircraft unexpected failures are a regular cause of flight disruptions, leading to decreased operational performance. Whenever such an unscheduled event occurs, a maintenance technician has to assess the defect and determine if the aircraft is able to safely perform the next flight. This process is known as the dispatch decision and depends on many variables. While the alternatives for aircraft dispatch are limited, the process of determining the appropriate corrective maintenance tasks and assessing the outcome for each decision alternative is a complex and time-consuming process. Currently, a maintenance technician on the platform has very limited access to relevant information and combined with the short time span available for decision making (i.e., 45 minutes in a typical turnaround), the result is often far from optimal with respect to operational performance. This research proposes a novel Decision Support System framework for aircraft dispatch to aid the maintenance technician in decision making. The aim of the system is to increase operational performance by aggregating all required information, evaluate the alternatives and ultimately propose a ranked set of feasible dispatch alternatives to the technician. Implementation follows by means of a mobile tool that enables onsite decision making, based on both the explicit knowledge captured in information systems and the tacit knowledge of the technician.

■ WB-03

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S103

Maintenance Operations

Stream: Production and Operations Management
Chair: *Ayse Sena Eruguz*

1 - Design of multi-component periodic maintenance programs with single-component models

Joachim Arts, Rob Basten

Capital assets, such as wind turbines and ships, require maintenance throughout their long life times. Assets usually need to go down to perform maintenance and such downs can be either scheduled or unscheduled. Since different components in an asset have different maintenance policies, it is key to have a maintenance program in place that coordinates the maintenance policies of all components, so as to minimize costs associated with maintenance and downtime. Single component maintenance policies have been developed for decades, but such policies do not usually allow coordination between different components within an asset. We study a periodic maintenance policy and a condition based maintenance policy in which the scheduled downs can be coordinated between components. In both policies, we assume that at unscheduled downs, a minimal repair is performed to keep unscheduled downtime as short as possible. Both policies can be evaluated exactly using renewal theory, and we show how these policies can be used as building blocks to design and optimize maintenance programs for multi-component assets.

2 - Joint optimization of production scheduling and condition-based maintenance planning

Bram de Jonge

We consider a single machine that is needed to process incoming jobs, but that also requires maintenance because of deterioration. The aim of this study is to jointly optimize these interfering processes. The incoming jobs have various lengths, and a cost is incurred for the total time that a job is in the system. Deterioration of the machine ultimately leads to failure, this interrupts the current processing of a job and results in high corrective maintenance cost. However, the monitored deterioration level of the machine can be used to schedule less expensive preventive maintenance activities in between jobs. We formulate the problem as a Markov decision process (MDP) and determine optimal policies that indicate when to process which job and when to perform maintenance. We provide insights on how production scheduling and maintenance planning interact.

3 - A simulation-based evaluation of dynamic task prioritization in maintenance management

Dietmar Neubacher, Nikolaus Furian, Clemens Gutschi

Availability of machines is crucial to be an efficient manufacturer and well organized maintenance operations are key to success. Due to the advancement of condition monitoring and predictive analytics the field shifts more and more from corrective to preventive task fulfillment. Nevertheless, especially in automotive production lines trained experts are rare and responsible for many machines simultaneously. As a consequence, the scheduling of corrective and preventive tasks significantly influences the performance of the production system. Despite the fact that researchers have already identified this correlation, merely straightforward heuristics are used in practice. Yet, these algorithms ensure an acceptable output of production lines, but the question arises if their performance could be further improved, by utilizing algorithms for dynamic bottleneck detection. Therefore, a conducted simulation study determines the reliability of selected bottleneck detection algorithms and evaluates their applicability to prioritize repair tasks. Multiple algorithms have been evaluated in course of this study. Results show that the Active Period Method outperforms simple ad-hoc heuristics and also other algorithms from literature. Further, the dynamic bottleneck ranking proves to be a suitable method to prioritize repair orders.

4 - Maintenance optimization for multi-component systems with a single sensor
Ayse Sena Eruguz, Rob Basten, Lisa Maillart

We consider a multi-component system in which a condition parameter (e.g., vibration or temperature) is monitored by a single sensor that gives a system level information. The outcome of monitoring indicates whether the system is functioning properly, is defective, or has failed. However, the condition signal does not reveal which component in the system is defective or has failed. The decision maker needs to infer the exact state of the system from the current condition signal and the past data, in order to decide when to intervene for maintenance. A maintenance intervention consists of a complete and perfect inspection followed by component replacement decisions. We model this problem as a partially observable Markov decision process.

■ WB-04

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S104

Optimal Control Applications I

Stream: Optimal Control Applications
Chair: *Gernot Tragler*

1 - Optimal prevention and adaptation in a stochastic flood model - an application of vintage-models in socio-hydrology
Michael Freiberger, Alexia Prskawetz

In economic models stochastic environmental shocks and their economic impacts are formulated fairly general. In contrast, e.g. flood damage in socio-hydrological flood risk models is more precisely defined. However these models lack the aspect of economic decision making, as they use a priori defined decision rules. Recent literature managed to account for this discrepancy by introducing a hydrological system into a neoclassical economic growth model, but was still missing the combination of stochastic flood events and optimal decisions. Our aim is to incorporate the economic aspects as well as the stochastic properties of floods into a socio-hydrological model. Therefore we formulate a two-stage optimal control problem with random switching time representing a neoclassical economy facing stochastic flood appearances. We apply a new technique to transform the arising problem into a vintage-structured optimal control model and thereby obtain new insight on the solution from an analytical and numerical point of view. We are able to identify critical parameters incentivising investments in flood protection.

2 - Optimal investments of a firm generating emissions: a bi-objective approach
Andrea Seidl, Richard Hartl, Peter M. Kort

We consider the problem of a firm which decides about investing into a capital stock needed for production. On the one hand the firm wants to maximize revenues, on the other hand it wants to minimize emissions which are caused by production. To handle the conflicting objectives, we apply the epsilon-constraint method. We sequentially solve the optimal control problem for the first objective with the constraint that the second objective must be lower than its value from the previous step minus a constant. In this manner we calculate the Pareto front for different initial state values. We analyze the impact of multiple objectives on the optimal solution path and determine a threshold curve which separates areas on the Pareto front differing with respect to the long-run steady state which is approached.

3 - Optimal control, endogenous population growth and the dynamics of economic growth
Jose-ramon Ruiz-tamarit

Population is usually considered an exogenous variable in standard economic growth models. This aggregate is modeled by assuming a constant rate of population growth. However, when population growth decisions are endogenized connecting the fertility choice with economic variables, the standard growth model changes abruptly its structure. Here we study the optimal growth problem, in continuous time and controlling for the rate of population growth. The involved exponential population growth at an endogenous and probably variable rate, transforms the standard optimal control problem with a constant rate of time preference, into another dynamic optimization problem where the Pontryagin's maximum principle cannot be directly applied. This is due to the "effective" non-constant discount rate, which makes preferences intertemporally dependent. In fact, depending on the degree of intergenerational altruism the discount rate depends on past and current rates of population growth. This new perspective of the optimal population problem establishes a clear link with the literature on endogenous discounting. Therefore, we adapt and apply the mathematical methods developed there to solve our own problem. Finally, we analyze the Hamiltonian dynamic system that emerges from the first order conditions under different technological scenarios, and we characterize both the short- and long-run dynamics.

4 - Radicalization of terrorists: an optimal control approach
Gernot Tragler

We consider an optimal control model based on the general idea that one can use diffusion models to analyse the spreading of radical ideas and the impact of corresponding counter-terror measures. The two state variables describe the number of supporters of a terror organisation and the number of actual terrorists, respectively. The terrorists are those who actually plan and perform the terror attacks, while supporters provide financial or logistic support, hide terrorists, spread the ideas of the terror organisation, etc. We include three different control variables to account for the different impacts of measures directed against the supporters and the terrorists, i.e., prevention, law enforcement, and the level of intelligence. The objective is to minimize the discounted stream of total costs consisting of the costs arising from terror attacks and those for the three control instruments. Model parameters are partly derived from empirical observations. The analysis covers results from the uncontrolled model, a version with optimal constant controls, and finally the optimal control model with dynamically optimal counter-terror measures.

■ WB-05

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S105

Orienteering and Traveling Salesman Problems

Stream: Vehicle Routing and Logistics Optimization I
Chair: *Alejandro Montoya*

1 - The competitive pickup and delivery orienteering problem for balancing carsharing systems
Layla Martin, Stefan Minner

In one-way car sharing systems, vehicles become unevenly distributed over time, as customer movements in general are unbalanced. Thus, operators reposition their fleet periodically. A common approach to rebalance car sharing systems is solving the corresponding pickup and delivery TSP. With the rise of Mobility as a Service solutions, operators find themselves in direct competition to each other, as customers (i.e., randomly) choose any available car. We formulate this as the competitive pickup and delivery orienteering problem (C-PDOP), in which both operators maximize their individual profit taking the actions of the competitor into consideration. The underlying routing problem, the pickup and delivery orienteering problem (PDOP), combines facets of pickup and delivery TSPs with TSPs with profits, as locations are only visited if they are profitable. We prove that the C-PDOP possesses pure-strategy Nash equilibria and provide an iterated best response algorithm (IBR) to find these. The IBR requires at most four calculations of the (NP-hard) PDOP. Playing the Nash equilibrium, operators are never worse off than by ignoring competition. In a numerical experiment, we show that the improvement by playing is significant over assuming to be the only market participant. We also compare the utility of the C-PDOP to a monopolistic, a welfare-maximizing, and an outsourcing solution.

2 - A hybrid algorithm for the family salesman problem
Ana Paias, Raquel Bernardino

We address the family traveling salesman problem (FTSP) which is a generalization of the known traveling salesman problem (TSP). In the FTSP the set of cities is partitioned into several subsets which are called families. The costs of traveling between each pair of cities and between the depot and each city are known. The objective is to determine a minimum cost route that: i) begins and ends at the depot; and ii) visits a given number of cities in each family. We present a non-compact integer linear programming model for the FTSP that was able to efficiently solve benchmark instances, up to 280 cities, whose optimal values were unknown. For the higher dimensioned instances, the ones that the exact method is unable to solve, we propose a hybrid heuristic designed to take advantage of the good characteristics of the exact method. We start by using the exact algorithm to solve an FTSP sub-problem which is induced by considering a subset of the families and then we complete the solution using implicit variable generation and a heuristic method. With this hybrid heuristic we were able to improve the best known upper bounds from the literature which were obtained using an iterated local search algorithm.

3 - Optimization of the LPG distribution system for an oil company
Özlem Çağlayangil, Necati Aras

This study is conducted with the aim of optimizing the LPG distribution system of an oil/gas company in Turkey. The current system consists of different components such as suppliers, truck depots, gas stations. The problem faced by the company is to determine which of 54 suppliers to work with, how much to buy from chosen suppliers, and when and how much to deliver to 810 stations. The distirbution takes place by 2 different type of vehicles of different capacity. The company has 11 different parking lots with a different fleet. We adopt a solution framework that consists of two stages. The first stage involves the partitioning the stations into clusters, where the total cost of purchasing and delivery is computed by approximating the delivery part. In the second stage, an inventory routing problem is solved to find the detailed distribution plan. For both stages we formulate mixed-integer mathematical programming models, which are solved by Cplex 12.8. The solutions obtained are promising in the sense that the total cost given by the solution is lower than the cost incurred by the company.

4 - The team orienteering problem with time-dependent profit
Alejandro Montoya

This study introduces the Team Orienteering Problem with Time-Dependent Profit (TOP-TDP). In this problem, the profit value of each customer changes during the planning period. Changes in the profit over time are represented as a discrete function. The objective of the TOP-TDP is to find a set of routes that maximize the total collected profit, such that: each customer is visited at most once; the total duration of each route is not greater than a maximum given time limit; and the number of routes are less than a number of vehicles. The TOP-TDP is inspired by freight distribution of some products to customers in emerging markets, where the total served demand at a customer depends on the arrival time of the vehicle. However, this problem can arise in other contexts such as in the tourist industry, where the profit can depend on events or congestions during a day at a given place.

We propose a mixed-integer linear programming formulation of the TOP-TDP that, running on a commercial optimizer, can solve small instances of the problem. For solving large-scale instances, we propose a simple two-phase heuristic. Firstly, our heuristic generates a pool of routes through a randomized constructive heuristic. Secondly, our approach assembles a TOP-TDP solution by solving a Set Partitioning formulation over the routes stored in the pool. We present computational experiments on both randomly generated instances and real-world data from a company.

■ WB-06

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S106

Stochastic Modeling and Simulation in Engineering, Management and Science III

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Chair: *Christopher Kirkbride*

1 - An integrated simulation-optimization framework for complex emergency medical services
David Olave, Stefan Nickel, Philipp Fath, Melanie Reuter-Oppermann

Health Care is one of the most important activities to ensure life quality for human beings, specially in critical situations such as accidents, natural disasters, terrorism or when acute ailments exist. In these cases, Emergency Medical Services (EMS) face big challenges due the complex nature of pre-hospital events. Complementary, Agent-based simulation is an excellent approach to find new strategies for facing this complexity. In this presentation, we implement a agent-based and discrete-event simulation model which is integrated with an optimization approach for deciding dispatch ambulance strategy. The goal of this methodology is to improve response times, service level, fairness and robustness in a real time framework. Furthermore, we present some computational results related to our approach.

2 - Coordination in ride hailing platforms: an agent-based approach
Harit Joshi, Saral Mukherjee

Global taxi market is estimated to be worth more than 100 billion USD in 2017. It has witnessed an evolution from a traditional decentralized model in which taxis operated independently to organizations owning and managing the fleet to multi-sided platforms matching supply and demand. Coordination is central to unlocking value through matching demand and supply. The value of coordination has not received due importance in the literature on ride-hailing models. In this paper, we aim to understand the value of coordination for different stakeholders like drivers and customers in various ride-hailing platforms. We evaluate the influence of situational contexts like spatial and temporal distribution of demand and supply, characteristics of customers and taxi drivers and network characteristics like traffic congestion on the value of coordination and propose a network-based model to analyze the ride-hailing phenomenon. We present analytical results for simple cases and build an agent-based simulation (ABS) for more realistic situations. We evaluate the impact of different decision-making rules for agents as well as the interaction between driver and customer agents on coordination using an ABS model.

3 - Simulation of passenger flows at a constrained cruise port: evidence from the island of Santorini
Michail Karpathiou, Fotios Katsigiannis

This paper implements a discrete event simulation model that depictures the landside passenger flow of a popular cruise terminal located in Santorini, Greece. The developed conceptual framework can be applied as a generic approach to other similar cruise ports. In brief, we propose a micro simulation model which represents in detail among many other elements, passenger flows towards a nearby touristic settlement by considering three transport alternatives i.e. cable car, stair path and donkey guides . We identify that the bottleneck of the examined system is the cable car which is the main tourist preference capturing more than 90% of the total traffic. This situation has also being reported by the local authorities and the port administration. Our work goes beyond the validation of the problematic situation by conducting a revenue loss analysis while also examining different capacity and service rate scenarios examining the spilled demand as a function of the average queue length. Finally, we conclude by evaluating potential enhancements to the examined system that could increase its profitability.

4 - Diffusion and adoption of technological innovations in the Mar del Plata cooperative sector: the invisibility of their work
Alicia Zanfrillo

The contagion of innovations originates in small groups of pioneers that influence a larger group known as imitators, developing a channel of great influence on the next ones interested in the incorporation of a product or service. In the emerging Argentine market the adoption of technologies is explained by the imitation effect rather than by a few precursors. The advantage of knowing the potential market for a new technology allows the definition of policies that facilitate its propagation in the target groups. The purpose of the work is to model the behavior of Mar del Plata cooperative sector in the access to internet resources in order to promote the dissemination of these technologies on the market potential. From the marketing perspective, a quantitative research of a descriptive type with techniques of secondary source analysis is undertaken to obtain, with the mathematical formulation of Bass (1968), the parameters of the speed of adoption of the presence of internet. Subsequently, an agent-based approach was used to simulate the incorporation into the Information Society considering: a) the dynamic nature of the potential market given the permeability to the life cycle of these entities and b) the presence of complementary products such as social media. The resulting adoption curve resembles the original one in a slow penetration of the market, constituting a challenge to promote its inclusion in the new economy.

■ WB-07

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S107

Scheduling with Resource Constraints I

Stream: Scheduling with Resource Constraints
Chair: *Morteza Davari*

1 - Optimizing naval flight event schedules at training ranges
Robert Dell, Robert Slye

This talk presents an integer linear program (ILP) to plan naval flight events at United States Naval Air Station Fallon training ranges. Fallon (consisting of over 240,000 acres and its surrounding airspace in Nevada) experiences heavy demand for its training ranges from both resident and visiting units. Our ILP serves as an aid to help planners deconflict the many varying requests for these ranges and to prioritize their use. The ILP's primary prescriptions provide a daily flight event schedule over a month that includes unit, event, day, start time, and range assignment that adhere to constraints on individual range availability, support aircraft, aircraft turnaround time, event prerequisites, and emitter availability. We present sample results for over 300 event request over a month.

2 - Scheduling and lot-sizing with considering controllable processing time and fixed carbon emission
Mehdi Bijari, Seyed Milad Mirnajafi Zadeh

In this paper, a new model has been presented for the simultaneous lot-sizing and flow-shop scheduling problem with controllable processing time and considering the limitation in carbon emission. The objective function minimizes the total sequence dependent setup cost, inventory holding cost, production cost and back order cost. Product demand is different in every period. Capacity of each machine is limited and non-stationary. Each machine has different, discrete and finite processing speeds.Access to machine is limited due to predictive maintenance plan. Each machine produces a percentage of scrap and the rate of waste production depends directly on the speed. The considered problem is NP-Hard. Sample problems have been randomly generated to do the experiments. The Solution time has been investigated, after solving instances.The solution time results evidence the efficiency of the model. Also influence of a constraint instead of penalty in the objective function has been studied, the computational results show that the constraint would decrease the CPU time by 30 percent.

3 - Precedence theorems and dynamic programming solutions for the precedence-constrained single machine weighted tardiness problem
Salim Rostami, Stefan Creemers, Roel Leus

Schrage and Baker (1978) proposed a dynamic programming (DP) algorithm to tackle precedence-constrained sequencing on a single machine. The performance of their DP, however, is limited due to memory insufficiency, particularly when the precedence network is not very dense. Emmons (1969) and Kanet (2007) described a set of precedence theorems for the problem of sequencing jobs on a single machine in order to minimize total weighted tardiness; these theorems distinguish dominant precedence constraints for a job pool that is initially without precedence relation. In this paper, we connect and extend the findings of the aforementioned articles to the problem of precedence-constrained single machine scheduling to minimize total weighted tardiness. We develop a framework for applying Kanet's theorems to the precedence-constrained problem. We also propose a DP algorithm that utilizes a new efficient memory management technique for solving the problem to optimality. Combining these two, our procedure outperforms the state of the art for instances with medium to high network density.

4 - A generic solution method for scheduling with inventory constraints
Morteza Davari, Jeroen Belien, Patrick De Causmaecker, Roel Leus

In this paper, we develop a generic solution method to solve a number of scheduling problems with inventory constraints. Our proposed method is an iterative dynamic programming approach that, in each iteration, produces lower and upper bounds that eventually converge to optimality. We study the behavior of the method on parallel machines, on a single machine and on problems with and without release dates and with different (regular) objective functions. Computational results suggest that the method outperforms most of the approaches that are available in the literature for many of the specific problems studied.

■ WB-08

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S108

Optimization Problems on Graphs and Networks

Stream: Combinatorial Optimization I
Chair: *Michele Monaci*

1 - Decision diagrams for solving a prize-collecting sequencing problem
Johannes Maschler, Günther Raidl

Decision diagrams (DDs) have shown to be a powerful tool for solving combinatorial optimization problems (COPs). Essentially, DDs represent a COP's solution space comparable to a dynamic programming's state graph. As the size of DDs grows in general exponentially with the problem size, relaxations of DDs are typically considered. Such relaxed DDs describe an overapproximation of the solution space, while being much smaller than the original DD. Hence, they represent discrete relaxations of the problem often yielding tight dual bounds. A prominent way to compile good relaxed DDs is by starting with a trivial relaxed DD and to perform incremental refinements. After each refinement, a better approximation of the set of feasible solutions is obtained. In previous approaches, the order of the applied refinements is predetermined. We consider a price-collecting sequencing problem for which such a predefined strategy is not applicable. We propose for this reason an incremental refinement algorithm that decides dynamically, based on the current best bound, what to refine next. The second part of our work is dedicated on deriving good primal solutions from a relaxed DD. It is based on the observation that the refinement removes many infeasible and in our case also suboptimal parts from the search space and provides a promising starting point for primal heuristics. Preliminary results show that strong primal and dual bounds can be obtained quickly which are then improved over time.

2 - Solving the order batching and picker routing problem as a clustered vehicle routing problem

Babiche Aerts, Trijntje Cornelissens, Kenneth Sörensen

The clustered vehicle routing problem is a recently introduced variant of the capacitated VRP in which customers are grouped into clusters. This is useful, e.g., for courier companies who commonly divide their distribution area in (micro-)zones, and assign zones to vehicles rather than individual customers. In the clustered VRP with soft cluster constraints, a vehicle must visit all customers in its assigned clusters, but may do so in any order. The clustered VRP (with soft cluster constraints) bears a large similarity with one of the most important problems in warehouse management: the (integrated) order batching and picker routing problem. The aim of this problem is to assign orders (clusters) to pickers (vehicles) and then determine the sequence in which each picker needs to pick the products (customers) in its orders. Notwithstanding the similarities between both problems, there are some differences, mainly in the structure of the data. The most important difference is that customers in clusters are geographically close, whereas products in orders may be scattered all over the warehouse. Nevertheless, the structural similarity between both problems begs the question whether solution methods developed for the clustered VRP may be instrumental in solving the order batching and picker routing problem. To this end, we test a heuristic developed for the former problem on instances for the latter, and study the adaptations which are required for it to perform efficiently.

3 - Monotonicity and conformality in multicommodity network-flow problems

Daniel Granot, Frieda Granot

Our main objective is to develop a monotonicity theory for minimum convex-cost parametric multicommodity network-flow problems defined over general graphs. Our results allow us to determine when it is possible to predict, without numerical computations, the direction of change of optimal multicommodity flows resulting from changes in arc-commodity parameters. In particular, we provide necessary and sufficient conditions that for every cost function satisfying some other mild conditions there exists an optimal multicommodity flow for which the flow of a commodity in a given arc a is nondecreasing (resp., nonincreasing) in the parameter of a distinct commodity in arc b. These conditions are that either (i) there are only two commodities and the underlying graph is series-parallel or (ii) there are three or more commodities and the graph is 2-isomorphic to a suspension graph. A characterization of the precise pairs of arcs for which the above monotonicity result holds is also provided.

4 - An empirical investigation of network polarization

Celso Ribeiro, Ruben Interian

This work proposes and explores a new quantitative characterization of the polarization phenomenon in networks. New tools for evaluating the polarization of a network are presented. We first characterize the homophily of each node individually. We depart from the definition of a new measure of the homophily of the nodes of a network and we consider the homophily distribution over the nodes as a primary indicator of the strength of polarization. Next, to address the polarization of the network as a whole, a probabilistic approach is developed. The approach is based on the straightforward computation of empirical cumulative distribution functions of sampled data from the network. These empirical distributions provide a more insightful understanding of the status of the network. They may be used not only to compare the polarization of groups of nodes or entire networks, but also to estimate the impacts of external interventions in terms of node polarization. The usefulness of the approach is illustrated on several case studies associated with real-life networks from different sources. Two graph optimization problems arising in this context are formmulated and explored to deal with the reduction of polarization: (1) the maximum number of treated nodes and (2) the minimum-cardinality balanced edge addition problems.

■ WB-09

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S109

Data Science in Optimization Algorithms

Stream: European Working Group: Data Science Meets Optimization

Chair: *Andrew J. Parkes*

Chair: *Daniel Karapetyan*

1 - Quick termination of poor performers in automated algorithm configuration

Daniel Karapetyan, Andrew J. Parkes, Thomas Stützle

Much of automated algorithm configuration is concerned with choosing the best algorithm out of a given set. This process is expensive as it usually requires full-scale testing of each algorithm, i.e. running the algorithm for a specified amount of time on several instances. Naturally, a poor performer can be detected earlier, saving computational resources. A well-developed approach (racing) is concerned with terminating after testing the algorithm on a subset of the test instances. Instead, in this talk, we study another approach focusing on termination of each of the test runs early. Our method is based on collecting the data along the run of the tests. We train our system to terminate poor performers as soon as the signal is strong enough to make the decision. We demonstrate a simple strategy that significantly reduces the overall experiment time while still finding 99% of the top algorithms. In future, we hope to use more advanced data science techniques to exploit the rich data that can be collected, to further improve the efficiency of the method. In our experiments, we use the Conditional Markov Chain Search framework, as it is specifically designed for automated generation of combinatorial optimisation algorithms.

2 - Features of genetic algorithms realization for the Euclidean combinatorial optimization problems

Oleksii Kartashov

Let C be an arbitrary combinatorial set. We carry out a one-to-one mapping of onto some subset E of the arithmetic Euclidean space. The set obtained as a result of such a mapping is called Euclidean combinatorial set. The specific properties of Euclidean combinatorial sets allow us to propose original approaches to the realization of genetic algorithms (GA) for solving optimization problems on these sets. As an individual (gene), we will consider the sequence of coordinates of the point of E. The crossover operator is of the greatest interest in this GA implementation. One of the most common ways of a crossover is to exchange of a parts from parent individuals. Unfortunately the resulting descendants may not belong E. A natural approach to obtain valid descendants is the solution of the problem of projecting an arbitrary point onto the set E. The solution of the problem for various classes of Euclidean combinatorial sets is known. Developing this approach it is possible to propose the other ways of obtaining descendants. For example, a new descendant may be obtained as a linear combination of parent individuals with coefficients determined by the values of the goal function at these points. The better the value, the greater the ratio. The proposed approaches were realized for the problems of optimal placement of a set of circles of different radii without mutual intersections, which was reduced to the optimization problem on set of permutations.

3 - Metaheuristics for the search for SAT heuristics
Andrew Burnett, Andrew J. Parkes

For local search to be effective it often requires internal heuristics in order to decide which moves such be made. Designing such heuristics is often the task of an expert, and can require significant efforts and time. Hence, it is a natural goal to automate the creation of such heuristics. This has previously been addressed by genetic programming (and other evolutionary methods). In this talk, we will discuss the potential for metaheuristics to create heuristics. The specific context is that of propositional satisfiability (SAT) and a set of local search methods known as 'WalkSAT'. We will discuss the potential for machine learning methods to enhance this search process.

4 - Machine learning of the quality of machine-generated heuristics
Andrew J. Parkes, Ender Özcan, Asghar Neema Mohammad Beglou

Previous work has shown that it is possible to automatically generate heuristics for the online bin packing problem. Furthermore, these heuristics significantly outperform human generated heuristics. However, there are two outstanding challenges: the search for heuristics can be slow as it is a form of simulation or expensive optimisation; the heuristics have no evident explanation, and this limits resulting scientific insights and generalisations. In this work, we study potential usages of machine learning to provide quickly computed surrogates and also to provide explanations of the space of heuristics.

■ WB-10

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S110

MCDA and Environmental Management I

Stream: Multiple Criteria Decision Aiding
Chair: *Luisa Paolotti*
Chair: *Filippo Fiume Fagioli*

1 - Assessing the sustainability of different poultry production systems: a multi-criteria approach
Luisa Paolotti, Lucia Rocchi, Antonio Boggia, Cesare Castellini, Adolfo Rosati

The aim of this study is to assess the sustainability of three different poultry production systems, in order to evaluate their suitability to address human food needs, as well as their environmental sustainability, economic feasibility and animal welfare. The three systems compared are: a conventional intensive indoor system, a free range system and a free range system combined with an orchard (where chickens graze in an orchard instead of in an area solely dedicated to the birds). A model based on multi-criteria decision analysis was developed, using PROMETHEE I and II. Environmental criteria were estimated using a life cycle assessment, while economic and social criteria were both collected on farms and from literature. The analysis took into account the preferences of different stakeholders involved in the production (farmers, consumers, scientists). The combined system ranked at the top position according to all three groups of stakeholders, followed by the free range and then the intensive systems. To complete the assessment, a sensitivity analysis was conducted, showing that this ranking was quite stable, as only 4 of the 20 criteria considered had rank reversal.

2 - Discrete multi-criteria methods for election of lands use alternatives in the Toro river hydro-basin (province of Salta, Argentina)
Juan B Grau, Jose M Anton, Rocio C. López, José A. Gualotuña, Diego Andina, Federico Colombo, Ana M. Tarquis

The Study Area is a part of Toro river hydro-basin situated in the Lerma Valley, in the Province of Salta, in the Argentine Northwest. It is a fertile small zone with loess soils and a temperate climate. It has around 11.600 ha., with approximately 60.000 inhabitants, of which 350 are beneficiaries of the actual irrigation projects. At present, the main activity is tobacco production, but due to regressive commerce and low prices, it is necessary to study a compressive plan to reorganize the land use and the "Modus Vivendi" of the population. That needs hydraulic management actions, improving the irrigation systems. The authors, from UCASAL and UPM, trained in agro studies, complemented with applied Decision Support Systems (DSS) including Discrete Multi-criteria Methods (MCDM), have applied them as an aid for planning to transform the uses of soils in these areas. They have used ELECTRE, AHP and Weighted PROMETHEE methods with a system of criteria grouped as environmental, economic and social, to guide actions and policies for use and conservation of these lands. The paper concentrates on these discrete MCDM, and on the alternatives indicated with them, and that could be used to propose recommendations for farmers and to aid the decision makers to elaborate the policies combining public and private actions, including conservation of soils and hydraulic management measures, population training activities.

3 - Assessing urban vulnerability: a hybrid multi-criteria decision-making process for East Naples (Italy)
Maria Cerreta, Giuliano Poli

Assessing the urban vulnerability is an open challenge for decision-making. According to the last report of the IPCC, the climate change influences natural and human systems by producing modification to their sensitivity, exposure and response capacity. It is clear that an understanding of the drivers affecting the meaningful changes to the landscape' Social-Ecological System (SES) is primary and it must be managed when tackling sustainability issues. The approaches of spatial evaluation and Hybrid-Multi-Criteria Decision-Making (H-MCDM) are able to support categorising, weighting and mapping of values with the purpose to identify priorities and select preferable solutions. Moreover, the Group multi-criteria decision making (GMCDM) offers wide opportunities for stakeholders if the Geographic Information System (GIS) implements the spatial visualisation of vulnerability and supports the experts to identify priorities clusters. This contribution focuses on two main questions for assessing urban vulnerability. The first concerns the uncertainty about the choice of a specific vulnerability model, and the need to share a common language for specialists with a different background. The second concerns the hybridisation of multi-criteria methods in order to lead a Spatial Decision Support System (SDSS) that detects critical urban vulnerability areas and localizes the intervention priorities. The approach has been tested on the east part of the city of Naples (Italy).

4 - Farm sustainability assessment: how to conciliate economic and environmental objectives
Filippo Fiume Fagioli, Luisa Paolotti, Antonio Boggia

The objective of this work is to present how Multiple Criteria Decision Aiding (MCDA) can be efficiently applied in the agricultural sector, in order to evaluate the level of sustainability of farms production activities. Farm management, which has a multidimensional structure and in which several different aspects have to be considered at the same time, is central for a sustainable development. In farm management, it is fundamental to take into account multiple criteria, considering not only the economic aspects related to farmer profitability, but also those connected with environmental protection and sustainability, maximizing economic benefit and maintaining the services and quality of natural resources over time. The aim of this work is to develop an MCDA tool for Decision Makers to implement sustainable planning strategies within farms. Using the Italian FADN Database (Farm Accountancy Data Network - RICA), farms with different cultivations in Italy have been evaluated, considering both economic (e.g. gross production value, total costs, exc.) and environmental criteria (e.g. quantity of pesticides and fertilizers used), in order to assess the level of sustainability of each cultivation, and consequently to draw useful guidelines for sustainable planning and management.

■ WB-11

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S111

E-Commerce & Social Media

Stream: Business Analytics
Chair: *Stiene Praet*

1 - Collecting and analyzing customers experiences from Trip Advisor social media

Carla Vairetti

Sentiment analysis or opinion mining is currently one of the most studied research fields. It aims to determine the attitude of people with respect to some topic. For example, businesses always want to find consumer opinions about their products (or services).

Limited research has been conducted applying social media analysis in hospitality research. One of the most important fields where Sentiment Analysis has a greater impact is in the industrial field. Small and big companies, as well as other organizations such as governments, desire to know what people say about their marques, products or members.

TripAdvisor is a travel website that provides rich travel-related information of reviews detailing travelers' experiences with hotels, restaurants, and tourist spots. The purpose of this paper is explore diner perceptions of Chilean restaurants, using 40,212 comments coming from 757 Chilean restaurants.

Additionally, we use econometric to analyze, interpret and make predictions about Chilean restaurants. An exploratory study allows us to understand if the efforts made by restaurants in the marketing area help to predict restaurant's rankings, to explain the rating of restaurants across the words and to find underlying topics in order to help to predict restaurant's rankings.

Conclusions and recommendations, to improve the quality of service, are provided in this work.

2 - Dfficiency in multi-channel retail chain store: a two-stage DEA approach with environmental factors and e-commerce indicators

Cristina Ciobanu, Kristof Coussement, Koen W. De Bock

Performance evaluation is crucial for multi-store retail firms in an intensely competitive environment that shifted from single to multi-channel. Consequently, we expect the integration of digital channels in the retailing operational environment to impact the performance of physical channels. This paper is a study case that investigates this premise, providing the literature with two contributions. First, driven by the high pace of growth of retail e-commerce sales, this study extends previous research on retail chain store efficiency analysis by enriching the traditional, operational indicators with e-commerce metrics. Second, an innovative two-stage Data envelopment analysis (DEA), i.e., a robust non-parametric technique, is used to identify exogenous factors with potential influence on store's efficiency. To this purpose, we employ the data of a major French DIY chain to calculate the technical efficiency for 105 stores, based on operational and e-commerce indicators, and determine the environmental factors that influence the store efficiency. Furthermore, we examine the impact of the e-commerce indicators on efficiency, considering two different model specifications, one including these digital metrics and another excluding them. Overall results suggest significant environmental factors impacting the store efficiency and support the importance of the e-commerce indicators for a comprehensive analysis of the store efficiency in a multichannel environment.

3 - Ssocial network analytics in micro-lending

María Óskarsdóttir, Cristian Bravo, Bart Baesens, Jan Vanthienen

Traditionally, in credit scoring, people's banking history is analyzed to assess their creditworthiness and to determine their reliability when paying back their loans. However, as data is continuously being generated in more volume and variety than ever before, there is foundation for new credit assessment approaches, in particular by incorporating new variables to capture borrower behavior going beyond simple repayment history. Specifically, variables that describe people's behavior have been shown to be good predictors of creditworthiness. In industry, this is being utilized by the means of smartphone applications, which facilitate micro-lending. These applications analyze the data generated when the phone is used to decide whether the person should be granted a loan. The impact of these platforms is especially important in developing countries where large portions of the population do not have any banking history, and therefore no means of receiving a loan in the traditional way. In this study, we apply social network analytics techniques to analyze a micro-lending smartphone application dataset. We build networks in various ways to capture different components of social interaction and similarity among users. These networks are then used and featurized for building scorecards and to determine which network effects are most predictive of creditworthiness. Furthermore, we discuss how the data can be utilized for fraud detection and product adoption.

4 - A data mining approach to analyze political communication on Twitter

Stiene Praet, Walter Daelemans, Tim Kreutz, Peter Van Aelst, Stefaan Walgrave, David Martens

Twitter is increasingly used by political parties to communicate with voters and media. However, existing works in political science focus largely on traditional media to study the intensity of political communication on certain topics, using manual encoding of the documents or word frequencies. Therefore, we propose a new data mining-based methodology to answer two main questions: which topics do parties communicate about on Twitter and how consistent is their communication on these topics? Classification models are built to predict political party based on the topic(s) of a tweet, where topics are defined by experts or data-driven. Our analysis was performed on 52.000 tweets by members of seven Flemish political parties in the winter of 2017. The expert and data-driven topics show that overall, political parties talk about the topics for which they have a reputation of competence. At the same time, our evaluation in terms of discriminative power (AUC) and interpretability of the topics reveals interesting nuances: extreme left and right parties communicate much more consistently about their topics than moderate parties. Also, additional complexities in party communication on Twitter are discovered, including event-driven communication, stylistic differences and the influence of party characteristics. We hope that this research will spark further multi-disciplinary collaborations to reveal insights into communication in the political world.

■ WB-12

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S112

Optimization and Simulation in Port Logistics

Stream: Maritime Transportation
Chair: *Dario Pacino*

1 - Job scheduling rail-mounted gantry cranes in an intermodal rail-road terminal

Michiel Van Lancker, Greet Vanden Berghe, Tony Wauters

An intermodal rail-road terminal (IRRT) is a logistical facility that transships containers between trains and trucks, thereby functioning as an interface for freight between rail- and road networks. Rail-Mounted Gantry Cranes (RMGs) are of crucial importance with respect to IRRTs, given that they are generally responsible for performing all its associated transshipments. These cranes span the entire width of the terminal, arching over tracks, roads and a temporary storage yard, and are mounted on a single rail system, meaning it is impossible for one crane to cross another. Because transshipping containers is a relatively slow activity, RMGs constitute a major bottleneck in IRRTs and, by extension, the freight transportation network as a whole. It follows that the efficient operation of these RMGs can have a large impact on the operation of the IRRT. In the presented research, the optimization problem of job scheduling for gantry cranes in an IRRT is studied. In this problem, each job corresponds to the transshipment of a single container, with the RMGs subject to non-crossing constraints. Scheduling the RMGs constitutes only a part of the terminal's total operations, other examples being the assignment of parking positions to trains and trucks, or the assignment of containers to positions on a train. It is therefore also worthwhile examining the effects of using different objective functions while optimizing on produced schedules in the context of a real use case.

2 - Landside container handling operations at an automated container terminal
Amir Gharehgozli

We study the operational problem of loading and unloading trains at a container terminal. Trains are served by two gantry cranes which spreads over all trains on parallel tracks next to each other at the terminal landside. Multiple terminal trucks are available to move containers from the stacking area to a drop off lane next to the train tracks and vice versa. In this paper, we first develop new integrated stochastic models for analyzing the performance of overlapping loading and unloading operations at the landside and develop design insights. These models capture the complex stochastic interactions among the gantry cranes, terminal trucks, and stacking area processes. Using these integrated models, we are able to check the performance of different stack layout configurations on loading and unloading operations. Second, we develop a mixed integer programming model to evaluate the effect of design level measures and parameters on the operational performance.

3 - An approach towards the container terminal management problem (CTMP)
Leif Meier

The Container Terminal Management Problem (CTMP) consists of several interdependent sub-optimization problems that are nowadays still often solved independently and within a sequence, leading to large optimization potentials. We did experiments with the well-studied Berth Allocation (CTMP-sub) -Problem as a key starting point for maritime operations and studied its behaviour from both, an operations and a strategic point of view using a realistic data set. Having classified a list of restrictions from real world scenarios, we propose their mapping into existing BAP models and its related sub-problems in a simple way to expand their applications and flexibility as a part of our strategy to approach the CTMP optimization potentials.

4 - A hybrid heuristic for the flexible ship loading problem
Jonas Christensen, Dario Pacino

The emergence of the mega-container vessels puts container terminals at an increased pressure. Bigger vessels require more crane moves per vessel, and terminals are under pressure to minimise the turnaround time for the vessels. Minimizing the turnaround time makes it possible for the carriers to realise more of the savings potential that comes with the bigger vessels, as they will not have to catch-up on the sea to stay on schedule because of port delays. For the terminal, improving productivity and minimising turnaround times helps to free up berth positions, and clears up capacity for another vessel.

Acknowledging that improving terminal productivity is a shared goal between the carrier and the terminal, the Flexible Ship Loading Problem investigates a collaboration between the terminal and liner shipping companies. The liner provides the terminal with a stowage plan based on container classes. The terminal then has the flexibility of determining the position of the specific containers, as long as it adheres to the provided stowage plan, while also scheduling transfer vehicles to retrieve the container from the yard and deliver it in front of the crane. Doing so will give the terminal better conditions for minimising the turnaround time for the vessel.

In this talk, we wish to present a new mathematical model for the Flexible Ship Loading Problem, and a hybrid heuristic to solve the problem. Both of which improves the state-of-the-art.

■ WB-13
Wednesday, 10:30-12:00 - SOUTH BUILDING UV S201

Financial Literacy and Risk Measurement

Stream: Financial Modeling, Risk Management and Managerial Accounting
Chair: *Alain Chevalier*

1 - Value and momentum in energy markets
Rita D'Ecclesia

A long literature finds that, on average, value stocks outperform growth stocks and stocks with high positive momentum outperform stocks with low positive momentum. Clifford Asness, AQR Capital Management (2013). When investor want "to beat the market" various approach may be used to assess the various stock performance. Two important capital market phenomena are the "Value" and "Momentum effect" used to explain investor's choices. Large debates are going on involving the Asset pricing studies and investor's aims. The momentum effect could work well for commodities and in particular for energy commodities. The aim of this paper is to analyse the price dynamics of energy commodities and to investigate the relationship between energy commodity prices and show how different risk drivers have come into play. Having analysed the behavior of energy commodity prices we measure how energy companies are exposed to energy commodity risks and investigate the momentum effect of energy commodities. Finally we test if the momentun effect could be used to provide information on energy company returns

2 - A generalized duration for mortality risk management
Marius Radermacher

Duration concepts are standard methods for measuring interest rate risks of portfolios. Macaulay duration, effective duration and Key-Rate duration are mostly used according to diverse types of yield curves. In this lecture, a generalization of the duration concept is presented, by using multi-dimensional Taylor series development. It allows to measure the interest rate risk based on forward rate yield curves. This idea will be adopted for actuarial purposes to investigate the sensitivity of mortality rates. Thus, it will give an opportunity for measuring the mortality risk of actuarial present values.

3 - Adaptive quantification of value-at-risk based on the energy distribution of asset returns
George Tzagkarakis, Frantz Maurer, Thomas Dionysopoulos

Capital requirements for financial institutions are based on the accurate quantification of the inherent risk. To this end, time is the important aspect for all the well-established risk measures, whereas risk managers make no explicit distinction between the information captured by patterns of different frequency content. Accordingly, the full time-resolution series is considered, regardless of the selected trading horizon. To address this issue, this paper proposes a novel value-at-risk (VaR) quantification method exploiting the time-evolving energy distribution of returns. Specifically, a time-scale decomposition is applied first on the returns series, followed by a nonlinear combination of the optimal subset of time resolutions for estimating VaR at a given trading horizon. Most importantly, our proposed energy-based method can be coupled with the commonly used, quantile-based, risk measures to enhance their performance. The experimental results reveal an increased robustness of our method in efficiently controlling under- or over-estimated VaR values.

4 - Going private transaction performance in emerging economies:a comparative study between Latin America and Asia
Alain Chevalier, Aurelie Sannajust

This paper is part of a worldwide research on private equity.We identify and explain the drivers of LBO operating performance in Latin America and Asia.We consider a large set of candidate drivers (financial,governance,cultural, microeconomic macroeconomic) and study their effects on performance on short and long terms.To conduct our study,we use Capital IQ as a data base as well as a hand collected data set covering LBOs Asian and Latin American countries.We use a large sample of transactions which occured between 2000 and 2015.To study the performance after delisting,we use OLS regressions.We introduce dummy variables which represent the different geographical areas. Our results show that GDP growth,industry growth and market return are important drivers that contribute to create value in LBOs.We also identify the famlily ownership and the leverage effects in Asia,the short term productivity and the tax effects in different countries,the long term return effect of public investors in some Asian countries.Among several contributions,this research allowed us to design a data basis which could be useful for other projects.

■ WB-14

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S202

ETHOR II Ethics and Societal Complexity II

Stream: OR and Ethics
Chair: *Dorien DeTombe*

1 - Is the Compram method usable by handling intergenerational poverty in Zodrenthe?
Simon Henk Luimstra

Intergenerational poverty described through the Compram methododogy

In ZO-Drenthe in the northern part of the Netherlands lives a rather great group of poor people. 1 of 9 children are being raised in poverty. In this researchperiod I discovered as a administrator some problems: eg the absence of a clear definition of poverty and the lack of a integrated policy.This journey is a theoretical session whereby I describe the elements of the Comprammethod and do some recommodations for handling this problem. The Comprammethod is constructed for the methodological field of social complexity. The goal is working towards a dynamic model with accepted interventions. In these methodology, attention is paid to the level of knowledge and sharing of knowledge, clashing rationalities, mutual power relations and emotions. The process is going after the last step in a programmatic approach with shared ownership. At this moment there is in ZODrenthe a notion of making policy based on the ideas of the methodology of handling the complex societal problem of intergenerational poverty. This issue is theoretical worked out to a basis conceptual model and will be enriched and will be practical implemented in three different administrations, Borger-Odoorn, Coevorden en Emmen. How is, in this process, handled with the element of knowledge, the element of power and the element of emotions? And what can you ad on the presented basic conceptual model? Is Compram an usufull tool in a local setting?

2 - Societal Complexity versus LEARN TO LIVE TOGETHER: contemporaneous 'Science-Culture-Religion Dialogue'. COMPRAM Methodology and 'Decisional Nomology' contributions
Nicolae Bulz

There is the OR community's related heritage, challenge, tensions/perspectives within the possible Science-Culture-Religion Dialogue'. In order to acknowledge the tragedy of war (mostly within the actual 100 years from the end of the WW1) at least the scientific community would advance any alternative solution comparing to the war oriented track of the 20 century - and no significant ideas/acts within the started 21 century.

There is the projects oriented (re)search from the still open International Consortium Generosity_Creativity_Solidarity: LEARN TO LIVE TOGETHER (hypothetical) reality, modeling/simulation/emulation and ideals generations - as a subtle turning point into the possible Network of Networks on.

The co-organizers of the current OR and Ethics stream into Euro Conference 2018 Valencia have synergic and original contributions within - i.e. Prof. dr. Dorien DeTombe's COMPRAM Methodology, and Prof. dr. Cathal Brugha's Decisional Nomology.

So, the study proceeds on the open Ethics and OR new realm onto the contemporary global (post-)crisis reverse as Inter/Trans/Co-disciplinary, Intercultural and Ecumenical approaches oriented within the thesis: Knowledge Society toward Consciousness Society. A related (f)act to tacit and explicit knowledge/innovation, and follow up consequences would draw up and extend an implementation of a 'Local' Nucleus of an IN OVO inquiring "Science-NATURE-Culture-SPIRITUALITY-Religion Meta-Dialogue".

3 - Inhabitants take responsibility of their health position
Hans Derks

The Dutch society is in transition. The transition must culminate in a society in which anyone who can take responsibility for his/her life and environment, where the government has only a facilitating role. The transition is a long-term development in the social domain, which has everything to do with individualization, emancipation and development in assertiveness. In Assen, they realized a new social institution which was meant to be the bridge between government and residents. Instead of improvement, the distance between government and residents enlarged. The domain where this issue focuses on is health, participation and sports.

We handle the issue with the COMPRAM-method (de Tombe 2015). The name of the process: Healty@Assen. The context is positive health, the health concept in which health, as the absence of disease shifts to the possibilities of the human being.. In this new concept of health it is about the individual, not about the disease. We use perceived health as assessment of health.

The problem statement is: How do we develop policy in the field of health, where the inhabitants take responsibility and do we get organizations behind inhabitants and the municipality in a supporting role? How do inhabitants come in the role of client? We defined 3 target-groups: Club of objective experts, Club of 13 with the most involved organizations, Club of 100 residents in their new role. In my presentation I show surprising outcome and the creative work methods.

4 - Equal rights and opportunities for women
Dorien DeTombe

The #MeToo reports in the media finally opened up the discussion of misbehavior of men towards women; a problem that is present over centuries in every country in every culture. With the #MeToo movement many people became aware that sexual abuse and humiliation in the family, on the workplace, in sports, in public areas and in religious circles should no longer be accepted. These daily abuses ruin women's lives. These abuses are related to difference in social power between men and women. Women abuse is a complex societal problem often presented as a cultural or religious habit that should not be torn at, however, human rights are women rights too. Now that there is an awareness this problem can be placed on the political agendas all over the world in order to protect women and children for mistreating by men. The problem can be analyzed, and changes can be suggested according to the Compram methodology to support the problem handling process. The Compram methodology, developed by Dorien DeTombe (2015), supports policy makers in finding, in a scientific based way, sustainable changes in a democratic way. The Compram methodology starts with the problem owner and a facilitator. In a six step approach the problem will be analyzed, defined, changed and evaluated by teams of experts and actors, including knowledge, power and emotion. With this methodology the problem will be analyzed step by step who benefits and who suffers from this misbehavior and how to change this.

■ WB-15

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S203

Scheduling Theory I

Stream: Scheduling Theory
Chair: *Kathrin Maassen*

1 - New approximate methods for the two-stage multi-machine assembly scheduling problem
Carla Talens Fayos, Paz Perez Gonzalez, Victor Fernandez-Viagas, Jose M Framinan

In this paper, we analyse the two-stage multi-machine assembly scheduling problem with the objective of minimising total completion time. A linear programming model and a new set of instances considering more than two machines at the second stage are presented. We also analyse the existing heuristics and metaheuristics, propose new ones and compare the corresponding solutions.

2 - Towards an effective column generation technique for solving large batch scheduling problems
Mendez Carlos, Mariana Cóccola, Rodolfo Dondo

Column generation (CG) is a decomposition technique widely used to efficiently solve a wide range of integer and integer-linear problem involving set-partitioning constraints such as vehicle-routing problems and crew-scheduling problems. Although CG became the leading optimization technique for solving many routing problems, just a few applications have been focused on short-term scheduling problems in the literature. Most algorithms were designed to only consider a single machine or multiple identical parallel lines and are poorly adapted to other configurations. Some of them are limited to solve identical parallel-machine scheduling problems by a CG approach. This paper increases the challenge by developing a novel MILP-based CG algorithm that is able to handle with single-stage short-term scheduling problem with non-identical parallel machines. Each generated column represents a feasible schedule on one machine and each feasible schedule is generated by solving a single machine sub-problem, which is based on a continuous time precedence-based MILP formulation. The best jobs allocation is chosen by the master problem. In order to generate the maximum number of feasible and profitable columns per iteration, the solver-options of the branch-and-cut package used for solving the slave problem are properly tuned. The iterative CG algorithm was developed by using the GAMS software and the computational results demonstrate the efficiency of this decomposition method.

3 - Scheduling with step-improving processing times
Eun-Seok Kim

We study a single machine scheduling problem of minimizing total completion time with step-improving processing times. For step-improving processing times, job processing times reduce by a job-dependent amount after a common critical date. We show that the problem is NP-hard in general. We formulate a Mixed Integer Programming model and develop an LP-based heuristic for the problem. Finally, we perform computational experiments showing that the proposed heuristic provides effective solutions.

4 - Simplifications and optimal solutions for the two-machine permutation flow shop regarding the diversity of processing times
Paz Perez Gonzalez, Kathrin Maassen, Jose M Framinan

In a two-machine permutation flow shop scheduling problem, the optimal makespan can be found in polynomial time using Johnson algorithm, while the problem with total flowtime objective is known to be NP-hard. Normally, test beds with processing times referring to a uniform distribution, U[1,99], are used since this distribution is known to produce instances which are hard to solve. Only a few works in the job-scheduling literature deal with other distributions, but using e.g. the normal or lognormal distribution might have advantages. Using these distributions, the coefficient of variation of the processing times (which we will call diversity of processing times) can be controlled and test beds with different levels of diversity can be generated. Depending on these levels of processing time diversity, several simplifications and methods for the 2-machine case can be used to generate optimal solutions. E.g. if no diversity exists on the first machine the flowtime can be easily computed using the dispatching rule Shortest-Processing-Time (SPT), even for a large number of jobs, instead of using heuristics or other solutions methods. An empirical study for the two-machine permutation flow shop with different levels of processing time diversity are shown.

■ WB-16

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S115

Discrete and Global Optimization III

Stream: Discrete and Global Optimization
Chair: *Thorsten Schmidt-Dumont*

1 - Piecewise linear function fitting via mixed-integer linear programming
Steffen Rebennack, Vitaliy Krasko

Piecewise linear (PWL) functions are used in a variety of applications. Computing such continuous PWL functions, however, is a challenging task. Software packages and the literature on PWL function fitting are dominated by heuristic methods. This is true for both fitting discrete data points and continuous univariate functions. The only exact methods rely on non-convex model formulations. Exact methods compute continuous PWL function for a fixed number of breakpoints minimizing some distance function between the original function and the PWL function. An optimal PWL function can only be computed if the breakpoints are allowed to be placed freely and are not fixed to a set of candidate breakpoints. In this paper, we propose the first convex model for optimal continuous univariate PWL function fitting. Dependent on the metrics chosen, the resulting formulations are either mixed-integer linear programming or mixed-integer quadratic programming problems. These models yield optimal continuous PWL functions for a set of discrete data. Based on these convex formulations, we further develop an exact algorithm to fit continuous univariate functions. Computational results for benchmark instances from the literature demonstrate the superiority of the proposed convex models compared to state-of-the-art non-convex models.

2 - Convex extensions in discrete optimization with their applications
Sergey Yakovlev, Oksana Pichugina

There exists a wide class of finite sets in the arithmetic Euclidean space that coincide with a set of vertices of their convex hull. Such sets will be called vertex-located sets (VLS). Properties of optimization problems on VLS and special methods for their solution are presented. A convex function defined on a convex hull of a finite set will be called a convex extension of the original function if their values coincide on the set. This research is based on theorems on an existence of convex, strongly convex, and differentiable extensions for functions defined on VLS. For an optimization problem on VLS with arbitrary objective function and functional constraints an equivalent mathematical programming problem with the corresponding convex extensions is proposed. Extremal properties of convex extensions for functions defined on VLS are studied. Sufficient conditions for a minimum of function on VLS, as well as its lower bounds for different classes of VLS are formulated. The research contains examples of VLS and algorithms for constructing convex, strongly convex, and differentiable extensions for optimization functions defined on these sets. The results are used to improve an efficiency of existing discrete optimization methods and to develop new approaches to optimization of special classes of functions on VLS.

3 - Black-box optimization for additive manufactured heat exchangers
Sebastien Cadalen

Additive manufacturing is a lever for efficiency improvement in the field of heat exchangers, as it enables a dramatic freedom in their design. However, this freedom comes along with an increased complexity in optimizing the exchanger to a particular purpose. This study deals with an air preheater with exhaust gas. To be competitive, the device must have a minimum weight and reach the desired performances in terms of pressure losses and heat duty.

The study was decomposed as follows: i) we used a dedicated process tool based on standard heat exchangers correlations; ii) we introduced additive manufactured designs. As correlations are not available, they were obtained thanks to Computational Fluid Dynamics (CFD). The process tool is then fed with theses correlations; iii) we fully automated a numerical chain including CFD and process simulation. Then, the constrained minimization problem was solved with various black box optimization algorithms.

The challenge comes from the CPU cost. Each design needs 8 simulations to build the correlations. The design space also shows infeasibility regions that could not be a priori determined. In average, 25 designs were tested per day and a total of 1,000 designs were tested.

Finally, the black box optimization algorithm has to deal with: lots of local minima, infeasibility, limited number of iterations. The introduction of new design and it optimization shows a gain of 20% on the weight for the same performance.

4 - A real-world application of the travelling salesman problem using non-deterministic data classification algorithms
Omer Celepcikay, Caner Okutkan, Egemen Berki Cimen, Emine Çelepçıkay

The traveling salesman problem has an important place in terms of public transportation. Today, Metro, Metrobus, Marmaray and Private Public Buses are playing a very important role in transportation in Istanbul city, because traffic density has always been a problem in the transition from the Anatolian side to the European side (and vice versa). For this reason, considering the metropolitan city of Istanbul as a test case, Metrobus transition points will be assessed as an effective tool as well as how to proceed in the case of future growth. In addition, the results of six different algorithms used in data analysis and classification will be compared with each other. Therefore, Rome, one of the largest cities in Europe, has been taken into account in order to measure the problem-based difference. This study aims to show the use of modern techniques in urban planning.

■ WB-17

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S205

Stochastic Programming

Stream: Stochastic and Robust Optimization
Chair: *Petr Lachout*

1 - Quantization of Lévy measures
Mark Anthony Caruana

In this paper we find the optimal approximation of the measure associated to the Lévy-Khintchine representation via a convex combination of a finite number N of Dirac masses. The quality of such an approximation is measured in terms of the Monge-Kantorovich or the Wasserstein metric. In essence, this procedure is equivalent to the quantization of measures. This procedure requires prior knowledge of the functional form of the measure. However, since this is in general not known, then we shall have to estimate it. It will be shown that the objective function used to estimate the position of the Dirac masses and their associated weights (or masses) can be expressed as a stochastic program. The properties of the estimator provided are discussed. Also, a number of simulations for different types of Lévy processes are performed and their results are examined.

2 - A branch and bound procedure for the stochastic assembly line balancing problem
Johannes Schnitzler, Raik Stolletz

We analyze the assembly line balancing problem where tasks have to be assigned to stations with the goal of minimizing the number of stations used. Task times are stochastic, leading to the possibility of incomplete work pieces. Therefore, we consider a constraint on the probability of finishing a work piece within the given cycle time. A sampling model is developed to account for generally distributed task times. We present a bidirectional branch and bound procedure in order to solve the model to optimality. A numerical study compares the performance of the algorithm to the solution with standard solvers.

3 - Stochastic optimization on a graph with random decision points
Petr Lachout

We introduce a graph with nodes activated in random times. The task is to optimize gain from a random process dynamically developing in time. The process is controlled at nodes of the given graph which are active. We intent to give a description of the random process and presents some basic relations, results.

References: [1] Bonnans J.F., Shapiro A.: Perturbation Analysis of Optimization Problems. Springer-Verlag, New York, 2000 [2] Rockafellar R.T., Wets R. J.-B.: Variational Analysis. Springer-Verlag, Berlin, 1998. [3] Shapiro A., Dentcheva D., Ruszczynski A.: Lectures on Stochastic Programming: Modeling and Theory. MPS-SIAM, Philadelphia, 2009.

■ WB-18

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S206

E-commerce Related Problems in Transportation and Logistics

Stream: Transportation
Chair: *Xuezhen Guo*

1 - A last mile delivery paradigm using microhubs with crowdshipping
Jane Lin

The rise of e-commerce and same-day delivery service has led to an increased freight movement in urban areas adding to the negative externalities, including traffic congestion, noise, pollution and greenhouse gas emissions. This study proposes and evaluates the performance of a microhub delivery paradigm in combination with crowdshipping. Performance was evaluated by comparing with the traditional hub-and-spoke delivery service paradigm. Evaluation measures included vehicle miles travelled, number of trucks and crowdshippers dispatched as well as fuel consumption and total daily operating cost. The proposed Microhubs with Crowdshipping (M+C) delivery paradigm aim to reduce the number of trucks and crowdshippers dispatched and their fuel usage as well as associated operating costs. The study also investigates the effect of key operational parameters such as network size, customer demand, crowdshipper payment and penalty rate on the performance of the proposed paradigm. It is found that the performance of the proposed M+C delivery paradigm is mostly suited for high customer demand irrespective of the network size. Higher penalty rate increases the attractiveness of the proposed M+C delivery paradigm, while higher crowdshipper compensation decreases the attractiveness of the proposed paradigm. The M+C delivery paradigm is also more suited to the cities with medium to high customer density and less so for cities with low customer density.

2 - A vehicle routing planning method for the city logistics considering carbon emissions

Jun-Der Leu

The concept of city logistics is to apply physical-flows methods and tools to the physical goods distribution within the geographic area of one city. Due to its logistics and distribution activities only occurred in one city scope, normally the small transport vehicles are used; again, considering the traffic flow is more crowded in the urban, the physical goods are usually distributed at low speed, and the cars have to complete goods delivery without turning off the vehicle when the transportation cars reach the demand point. These characteristics above lead to an increase in carbon oxide emission. So, how to carry out efficient delivery of goods in the urban area, taking into account the negative effects of carbon emissions will be an issue for the future urban development. Although the application of Vehicle Routing Problems (VRP) in regional logistics has developed several different scenarios, these models are mostly based on the geographical distribution of large-scale logistics, and cannot fully meet the city logistics characteristics mentioned above. In this paper, a distribution planning method for city green logistics which considers the logistics efficiency as well as carbon emissions is developed. This method is based upon the city distribution networks model, adding the characteristics of traffic congestion, the speed of vehicles, and the function of carbon emissions. The results are presented in heuristics and be validated by a case application.

3 - Optimizing line haul routing for a Brazilian e-commerce company

Marcio Oshiro, Felipe Moreira, Henrique Watanabe

B2W Digital is the leading e-commerce company in Latin America that operates in Brazil. It controls most part of its logistic operations which includes 10 distribution centers,6 hubs and almost 200 operational centers spread throughout the country. The company delivers millions of orders each year. Hence, Vehicle Routing Optimization can greatly decrease the company's transportation costs. This work presents a real world variant of the classical Vehicle Routing Problem formulated to attend the needs of the line haul routings for B2W. This variant considers many kinds constraints, e.g. time windows, pick-up and delivery, vehicle capacity, heterogeneous fleet, multiple depots, 2-echelon routes, among others. Also Brazil is a large country with a large population and this makes the problem even more complex given the high number of possible origins and destinations. Another concern is the trips that require more than 1 day, since labor laws affect duration and cost of these trips. A MILP formulation for this routing problem is presented and, since the real instances are too large, the approach proposed is a matheuristic. This matheuristic decomposes the problem in pairs of pick-up/deliveries and after solving a subproblem includes a new pair into the subproblem. At the end, an improvement phase is run.

4 - A conceptual framework for city logistics transition with crowdsourced delivery

Xuezhen Guo, Jacqueline Bloemhof, G.D.H. (Frits) Claassen

With the rapid global urbanization and boosted Business to Customer (B2C) e-commerce application, city logistics face unprecedented challenges of sustaining the increasingly demanding online-shopping delivery service at reasonable costs while mitigating the traffic related problems (e.g., the congestion problem, noise, air pollution in cities). Crowdsourced delivery (CD) as an emerging "sharing economy" innovation has great potentials of improving the current city logistics system and a transition on city logistics by integrating CD initiatives has been already on the way.

However, due to the short history of CD, there has been relatively little literature addressing this topic, not even to mention the conceptual development that specifically targets at CD integration to the city logistic system. This research develops a conceptual framework that aims to facilitate city logistics transition with the incorporation of CD initiatives using a phase-wise practice-based approach. A computer-based simulation study is conducted to demonstrate the usefulness and validity of the framework as well as the potential benefits that CD could bring to city logistics.

■ WB-19

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S207

Sustainable Operations

Stream: Supply Chain Management I

Chair: *Peter Berling*

1 - Impact of biomass commercialization on procurement strategy and environment in agricultural processing

Onur Boyabatli, Buket Avci, Bin Li

This paper considers an agricultural commodity processor that procures a commodity input to produce a commodity output in the presence of input and output spot price uncertainties. We examine the impact of commercializing the output waste as biomass on the procurement strategy and profitability of the processor. The processor can procure the input via quantity flexibility contracts from two suppliers, a local supplier with lower exercise cost and a far-away supplier with a lower reservation cost, in advance of the selling season and from the spot market on the day. After commercialization, the processor sells the biomass, that would otherwise go to the landfill, to a contracted buyer. We find that the optimal procurement strategy switches from single sourcing to dual sourcing in a certain region of contract parameters after commercialization. We also find that as the correlation between input and output spot prices increases, (i) the total reserved contract volumes increase, (ii) the local supplier gets increasingly preferable and (iii) the profit improvement from biomass commercialization decreases. Using a calibration based on the palm industry, we show that failing to update the procurement strategy after commercialization leads to a significant profit loss. Using a framework for assessing the greenhouse gas emissions along the supply chain, we show that the commercialization of biomass can do more harm to the environment due to the change of procurement strategy.

2 - Bioenergy supply chain network planning problem

Halit Uster, Gokhan Memisoglu

We consider planning and design of an extended supply chain for bioenergy networks (i.e., networks for multi biomass as well as biofuel logistics) in an integrated fashion while simultaneously addressing strategic and tactical decisions pertaining to location, production, inventory, and distribution in a multi-period planning horizon setting. In our modeling, we also explicitly incorporate realistic operational parameters, including biomass deterioration rates and transportation economies of scale. We devise an solution approach based on Benders Decomposition and present computational results demonstrating its efficiency on a wide-ranging set of problem instances. Furthermore, we develop a realistic case using data pertaining to the state of Texas and conduct an extensive analysis on the effects of varying input parameters on the design outcomes for a bioenergy supply chain network.

3 - New product diffusion in closed-loop supply chains

Emre Nadar, Baris Emre Kaya, Kemal Goler

We study the sales planning problem of a manufacturer who sells new and remanufactured versions of a product over a finite life cycle. We develop a dynamic model in which demand arrives according to a slightly modified Bass diffusion process and end-of-use product returns required for remanufacturing are constrained by the earlier sales. We analyze the effects of the key market and operational characteristics on optimal sales, manufacturing, and remanufacturing volumes. In our model the manufacturer may simultaneously improve its economic and environmental performance by partially satisfying the initial demand. This can indeed occur when innovators contribute more heavily than imitators to the diffusion process or an unmet demand is likely to be backlogged to be satisfied with a remanufactured product. But the optimal sales volume may increase with the backlogging rate when it is sufficiently high, leading to a poorer environmental performance. The manufacturer of a search good has the advantage of keeping future demand intact regardless of initial sales, compared to the manufacturer of an experience good. Partial demand fulfillment can thus be profitable for search goods under a greater number of imitators or a lower backlogging rate. If partial demand fulfillment is profitable for both goods, the manufacturer of a search good sells more to enable a sufficient returns volume for the larger future demand.

4 - The art of modeling and stable development of the world
Lyudmila Kuzmina

Research is devoted to fundamentals of modeling, and Higher Education problems. Modeling as Art is connected with the level/quality of Knowledge in areas of natural Sciences, multidisciplinary ones, with problems in training-teaching of Specialists in complex natural/engineering domains. The principles of subject teaching are discussed, which lead to activating / governing methods for Higher Education in any area. The modeling of systems thinking / system dynamics, applied to multidisciplinary objects of various nature, provides a sustainable World.

Subtitle of the presentation:

fundamental aspects of higher Education from viewpoints of both nonlinear analysis and Operational Research

■ WB-20

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S301

Decision Analysis for Investment Portfolio Selection and Resource Allocation

Stream: Decision Analysis and Decision Support Systems
Chair: *Mohammad Mehdi Hosseinzadeh*

1 - On various solutions of areas allocation problem
Sergey Shvydun, Fuad Aleskerov

Over the last years, the problem of overlapping territorial claims between different countries have become more acute in many regions. Potential prospects of areas exploitation (e.g. natural resources) or their location (e.g. important sea routes) have led to some potential tensions or even conflicts between interested parties which, in turn, create serious damage to the environment in the region, countries' economies and their inhabitants. Thus, there is a strong need to find some fair and peaceful resolution of these competing territorial claims. We consider the areas allocation problem from the mathematical point of view. Based on introduced model of utility values with respect to main resources and preferences of interested countries over disputed areas, we proposed several models of areas allocation. Two main approaches are used - each territory is allocated to a single country, and each territory can be allocated to several countries - so called shared allocation. To test the proposed models, we have also applied them to the problem of areas allocation in Barents Sea and other regions of the Arctic. As a result, we proposed several allocation scenarios and evaluated total dissatisfaction level of each interested party. We consider our work as an exercise to attract an attention of decision-making authorities since we strongly believe that such models and evaluations based on them can be helpful for the process of corresponding decision making.

2 - Investment frontier in mean-lower partial moment portfolio selection framework
Dipankar Mondal, Selvaraju Natarajan

Despite several advantages of lower partial moment (LPM) as a measure of investment risk, the variance is widely used just because of its computational simplicity and geometrical easiness. The portfolio selection under mean-LPM framework becomes more complex when proportional wealth is invested in risky assets as well as a risk free asset. This is because an investment frontier, which represents all linear combinations of a risk free asset and some arbitrary risky portfolio, is not always linear in the mean-LPM space. The linearity is obtained when the target is either risk free rate or mean return of overall investment portfolio. For other targets the linearity is not guaranteed.

In this paper, we study the shapes and behaviours of the investment frontiers regardless of any targets. Besides theoretically delineating several properties of the frontiers, we present empirical evidence to validate the analytical developments. We introduce three main three properites: convexity, monotonicity and convergence. Beyond these, we empirically observe a special behavior when mean return requirement changes. Since, the properties are developed without imposing any restrictions on the probability distribution of asset returns, they are unaltered in all scenario.

3 - DEA to support decision-making in portfolio problems
Mohammad Mehdi Hosseinzadeh, Sergio Ortobelli, Farhad Hosseinzadeh Lotfi

A great deal of concern among investors and academic researchers investigating modern portfolio problems is how to adopt the best fitting performance criteria over different market conditions. They typically use several criteria to reduce the dimensionality of the portfolio problems. In addition, adopting some asset selection criteria that select only efficient assets as portfolio choices reduces portfolio selection complexity. This paper is carried out by developing a consistent approach to deal with portfolios' asset selection problem with the Data Envelopment Analysis (DEA) as a non-parametric efficiency evaluation tool. DEA is a linear programming methodology to evaluate and assess the relative efficiency and to estimate the production frontier of Decision Making Units (DMUs) that employ multiple inputs and outputs. We consider different input/output sets such as static and dynamic criteria to evaluate assets efficiency scores with a 10-year ex-post analysis that includes the recent financial crisis. Finally, we select efficient assets for the portfolio and compare the ex-post wealth of portfolios obtained based on DEA approaches, a uniform portfolio strategy, and several risk-reward performance measures. The asset's efficient comparison points under different criteria sets, can provide useful insights to decision makers. The ex-post empirical comparison results support the proposed approach as a good tool for assets performance measure and portfolio problems.

■ WB-21

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S303

Applications of Optimal Control

Stream: Nonlinear Programming: Theory
Chair: *Hector Ramirez*

1 - Controlling recirculation rate in minimal-time bioremediation of natural water resources
Victor Riquelme, Alain Rapaport

We revisit the minimal time problem of in-situ decontamination of large water resources with a bioreactor, considering a recirculation flow rate in the resource as an additional control. This new problem has two manipulated inputs : 1. the flow rate of the treatment in the bioreactor (which enters nonlinearly in the dynamics because of the biological dependancy between the flow rate and the concentration at the output of the bioreactor) 2. the flow rate of the recirculation in the resource between the pumping and reinjection locations (which enters linearly the dynamics). Although the velocity set of the dynamics is non convex, we show that the optimal control is reached among non-relaxed controls. The optimal strategy consists in three sequential steps: 1. do not recirculate water and take the flow rate of treatment that maximizes the concentration decay in the resource. 2. recirculate water at maximum rate and carry on with the flow rate that maximizes the concentration decay. 3. carry on with recirculation but do not treat the water (i.e. bypass the bioreactor). Finally, we show on numerical simulations that significant gains in processing time can be achieved when controlling the recirculation flow rate.

2 - Characterizing the optimal profile of the open pit mine planning problem in the continuous framework
Emilio Molina, Jorge Amaya, Cristopher Hermosilla

In this work we address two problems: the final open pit problem (FOP), in which the optimal profile must only satisfy the slope condition, and the capacitated final open pit (CFOP), in which we add a capacity condition, imposing that the total mass to be extracted is limited by a given upper bound; for this two cases, the criterion is to maximize the total benefit.

Instead of using the well known block model approach through binary decision variables, our approach is based on continuous functional analysis, giving rise to optimization problems in an appropriate functional space (absolutely continuous functions), which allows for an imposition of slope constraints associated with geotechnical stability.

We derive existence results and investigate some qualitative properties of the solutions as, for example, the characterization of the border of the final pit, in the two-dimensional case. We essentially prove that the value distribution along the lower border of the optimal pit must be zero, when the slope and capacity constraint are not actives. This result comes from the tools provided by the calculus of variations and optimal control. Based on those properties, we propose an algorithm and present numerical results on some standard cases.

3 - Optimal control of biogas production for the chemostat
Antoine Haddon

In this work we deal with the optimal control problem of maximizing biogas production in a chemostat. The dilution rate is the controlled variable and we study the problem over a fixed finite horizon for positive initial conditions. We consider the single reaction model and work with a large class of growth rate functions. With the Pontryagin Maximum Principle, we construct a one parameter family of extremal controls of type bang-singular arc. The parameter of these extremal controls is the constant value of the hamiltonian. Using the Hamilton-Jacobi-Bellman equation, we identify the optimal control as the extremal associated with the value of the hamiltonian which satisfies a fixed point equation. We then propose a numerical algorithm to compute the optimal control by solving this fixed point equation. We illustrate this method with the two major types of growth functions of Monod and Haldane.

4 - Bioremediation of water resources: an optimal control approach
Hector Ramirez

This talk deals with the bioremediation, in minimal time, of a water resource (such as lakes, reservoirs, etc.) using a single continuous bioreactor. The bioreactor is connected to the reservoir through several pumps. Typically, one pump extracts polluted water and other on injects back sufficiently clean water with the same flow rate. However, we also analyse more complex pumps configurations. So, we state minimal-time optimal control problems where the control variables are related to the inflow rates of the pumps. For those problems, we analyse the existence of their solutions as well as their optimal synthesis (via Pontryaguin's principle). We also obtain, for some pumps configurations, explicit expressions of their value functions via Hamilton-Jacobi-Bellman techniques.

■ WB-22

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S304

Multiobjective Portfolio Optimization

Stream: Multiobjective Optimization
Chair: *Iryna Yevseyeva*

1 - Thematic portfolio optimization
Florian Methling, Rüdiger von Nitzsch

In recent years, thematic exchange-traded funds (ETF) have increased in economic significance. Investors in thematic ETFs have more than just financial objectives and gain a non-monetary added value from a thematic portion in their portfolios. Therefore, traditional portfolio optimization models which target only financial criteria cannot suit these investors' needs anymore. Nevertheless, to count in their thematic interests, investors adapt a core satellite strategy in which conventional core portfolios and thematic satellite portfolios are combined. Thus, these portfolios are separately optimized without further considering inter-portfolio correlation effects. Since modern portfolio theory has originally been established to, inter alia, optimize these correlation effects, portfolios can only be efficient by chance. Therefore, this study targets the correlation effects between conventional and thematic portfolios and introduces a tri-criterion thematic portfolio optimization model as an overall framework. Throughout a two-part analysis with tradable ETFs and a simulation with 250,000 draws and 1,750,000 portfolio optimizations performed, the status quo is compared to the new model. Quantifying the suboptimality, simulation results show a mean portfolio improvement of 6.23 % measured as relative yield enhancement. Further analysis concludes that the more narrowly a theme is being defined and the more particular it is relative yield enhancements can increase up to 46.88 %.

2 - Granular-based interactive portfolio optimization model for investment decision aids
Kao-Yi Shen, Gwo-Hshiung Tzeng

Portfolio optimization has been an important research subject in both financial and operational research (OR) societies, which leads to significant impacts in the global mutual fund markets. The present study attempts to propose a granule-based interactive approach to resolve the complicated portfolio optimization problem, which is based on the combination of decision-making methods and machine learning techniques. The expected advantages are threefold: (1) select the candidate stocks to form a portfolio with superior financial performance in the future, (2) identify the relative weight of each attribute of an investor by a multiple attribute decision-making (MADM) method, and (3) leverage the adjustable information-granule to form a changeable multiple objective decision-making (MODM) model for the portfolio optimization problem interactively. In here, the interactions reside among the investor's given preferences and the MODM model. If the MODM model fails to yield a solvable solution, this approach will adjust the size of information-granule on the considered attributes sequentially according to its importance of the investor. This innovative idea is inspired the concept of changeable spaces, proposed by Prof. Tzeng in MODM, which extends the classical Pareto and DeNovo solution. A conceptual research flow will be illustrated in the conference.

3 - Asset management optimization: a framework to reduce costs and risk for utilities management
Luis Dias, Luis Guimarães

Efficient and robust maintenance policies are of vital importance in asset management because of their fall-backs into the safety and economics of companies and plants operation. A maintenance strategy that takes both risk and costs minimization at the same level is often difficult to obtain. When the condition of a system can be continuously monitored and the equipment risk can be assessed, it is possible to combine Condition-based with Risk-based maintenance strategies aiming to obtain a policy that trades off risk with maintenance costs. In this work we aim to develop a framework capable of being generalized to several kinds of assets in the utilities industry that combines both Risk Based Maintenance (RBM) and Condition Based Maintenance (CBM). The goal is to determine the optimal degradation state in which maintenance should be performed when we consider the Decision Maker (DM) risk profile. The problem studied in this work is formulated as a multi-objective search aiming at simultaneously minimizing multiple objectives of interest such as risk and costs. For a closer approximation to real world problems, the model describing the evolution of the degrading system is based on the use of the Markov model and the Monte Carlo (MC) simulation. The maintenance policies for the studied assets will be generated using a MOEAs (Multi

Objective Evolutionary Algorithms) that determines which will be the ideal condition maintenance strategy considering the company profile.

4 - Cyber security portfolios selection under limited budget constraints
Iryna Yevseyeva, Michael Emmerich, Vitor Basto-Fernandes, Stefan Parpurov, Helge Janicke

Nowadays cybersecurity becomes a concern for most of the organisations. Hence, the decision should be made on how to allocate limited cybersecurity budget to the available set of controls for protecting a company in the best way. In this work, an approach for quantifying and selecting the most efficient portfolios from possible permutations of controls is provided. Several metrics are used to judge a portfolio's strength. Pareto front of optimal portfolios can be selected, allowing organisations to see different trade-off choices for different metrics and allowing organisation to choose one portfolio depending on which of the above metrics they value the most or using some well-known trade-off metrics. The approach is tested on a real breach data set and yielded interesting insight with regards to control effectiveness and the severity of various vulnerability categories.

■ WB-23

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S305

Lot Sizing III - Remanufacturing

Stream: Lot Sizing, Lot Scheduling and Production Planning
Chair: *Onur Kilic*

1 - A MILP model for closed loop production planning in the automotive industry: a case study
Julien Maheut, Angel Ruiz, José P. Garcia-Sabater

Throughout the last decade, the automotive sector has undergone an important transformation not so much because of the increase in complexity in the models offered to the market but also because of variants with increasingly shorter life cycles. Some production facilities initially designed for high production volumes and limited flexibility as is the case with the foam carousels of seats had to modify their management to face the new industrial realities. In this communication, we propose a multi-period, multi-product MILP model for planning the production of car foam from a closed-loop carousel where the batches and volumes to be manufactured must be programmed during each day, as well as there are restrictions on volumes of products to be stored. A sensitivity analysis where the impact of the number of changes, the storage capacity and the flexibility in the productive capacity on the level of service are analyzed.

2 - Perishability in integrated procurement and reprocessing planning of reusable medical devices in hospitals
Steffen Rickers, Florian Sahling

We present a new model formulation for a multi-product dynamic order quantity problem with product returns and a reprocessing option. The optimization includes the limited shelf life of sterile medical devices as well as capacity constraints of reprocessing and sterilization resources. The time-varying demand is known in advance and must be satisfied by procuring new medical devices and/or by reprocessing used and expired ones. The objective is to determine a feasible procurement and reprocessing schedule that minimizes the incurred costs. As even small problem instances are not solvable in reasonable time, a new heuristical approach is presented.

3 - Six sigma methodologies in airline operations
Ramesh Bollapragada

The purpose of the paper is to investigate the financial and operational benefits when deploying Six Sigma methodologies in airline operations. Six Sigma statistical analysis is used to measure the current performance of each critical metric involving the operational processes within international and U.S. domestic airline industry. Using six sigma level or the current sigma level (whichever is higher) as the benchmarking tool, this paper compares the compensation expenses caused by the variations in operational processes before and after the sigma level is achieved. The aggregate annual savings obtained across all the critical metrics is in the order of billions of dollars.

4 - The economic lot sizing problem with remanufacturing: new structural properties and polynomial-time heuristics
Onur Kilic, Wilco van den Heuvel

The economic lot sizing problem with remanufacturing considers a firm facing time-varying demands and returns over a finite number planning horizon. The demand can be met by manufacturing new products and remanufacturing returned products. It is assumed that new and remanufactured products are identical and regarded as serviceables. The firm holds serviceable and return inventories. The objective is to minimize production and inventory costs while satisfying demands on time. We provide structural results and develop a class of polynomial-time heuristics for this problem. The main behind our work is to decompose the problem into sub-problems which can be handled in polynomial-time. We identify the network flow structure of the problem and derive properties of its optimal solution. Based on these, we decompose the problem and show that sub-problems can be solved in polynomial-time. The decomposition does not warrant a polynomial-time algorithm as the number of sub-problems is not polynomially bounded. We overcome this by evaluating a carefully chosen set of sub-problems. This leads to a class of polynomial-time heuristics whose time-complexity is a function of how sub-problems are chosen and solved. We demonstrate the effectiveness of our heuristics by means of a numerical study and show that they outperform earlier ones and provide almost optimal solutions.

■ WB-24

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S306

Dynamical Models in Sustainable Development IV

Stream: Dynamical Models in Sustainable Development
Chair: *Alvin Henao Perez*
Chair: *Pierre Kunsch*

1 - Optimal allocation rules with waste considerations
Sara Rezaee Vessal, Sam Aflaki

We study capacity allocation of a scarce and perishable product among stock'out-averse retailers that face stochastic demand. We focus on two commonly practiced allocation mechanisms and '''using a dynamic model''' characterize the conditions under which each allocation mechanism performs superior from a waste and profit point of view.

2 - Analysing control strategies for urban air pollution through a system dynamics model
Jenny Rocio Rios Martinez, Y Olaya

Urban Air Pollution is recognized as a substantial global problem that affects population's health and quality of life. According to The Lancet Commission, cities contain 55% of world's population and it is expected that the rapid speed of urbanization continues rising. Urbanization economic prosperity led to higher motorization and industry development, which increase the use of fossil fuels and therefore the emission of pollutants to the air. Although all regions of the world are affected by air pollution, larger impacts are more evident in low-income and middle-income cities as they are developing economies with little or no control of pollution caused by industrial and vehicular emissions. A broad range of health impacts have been seen from the exposure to air pollution. Particle Matter (PM) exposure caused respiratory and cardiovascular diseases. Controlling urban air pollution will advance in building sustainable cities and communities as well as to improve health in countries around the world as two of the sustainable development goals established by the United Nations. The aim of the present study is to analyse a set of strategies (policy, regulation and technology) that can control the emission of pollutants in the atmosphere as well as to inform and mitigate health impacts for the population in the city of Medellin Colombia.

3 - A system dynamics model to evaluate the impacts of overloaded vehicles transporting ornamental stones in Brazil

Glaydston Ribeiro, Verônica Ghisolfi, Gisele Chaves, Romulo Orrico, Ivone Hoffmann, Leonardo Perim

Vehicle overloading in road cargo transport contributes to the bad conditions of Brazilian highways, to the reduction in the pavement's lifespan and to the increased risk of road accidents. The state of Espírito Santo, located in the southeast region of Brazil, stands out in the national production of ornamental stones. However, these stones are transported to the port by road and the transporting vehicles are usually overloaded, causing several accidents and contributing to the deterioration of the pavement. The purpose of this work is to present a System Dynamics model to evaluate the relationship between vehicle loading policies in road transport of ornamental stones and the variation in the percentage of overload and the costs associated with their negative externalities. Particular attention is given to operational costs, pavement maintenance and road accidents costs. The model also evaluates the best vehicle loading policy to minimize total system costs, considering the relative importance of each cost category. The results confirm the advantages of the business strategy that favors the reduction of transport operating costs by overloading vehicles. However, as the vehicle overloading increases, the social costs of pavement maintenance and road accidents also increase. Therefore, the best vehicle loading policy depends on the relative importance attributed to the operational and social costs involved.

4 - Effects of integration of renewable energy sources on financial statements of electric conventional generation plants.

Alvin Henao Perez, Guisselle Garcia

Integration of renewable energy sources (RES) to energy systems imposes great challenges over such systems mainly because of their intermittency (variability and uncertainty). In particular, electricity conventional plants may be able to ensure the load-generation balance of an electric system based on RES, so they become a cost-efficient complement in that system, or may be displaced by renewable generation plants, so the existence of conventional plants is threatened. The purpose of this research is to analyze the effects of electricity generation from RES over financial statements of conventional generation plants to provide information that helps conventional generators to design strategies to cope with those challenges. The methodology uses a binodal system linked by a transmission line with limited capacity. We allocated a renewable generator, a conventional plant and a load in one node. While in the other a load and aggregated conventional plants. The operation of the system is simulated and data is used to build a Dynamic System model to analyze the effects on income statement of conventional generation plants. The results are used to compare the AS-IS (conventional plants only) system and TO-BE system (integration of RES).

■ WB-25

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S307

Novel Algorithms for Scheduling Problems

Stream: Combinatorial Optimization II
Chair: *Erwin Pesch*
Chair: *Dominik Kress*

1 - A mechanism design for scheduling problems with multi machine agents

Alexander Herbst, Ulf Lorenz

Mechanism design theory has evolved from classical game theory and provides many interesting applications in different mathematical areas. Beside its appreciation as a powerful tool to design sensible auction formats there has already been conducted a wide range of research in coherence with scheduling. The resulting settings with clashs of interests between different participants (also called agents) often lead to highly relevant scheduling problems, but so far, most publications in this context only treat the existence of agents that control exactly one machine resp. job. In this paper we investigate a setting in which each agent is owner of two similar machines that only differ in their production speeds. These two individual speed values are supposed to be private knowledge of the agents and by following a classical goal of mechanism design we are interested in scheduling mechanisms which influence the machine agents to report their private information truthfully. The aim of this investigation is a solid basis for future research in the still unexploited multi machine agent environment.

2 - Conflict-free yard crane routing in an automated container terminal

Erwin Pesch, Jenny Nossack, Dirk Briskorn

We focus on a container dispatching and conflict-free yard crane routing problem that arises at a storage yard in an automated, maritime container terminal. A storage yard serves as an intermediate buffer for import/export containers and exchanges containers between water- and landside of a maritime terminal. The considered storage yard is perpendicular to the waterside and employs two rail mounted gantry cranes that have different sizes and have thus the possibility to cross each other. The problem at hand evaluates in which order and by which crane the import/export containers are transported in order to minimize the makespan and prevent crane interferences. We solve this problem to optimality by a branch-and-cut approach that decomposes the problem into two problem classes and connects them via logic-based Benders constraints. We assess the quality of our solution method in a computational study.

3 - Planning and scheduling in open-pit mining

Chris Potts, Antonio Martinez-sykora

The profitability of an open-pit mining project is highly dependent on a plan that specifies what material is to be extracted and when this will occur. It is common practice to create a discrete version of the problem by partitioning the area to be mined into a set of blocks, where each block has an estimated monetary value if it is mined. The problem is to decide which blocks are to be mined in each time period of the planning horizon so that the net present value is maximized. There is a complex system of precedence constraints that restrict the order in which blocks are mined. Intuitively, a block cannot be mined until the blocks immediately above have already been extracted. More generally, safety considerations prevent the slope created by the remaining blocks in the mine from becoming too steep. As a further constraint, the amount of mining within any time period is limited by the speed at which blocks can be extracted and by the capacity of the plant that processes the blocks that are mined. This talk reviews the literature on models and algorithms for scheduling the extraction of blocks in open-pit mining. Moreover, we describe our solution methods that have been developed for the Phase-X Mine Design Challenge that was run by Unearthed in collaboration with BHB Billiton in 2016.

4 - Pick up plan in case of shuttle racks warehouse - an optimization approach

Dawid Kansy, Pawel Hanczar

Shuttle racks system is dedicated to store fast-moving goods on pallets, ensuring high efficiency in the use of storage space. The radioshuttle is used to loading and unloading in the indicated tunnel. The radioshuttle system consist of shelves and a remote controlled transfer trolley. The research problem is to develop the tools which effect of action will be a pick up plan of collecting goods from the location of shuttle racks which ensures a minimum number of blockade which is equivalent to the lack of goods. The shuttle racks system operates in accordance with the FIFO strategy - in case of many stock keeping units (SKU), shuttle system can block picking process, because goods which have been reserved for order are in the middle of racks. Before we get the pallet which is reserved for the order, necessary is remove from the racks several pallets, because system does not allocate goods according to the orders. The MIP (Mixed-Integer Programming) ensures that the goods are picked up from the shuttle location in the way of minimizing the number of lacks or completely eliminating them. The main aims are to present an algorithm of shuttle racks system that will plan storage location before goods are based on backorders. As a result of it, goods will be located lengthwise of the shuttle tunnel according to the order. Algorithm will base on Mixed-Integer Programming model. The work presents the model and verifies the basic characteristics of the problem and the solution.

■ WB-26

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S308

Vehicle Scheduling and Rolling Stock

Stream: Public Transportation I
Chair: *Anita Schöbel*

1 - Location planning of charging stations and vehicle scheduling for electric buses in public transport
Nils Olsen, Natalia Kliewer

For a cost-efficient use of electric busses in public transport, the charging stations must be located within the route network in such a way that required deadhead trips are as short as possible. To overcome range limitations of electric buses, detours to charging stations are necessary. With present state, there are solution approaches for scheduling electric vehicles in public transport which consider fixed locations of charging stations determined in advance. On the other hand, location planning problems for charging stations are being solved in order to provide an operation of offered service trips by electric vehicles. Since locations of charging stations directly influence resulting vehicle schedules, location planning and vehicle scheduling have to be considered in a simultaneous manner in order to open up optimization potentials. For this purpose, we present novel solution methods for the simultaneous optimization of vehicle scheduling and location planning of charging stations for electric vehicles in public transport. We show that a simultaneous consideration of these two problems lead to significant cost savings regarding fixed costs of electric buses and charging stations as well as operational costs for deadheading. Therefore, we present heuristic and exact solution approaches.

2 - Stochastic maintenance location routing for rolling stock
Denise Tönissen, Joachim Arts, Max Shen

Rolling stock needs regular maintenance in a maintenance facility. Rolling stock from different fleets are routed to maintenance facilities by interchanging the destinations of trains at common stations and by using empty drives. We consider the problem of locating maintenance facilities in a railway network under uncertain or changing line planning, fleet planning and other uncertain factors. These uncertainties and changes are modeled by a discrete set of scenarios. We show that this problem is NP-hard and provide a two-stage stochastic programming formulation. We reformulate the two-stage problem to an efficient mixed integer programming (MIP)formulation, an accelerated Benders decomposition algorithm and a new column-and-constraint generation algorithm. Our column-and-constraint generation algorithm contains (partial) Benders decomposition and the MIP formulation as special cases and can be used to trade-off computational speed and memory requirements. Our column-and-constraint algorithm outperforms (partial) Benders decomposition in computational time and the MIP formulation in memory requirements.

3 - Rolling stock scheduling with maintenance requirements at the Chinese high-speed railway
Qingwei Zhong, Richard Lusby, Jesper Larsen, Qiyuan Peng

How to improve the efficiency of rolling stock planning has always been the focus of railway companies. Presently at the Chinese high-speed railway, rolling stock planning is usually done by dispatchers. Due to the dispatcher's own experiences and some other factors, it is often difficult to quickly obtain an optimal rolling stock schedule that matches the timetable and which also satisfies the maintenance requirements. In this talk, we decompose the problem of rolling stock planning with maintenance into two steps. First, we solve a flow based model that ignores maintenance to obtain multiple rolling stock schedules. In a second phase we then attempt to obtain a maintenance feasible rolling stock schedule, starting from the solutions found in the first phase. We present the results of testing the developed methodology on railway networks from the Zhengzhou Group, one of the most important railway transportation hubs in China.

4 - Designing cost-minimal public transport systems
Alexander Schiewe, Anita Schöbel

In public transport planning, separate planning steps like line planning, timetabling or vehicle scheduling, are often considered consecutively. This leads to overall suboptimal solutions, since the objectives of later planning steps cannot always be correctly computed in the earlier stages or a solution of an earlier stage may even exclude overall optimal solutions.

In this talk, we consider cost-minimal public transport systems, i.e., we propose a method to find the overall best solution w.r.t. operational costs. Since these are determined by the vehicle schedule, which is often considered last in the planning process, a new approach is necessary.

We present a model that finds the cost-minimal vehicle schedule for a given public transport system by finding a cost-minimal cover of the transportation system with vehicles such that all passengers can still travel. We discuss theoretical properties of this approach and present first computational results on instances of different size. Furthermore, we compare our approach to the classical sequential approach and investigate the trade-off w.r.t. passenger convenience.

■ WB-27

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S309

Network Design

Stream: Production, Service and Supply Chain Management
Chair: *Roland Braune*

1 - Three-steps approach to design the distribution network
Imma Ribas, Amaia Lusa, Albert Corominas, Manuel Mateo

The distribution network is an important part of the Supply Chain and its design has to be consistent with the characteristics of the whole Supply Chain. The fast increase in the variety of ways to deliver products to customers, parallel to the development of online sales, makes its design even more complicated. In this communication we present an approach divided in three steps, which allow designing the distribution network from the general structure to the more detail options. In each step characteristics of the product as well as the market and customers are considered. The first step consists of deciding the position of the decoupling point, which determines the degree of product customization (design characteristics), since it is the place where the assembly or final product takes place, and the total lead time to send the product to the market. The second step decides among centralized or decentralized distribution network considering the value density of the product and its life cycle, the market adaptation and the volume of demand by customer, among others and, finally, in the third step the delivery of the product to the customers is decided taking into account some factors as the volume of demand, uncertainty of demand, product volume and weight and how the customer can place the order, the cost and service level given.

2 - Designing the distribution network of services

Amaia Lusa, Imma Ribas, Albert Corominas, Manuel Mateo

The configuration of the distribution network is part of the Supply Chain design. There are few works dealing with SC design from a methodological point of view, and even less focusing on services distribution. Most authors focus just on the channel of service delivery (the means of communication through which a service is delivered to the customer), leaving aside decisions regarding the whole distribution network. A two-step framework and the relevant factors for designing an appropriate distribution network of services are presented: the first step consists in deciding the position of the decoupling point (design to order; make to order; assemble, or finish, to order), which determines the point at which the distribution of the service starts; at the second step, decisions regarding front office facilities (without, centralized or decentralized and near the market) and the service delivery are dealt with. To take the most appropriate decisions, several relevant factors regarding the objectives of the company, the cost of the front office facilities, the capacity for attracting customers, the separability (the extent to which the service can be delivered without the physical presence of the customer), the importance of the physical access, the characteristics of the product and the market (demand and customers), the possibility of gaining economies of scale or the level of customer interaction, among others, are taken into account.

3 - Lagrangian heuristics for the location-allocation problem with stochastic demand and congestion

Pratibha Saini, Sachin Jayaswal, Navneet Vidyarthi

Location-allocation problems with stochastic demand and congestion (LAPSDC) arise in several planning contexts that require deciding the location of service facilities and their capacities; and the allocation of the stochastic demand of the user zones to the located service facilities. Examples include location of emergency medical clinics; preventive healthcare centers; refuse collection and disposal centers; stores and service centers; bank branches and automated banking machines; internet mirror sites; web service providers (servers); and distribution centers in supply chains. The problem seeks to simultaneously determine the location and capacities of service facilities, and allocate user's stochastic demand to these facilities such that the total cost, which consists of the fixed cost of opening facilities with sufficient capacities, the access cost of users' travel to facilities, as well as the congestion cost at the facilities as a result of user's waiting due to stochastic demand rate and service times, is minimized. We present two approaches, namely Lagrangian relaxation and Lagrangian decomposition, to obtain lower bounds to the problem. While lower bounds are provided by the Lagrangian sub-problems, two heuristics are proposed that uses the solution of the sub-problems to construct an over-all feasible solution. Computational results to test the two approaches in terms of lower bound and optimality gap are presented.

4 - Aggregation and relaxation approaches for a multi-period network design problem

Roland Braune

The subject of this contribution is a multi-period network design problem for strategic-tactical planning of material flows between plant locations of a manufacturing company. The network's nodes (locations) provide limited storage capacity for goods and are able to handle only predefined maximum levels of material flows. Transport capacities on edges can be allocated in integer multiples of a base capacity that corresponds to a single truck load. The number of truck loads that can be moved between two nodes in the network depends on the driving time and the vehicle's temporal availability. A further peculiarity of the problem arises from the fact that transport resources can be shared among multiple connections.

Long planning horizons and a huge number of commodities are major drivers of complexity for the problem at hand. We first present various Lagrangian relaxation approaches, including an adaptation of the well known shortest path relaxation and a time-based approach, allowing for a decomposition into single-period subproblems. Furthermore, we analyze aggregation techniques of different kinds. A time-based aggregation concept is embedded into a multi-level refinement heuristic, while different commodity aggregation schemes try to "bundle" material flows. The common goal of all the presented methods is a significant reduction of the complexity of the problem's MIP formulation to accelerate the retrieval of lower bounds, upper bounds and ideally optimal solutions.

■ WB-28

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S310

Scatter Search and Path Relinking

Stream: Memory-based Heuristics

Chair: *Jesus Sanchez-Oro*

1 - A critical-path based evolutionary algorithm for the flexible job-shop scheduling problem

Grigoris Kasapidis, Dimitris Paraskevopoulos, Panagiotis Repoussis, Christos Tarantilis

The flexible job-shop scheduling problem (FJSSP) is a well-known combinatorial optimization problem that has attracted the attention of both practitioners and researchers the last decades. State of the art solution methodologies involve evolutionary algorithms combined with exact or local search methods, which aim at performing a good exploration and intensification of the search of the solution space. We propose two solution frameworks to solve the problem: a) A tabu search algorithm which uses state of the art neighbourhood operators proven to be very effective on the classical job-shop scheduling problem (JSSP), as well as perturbation operators which enable diversification. b) A scatter search algorithm, that uses a path relinking mechanism to produce offspring. We also introduce specific metrics for measuring the seldomness of the solutions met throughout the search history, as well as the solvency of parent solutions in the evolution process. The last two metrics are used to drive the recombination of parent solutions as well as to guide the local search towards promising regions of the solution space. To assess the performance of the proposed algorithms, we use FJSSP benchmarks of the literature. The proposed algorithms are compared to the state of the art of the literature and computational results are presented and discussed. This work is supported by the European Commission under the project DISRUPT (723541).

2 - GRASP with path relinking for a multi-objective waste management problem

Laura Delgado Antequera, Jesus Sanchez-Oro, Rafael Caballero, Rafael Marti

It is nowadays a fact that basic services such as public transportation, or school and hospital locations require a good if not optimal design. This is especially true in the context of waste management in which different mathematical programming techniques have been applied in order to include several aspects such as labor conditions, environmental goals or equipment constraints, that might conflict. The simultaneous consideration of several factors usually implies considering multi-criteria models to provide a set of feasible solutions to tackle these real problems.

In this talk we provide a tool to generate a good approach to the Pareto front for a multi-criteria waste collection problem. In particular, we propose a hybrid metaheuristic hybridizing GRASP and VNS. The resulting method is coupled with Path Relinking (PR) for improved outcomes. PR is a metaheuristic originally proposed in connection with the tabu search methodology, but it has become very popular due to its effectiveness, as a post-processing in GRASP. Additionally, we propose an interactive method to guide the decision process to the most preferred solution. This methodology is implemented within a Guide

User Interface to visualize the process. We apply our method to a benchmark set of public domain instances together with a real instance for the waste collection problem in a southern Spanish region.

3 - An application of tabu search to a circular layout problem

Eduardo G. Pardo, Juan David Quintana Pérez, Abraham Duarte, Manuel Laguna

Many optimization problems are stated as layout problems, where the purpose is to optimize an objective function when a graph, which represents the input instance, is embedded into another particular graph, named the host graph. Layout problems can be divided depending on the structure of the host graph. The most common structures for host graph include, among others: linear graphs, circular graphs, grid graphs, hypercube graphs, or tree graphs. In this work we tackle a well-known optimization problem, where the objective function is defined over the embedding of a graph into a circular graph. The problem tackled, named Circular Cutwidth Minimization Problem consist in minimizing the number of the edges of the input graph that crosses the region among every pair of consecutive vertices in the circular layout. In this work we illustrate a work-in-progress algorithmic proposal, based on Tabu Search. The method starts from a feasible solution obtained with a greedy constructive procedure. Then, a Tabu Search is applied as a general method to intensify the search within the solution space. The method uses a short-term memory to avoid the exploration of already evaluated solutions. The obtained results are very competitive with the current state of the art for the problem over the reference sets of instances.

4 - Improving the quality of hierarchical graph drawings with hybrid VNS-SS

Jesus Sanchez-Oro, Anna Martínez-Gavara, Manuel Laguna, Rafael Marti, Abraham Duarte

In automated graph-drawing systems it is interesting to locate vertices and arcs in positions that produce graphs with desired properties. Procedures that preserve key characteristics when updating an existing drawing are usually name dynamic procedures. These methods are particularly useful in areas such as planning and logistics, where updates are frequent. This work presents an algorithm which hybridizes the scatter search methodology with variable neighborhood search for the incremental drawing problem in hierarchical graphs. These drawings can be used to represent any acyclic graph. The extensive computational experiments show the performance of the proposed algorithms.

■ WB-29

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S311

Cutting and Packing II

Stream: Cutting and Packing
Chair: *Tony Wauters*

1 - Solving the 3D bin packing problem: improved heuristic solutions for a case in the automotive industry

Andreas Beham, Roland Hanghofer, Stefan Wagner, Michael Affenzeller

Solving the three dimensional bin packing problem is a very challenging task. Several more or less elaborate algorithms exist to solve the problem, among them the fast extreme point heuristic described by Crainic et al. 2008. In a research project funded by the Austrian Research Promotion Agency we applied this heuristic to real-world packing problems arising in the automotive industry for loading shipping containers and trucks. We developed several improvements to the heuristic and added additional constraints and decisions. In addition to the packing position, the heuristic decides on rotation and tilting an item. The added constraints are to consider items that are not stackable and must be put on the ground, items that can only bear a certain load, items that must be supported, items that must not be put on top of other items, and items that must be loaded before others. Together with our company partner we defined a matrix with coefficients of friction and calculated the required weight to fasten items in order to satisfy securing of cargo. In the talk we will describe the heuristic, the packing instances, show results and discuss further open issues.

2 - Open source simulation tool to evaluate dynamic stability metrics for the container loading problem

David Álvarez-Martínez, Juan Camilo Martínez, Daniel Cuellar-Usaquen

An open source application (PackageCargo) was developed to calculate, visualize, and save efficient packing patterns for instances of the Container Loading Problem, and it has a dynamic simulation environment to obtain performance indicators related the dynamic stability of such patterns. The simulation tool is based on the physics engine Physx' SDK 3.0. Physx is used mostly in the real-time simulation of physics and is frequently implemented in videogames. This means that the engine is capable of trading accuracy for simulation speed and is in most cases non-deterministic. However, a benchmark test comparing Physx with software designed for accuracy in dynamic simulations (Autodesk Inventor' and ANSYS') shows that the developed application has adequate precision, while producing the results in a fraction of the time used by the standard simulation software. The application has many available functions for the end user, but in this project, it will be used mainly to evaluate the accuracy of new dynamic stability metrics. These metrics are found using the kinetic parameters of the load such as mass distribution, coefficient of friction, and rigidity. Future works may address the possibility of predicting loss of support, tipping, or the reach of critical velocity that would damage the cargo, which can lead to a mechanical model that measures dynamic stability without the need to subject the packing pattern to a physics simulation.

3 - A GRASP algorithm for multi container loading problems with practical constraints

Francisco Parreño, Maria Teresa Alonso Martínez, Ramon Alvarez-Valdes

We present a GRASP algorithm for the multicontainer loading problem of a company that has to serve its customers by putting first the products on pallets and then to load the pallets onto trucks. The solutions consider five types of constraints: • geometric constraints, so that pallets are completely inside the trucks and do not overlap; • weight constraints, limiting the total weight a truck can bear and the maximum weight supported by each axle, • the position of the centre of gravity of the cargo; • dynamic stability constraints, to avoid cargo displacement when the truck is moving; • as well as the delivery date for each product.

The approach is based on a Greedy Randomized Adaptive Search Procedure (GRASP) to solve the problem. The approach is able to find high-quality realistic solutions in short computational times. Some improvements methods tailored to the problem have been developed, including an adaptation of ejection chains.

The computational results on a real set of test instances show that the algorithm is very efficient for a wide range of multi container loading problems and can be very easily adapted to other constraints of the problem. We also provide a comparison with an integer programming formulation. The comparison justifies the use of a metaheuristic algorithm.

4 - A parallel tree based approach for the 3D cutting and packing problem

Everton Fernandes da Silva, Tony Wauters

3D Cutting and Packing Problems for regular pieces consist of allocating a set of small items (boxes) inside a set of larger items (containers). Within the subproblems originated, the 3D Single Knapsack Problem (SKP) and the 3D Single Large Object Placement Problem (SLOPP) consist of maximizing the value of placement of a set of boxes with different values into a single container. The former problem considers a set of strongly heterogeneous boxes and the latter considers a weakly heterogeneous set of boxes. For these problems, the non-overlapping, the bounding and the rotation constraints are considered. This study proposes a parallel approach to solve the SKP and the SLOPP by applying a search procedure in a tree structure and solving combinations of subset of boxes. To reduce the search effort, a list of feasible and infeasible solutions already found is maintained and each node to be investigated is first checked if no symmetrical or dominant solution is already in any of these lists. In the affirmative case, the node is automatically pruned or branched according to which list its symmetrical or dominant solution is placed. Experimental tests were executed on classic benchmarks and instances generated by a generator from the literature. The obtained results were compared to methods from the literature that, in a previous comparison investigation, had the best performance for the considered instance sets.

■ WB-30

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S312

Strategic Customers in OM Games

Stream: Game Theory and Operations Management
Chair: *Anton Ovchinnikov*

1 - Strategic service operations of two-sided market platform with backward compatibility
Dohoon Kim

We consider a dominant platform provider (PP) operating both legacy (A) and new (B) platforms, which connect users with suppliers in a two-sided market (TSM) context. In addition to the typical indirect network effects in TSM, backward compatibility (BC) works on B. Thus, users joining B can also enjoy the services provided by suppliers using A. Users and suppliers are linearly differentiated between two platforms as in the Hotelling model, and play a subscription game of choosing one platform at the lower level. The suppliers in B may suffer from congestion, which can be alleviated by PP's investment on B. PP also determines price margins for the supplier sides. Our equilibrium (eq.) analysis in the subscription game identifies an interior eq. (coexistence of both platforms in both sides). Though BC plays a stabilizing role for the interior eq., its stability is fragile due to the network effects. Rather, some boundary eq.'s, where at least one side tips to A or B, are more likely to be stable. BC is a key factor that characterizes the stable boundary eq.'s The upper stage game is led by PP, which tries to maneuver the system toward one of stable boundary eq.'s using price margins and investment. PP prefers all-B boundary eq. when the indirect network effect and the maximum price margin for B are large, and puts significant investment in B. With small indirect network effect for suppliers, however, PP does not invest in B and choose a separate boundary eq.

2 - A cooperative game approach to the job scheduling problem
Eric Bahel, Christian Trudeau

The job scheduling problem is a classic operational research problem in which agents have jobs to be executed by machines in given time slots, with each machine being able to process only one job at a time. We study this problem using cooperative game theory, focusing on how to divide the minimum cost (of executing all jobs) between the agents. First, we describe all stable allocation methods, which charge only users whose jobs are executed in peak-demand time periods. Second, using properties designed to avoid strategic mergers or splits of the jobs, we offer axiomatizations for two remarkable stable allocation methods. After observing that all stable solutions fail the Unanimity Lower Bound (ULB) property, requiring that everybody pay an equal share of the first machine (which is needed by all), we study and axiomatize the Shapley value, which satisfies ULB. A compromise is then proposed between Stability and ULB.

3 - Sharing the revenues from broadcasting sport events
Gustavo Bergantinos, Juan D. Moreno-Ternero

We study the problem of sharing the revenue from broadcasting sport events, among participating players. We provide direct, axiomatic and game-theoretical foundations for two focal rules: the equal-split rule and concede-and-divide. The former allocates the revenues generated from broadcasting each game equally among the participating players in the game. The latter concedes players in each game the revenues generated by their respective fans and divides equally the residual. We also provide an application studying the case of sharing the revenue from broadcasting games in La Liga, the Spanish Football League. We show that hybrid schemes, combining our rules with lower bounds and performance measures, yield close outcomes to the current allocation being implemented by the Spanish National Professional Football League Association.

4 - Strategic consumer behavior in premium-status loyalty programs
Anton Ovchinnikov

We propose a Stackelberg game model and provide empirical evidence to study the impact of strategic consumer behavior on the firm's profits and consumer surplus in the context of premium-status loyalty programs.

■ WB-31

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S313

Behavioural Operations and Games II

Stream: Behavioural OR
Chair: *Ilkka Leppanen*

1 - The impact of competition on product and process development decisions: evidence from a behavioral experiment
Margarita Gladkova, Timofey Shalpegin

In many situations, competition affects people's behavior, and this research focuses on the analysis of managers' behavioral patterns under competition. There is no theoretical consensus in the literature on how competition affects managerial decisions. While some research finds tougher competition may lead to higher efforts of the competitors, other studies confirm the competitors are more likely to give up in such a case. We conducted behavioral experiments to address this problem in the context of operations decisions. Our participants were top-level managers and they needed to manage a virtual company. The subjects played the Decision Base Game developed by Celemi. They were Russian executives enrolled in an MBA program at the Graduate School of Management, Saint Petersburg University, Russia. All subjects were allocated to teams of 4 to 6, each role playing as separate companies operating on the rapidly changing markets and competing for the same customers. Manipulating the perceived level of competition, we observed how the teams made their operations management decisions. We collected data on their decisions (e.g. investments in research and development of new products; expansion and modernization of production), as well as on the proxies of their actual efforts such as the time spent on those decisions and the intensity of communication.

2 - Suppliers' learning: aggregate and individual levels
Mohsen Ahmadian, Roger Blake, Ehsan Elahi

This research uses the results of laboratory experiments in which subjects playing the role of suppliers competing to win the business of a buyer who is outsourcing the manufacture of a commodity product and defines three different competition criteria: fill-rate, base-stock inventory level, or a parameter designed to intensifies the competition to its highest level. This study uses the quantal response equilibrium model to examine whether bounded rationality and learning can offer some explanation for the deviation of the experimental results from theoretical predictions. Moreover, we conduct individual level analysis and employ K-means clustering method to explore the learning patterns within the subjects. The aggregate level results indicate that the bounded rationality models fit our experimental data better than the model of perfect rationality. The learning model shows that the level of rationality and the subjects' learning behavior differ between three competition types. Furthermore, the individual-level analysis shows that all subjects do not behave similarly. We can identify three subject groups based on their learning behaviors: (1) "Randomizer learners", who learn, but their decisions are strongly affected by factors not included in our model; (2) "Strong learners", who learn fast, and our model is a good predictor of their decisions; and (3) "Non-learners", who do not learn or make less rational decisions as the competition proceeds.

3 - Behavior of the agent when the information is distorted by the principal

Andrei Matveenko

In economics, the situation in which the manager (principal) provides the informed agent with data based on which the agent makes her decision is widely considered. In the standard model, it is assumed that their interests do not coincide, the agent has an opportunity to deceive the principal, and the principal's task is to compile a contract menu, such that when choosing the optimal contract for himself, the agent truthfully discloses information and acts in the interests of the principal. However, there is another possibility: the principal informs the agent with the wrong information in order to encourage her to act properly. This possibility is almost not studied in the literature, although it is quite realistic. To model the situation, we study a problem of discrete choice under uncertainty. The key feature of our model is costly information acquisition by the decision maker (agent). The cost, as it is traditional in Rational Inattention literature, is modelled as a reduction in entropy. In our formulation of the model, the information is acquired from a firm's manager (principal); that is the manager, who delegates the decision to the agent, faces the costs. In this framework, we analyze the optimal initial information setup which the manager provides to an agent. We show that the manager, in some cases, might find it optimal to report the underlying distribution of the states of the nature not truthfully.

4 - Building a hierarchical evaluation model by using interpretive structural modeling: a case study of ERP implementation risks

Ilker Gölcük, Adil Baykasoğlu

The role of information technologies on the business activities of the firms is rapidly expanding. The compelling market pressures lead firms to use sophisticated software to maintain their operations. ERP software is one of such solutions which help firms to integrate all the business functions for operational efficiency and effectiveness. Unfortunately, real life practice shows that neither all the firms have been successful in implementing ERP systems nor the ERP systems have been used effectively. Therefore, firms focus their attention to critical success factors based evaluation frameworks in order to reduce the chance of failure in ERP implementation. Because a vast amount of critical success factors has been reported in the literature, decision makers face difficulties in dealing with large number of factors. Problem structuring methods provide decision makers with a systematic help in identifying the most critical factors. In this study, interpretive structural modeling has been used to build a manageable and understandable evaluation model. A real life case study is provided in order to demonstrate the applicability of the model.

■ WB-32

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S314

Vehicle Routing

Stream: Routing, Logistics, Location and Transportation
Chair: *Pedro Castellucci*

1 - A systematic intelligent solution for parts logistics optimization

Wenlian Lu, Yaoting Huang, Boyu Chen, Zhongxiao Jin

Part logistics is increasingly important to modern industrial activities and becomes a hot topic in operational research. Due to complexity, intelligent algorithms show great power to solve the logistics optimization problem related to the vehicle routing problem (VRP). However, most of the existing methods to VRP are either limited to single-depot and multiple-customer case or non-practical constraints and assumptions. In this work, we incorporate diverse intelligent algorithms to build up a systematic solution towards real-world parts logistics problems. This solution is mathematically a large-scale multiple-depot and multiple-customer VRP with time-window and loading constraints. First, a heuristic algorithm is generated to initialize feasible schemes by imitating manual planning. Second, parallel Simulated Annealing algorithm is utilized to optimize, accelerated by a novel bundle technique, with heuristically algorithms for routing, packing and queuing associated. Finally, we employ a process for post-optimization. Based on these algorithms, the Shanghai Automotive Industry Corporation (SAIC) has successfully established an intelligent management system to obtain a systematic solution for their large-scale parts logistics planning. This system is proved to enable represent manual planning with faster and more efficient performance, and can be easily evolved to meet the future growing requirements.

2 - Integrated maintenance tail assignment considering heterogeneous fuel consumption

Manuel Fuentes, Luis Cadarso

The tail assignment problem is the stage where sequences of flights are assigned to specific aircrafts in the planning process of an airline. Maintenance tasks do have an impact in the planned operations, so integrating maintenance planning within the tail assignment problem leads to better solutions. This way, the resulting assignments are more robust and the overall cost is lower.

Tail assignments are commonly determined separately for different fleets. Moreover, it is also common that all aircrafts of a fleet are treated the same way, so the operational costs are dependent on the flight leg only. But in general, fuel consumption is not homogeneous, being usually different for different aircrafts flying the same flight leg. This is due to either, the age of the aircraft, or the fact that the same aircraft model can mount different power plants, presenting differences in fuel consumption.

We present an integrated model for solving the tail assignment problem and the maintenance planning, considering heterogeneous operational costs related to fuel consumption. We make use of historical data for leg-tail pairs cost estimation.

3 - A practical routing model in terms of reliability of arrival time to destination

Yoichi Shimakawa, Hiroyuki Goto, Yohei Kakimoto

In this study, we propose a practical routing model to maximizing the deviation of arrival time to destination with the idea of truck transport. Many researchers assume that the vehicle take the shortest path to its destination in routing distance and time. In case of a routing problem in a country area, the assumption causes no problem because the density of the road is sparse. Many drivers do not have any alternative route. However, in urban area, drivers have many routes to their destinations. They can find their route based on their own ideas. That is, if a driver in an urban area can take a shortest path with high delay risk or touch a long distance path with no delay risk, they would take the latter case. The rule of selecting a route by the driver in an urban area is based on high reliability in driving time to destination points. In this study, we try to calculate the route for the driver in an urban area from their practical standpoints. In numerical simulation, we use a high density road network from Digital road network in GIS. The road link has distance, average time to pass it and reliability that estimates the variance for average time. We show the difference of routing between our model and an ordinary method in numerical simulations.

4 - A logic-benders decomposition algorithm for a network scheduling problem with cross-docking

Pedro Castellucci, Alysson Costa, Franklina Toledo

Cross-docking is a strategy that can be used to increase consolidation rates in logistic distribution systems. Although there has been an increasing interest in methods and models to schedule the unloading/loading of trucks in inbound and outbound doors within cross-docks, there is not a comparable amount of research on distribution networks which have cross-docks as some of its nodes. We propose a flexible mixed-integer linear model and a decomposition strategy for a network scheduling problem with cross-docking. The model is flexible in the sense that it can accommodate some practical extensions without significant additional modeling effort. The decomposition strategy is based on the Logic Benders framework and enables us to decompose the problem by cross-dock and by final destination. Therefore, it is possible to contemplate different cross-docks' characteristics by adapting the sub-problems, without changing the master problem or the general structure of the decomposition algorithm. Our results show that the decomposition strategy is more effective than solving the model with a well-established computational package, even for the basic problem.

■ WB-33

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S315

New Applications and Perspectives I

Stream: Data Mining and Statistics
Chair: *Pakize Taylan*

1 - Do we need more advanced and complex model to predict micro-enterprises failures?
Aneta Ptak-Chmielewska

Research analysis of micro-enterprises behavior are still rare, due to lack of individual level data. Micro-enterprises failures are strongly connected with the owner characteristics, because in such enterprise the owner is the only worker or working with 1-2 additional co-workers. Owners abilities, competences and managerial skills determine the success or failure of the enterprise. In recent research we tend to apply more and more complex models to increase the predictive accuracy, the precision and effectiveness of our predictions. However it is not so obvious that increasing complexity increases the effectiveness. In this paper the sample of 900 micro-enterprises were analysed. The information on qualitative factors was available and utilized in modelling. Two groups of models were estimated. First group of models - simple static parametric models like logistic regression or nonparametric like decision tree. Second group of models - more complex models like survival models and random survival forests. Two research hypothesis were verified: (i) Socio-demographic characteristics of the owner are the most important factor in determining the micro-enterprises failures and (ii) predictive accuracy of the simple models are as good as of the more complex models.

2 - Nudgital: critique of a behavioral political economy
Julia Puaschunder

Behavioral Economics revolutionized mainstream neo-classical economics. A wide range of psychological, economic and sociological laboratory and field experiments proved human beings deviating from rational choices as standard neo-classical profit maximization axioms failed to explain how human actually behave. Human beings rather use heuristics in their day-to-day decision making. These mental short cuts enable to cope with a complex world yet also often leave individuals biased and falling astray to decision making failures. What followed was the powerful extension of these behavioral insights for public administration and public policy making. Behavioral economists proposed to nudge and wink citizens to make better choices for them and the community. Many different applications of rational coordination followed ranging from improved organ donations, health, wealth and time management, to name a few. Yet completely undescribed remains that the implicit hidden persuasion opens a gate to deception and is an unprecedented social class division means. Social media forces are captures as unfolding a class dividing nudgital society, in which the provider of social communication tools can reap surplus value from the information shared of social media users. The social media provider is outlined as capitalist-industrialist, who benefits from the information shared by social media users, or so-called consumer-workers, who share private information to interact with friends.

3 - Discrete analogues of bivariate continuous distributions
Alessandro Barbiero

Modeling correlated count data through some bivariate (or multivariate) discrete distribution is essential in many real-world applications in a wide range of fields, such as industrial quality control, healthcare, marketing, management science, and many others. Moreover, finding a discrete analogue to a continuous distribution can be useful in those problems where dealing with a continuous model is computationally cumbersome and substituting it with an appropriate discrete model can produce an approximate but still acceptable solution with a much smaller computational effort. In this work, two methods for deriving a bivariate discrete distribution from a bivariate continuous distribution are discussed, which retain the expression of either the joint density function or the joint survival function. These methods can be regarded as the bivariate extension of two popular methods used for deriving a discrete counterpart of a continuous distribution; they can be used as viable alternatives to existing techniques of construction of bivariate discrete random variables. Examples of application to several continuous distributions are presented in order to illustrate how the procedures work. A real dataset taken from the literature is eventually analyzed and fitted using two discrete analogues of a bivariate exponential distribution.

4 - Modelling and managing dynamic pricing strategy for an intensive competitive battle in the drugs industry, using "agile" system dynamics
Kim Warren

A leading drugs company with 100% of a EUR 50m/year medication market faced entry by an aggressive new rival over just 10 weeks of the key sales season. With just a few days to plan a response, a fast but rigorous process had to be adopted to build a working quantitative model that would not only enable immediate strategy development but also provide continuing tactical guidance as events progressed. The resulting strategy held loss of sales to just 15% and - crucially - sacrificed little of the product's price and profitability. This episode illustrates an "agile" approach to building system dynamics models. Typical modeling starts with qualitative mapping of possible relationships to produce a causal diagram. Expert modelers then construct a matching software model structure, and seek data to produce a working model. Finally, the model is validated before being used to solve the problem. This process takes too long, costs too much, and is unreliable. Fundamental system dynamics principles suggest a simpler, faster and more reliable process, which moves immediately - less than 1 hour - from the performance of concern to a simple, yet quantified and working model of how changing asset-stocks are driving that performance. From there, interdependencies are traced - extending the working model. Validation is continual, through checking that the simulation matches reality. Valuable insights emerge throughout the process

■ WB-34

Wednesday, 10:30-12:00 - SOUTH BUILDING UV S113

Recent Advances in DC Programming

Stream: DC Programming and DCA
Chair: *Hoai An Le Thi*

1 - On DC decompositions of polynomials: from DSOS decomposition to DSOSC decomposition
Yi-Shuai Niu

Polynomial optimization is a special case of DC (Difference of Convex functions) programming, however representing any multivariate polynomial into a dc function is a hard mission. We propose in this paper some new results on dc programming formulations of polynomial optimization. We will focus on polynomial decomposition techniques. Firstly, we propose four algorithms to formulate any multivariate polynomial into DSOS (Difference of Sums-Of-Squares) decompositions, and then extend these approaches to generate DSOSC (Difference of Sums-Of-Squares Convex) decompositions (i.e., dc decompositions). Some numerical results of our proposed methods will be also reported.

2 - DCA based algorithms for solving a class of mathematical programs with equilibrium constraints
Thi Minh Tam Nguyen, Hoai An Le Thi

We investigate a class of Mathematical Programs with Equilibrium Constraints (MPEC) in which the objective function is continuously differentiable with Lipschitz continuous gradient, and the constraint set includes a parametric variational inequality. We replace this inequality by a smooth equation and employ a penalty technique to reformulate the resulting problem as a DC (Difference of Convex functions) program. A variant of DCA (DC Algorithm) and its accelerated version are proposed to solve this DC program. As an application, we tackle the second-best toll pricing problem with fixed demands. Numerical experiments on three networks with data taken from MacMPEC illustrate the efficiency of the proposed algorithms.

3 - A DC programming approach for robust joint beamforming and artificial noise security scheme
Phuong Anh Nguyen, Hoai An Le Thi

This paper is concerned with the problem of secure transmission for amplify-and-forward multi-antenna relay systems in the presence of multiple eavesdroppers. Specifically, spatial beamforming and artificial noise broadcasting are chosen as the strategy for secure transmission with robustness against imperfect channel state information at the destination and the eavesdroppers. In such a scenario, the objective is to maximize the worst-case secrecy rate while guaranteeing the transmit power constraint at the relay and the norm-bounded channel uncertainty. We reformulate the problem as a general DC (Difference-of-Convex functions) program (i.e. minimizing a DC function under DC constraints) and develop a very inexpensive DCA based algorithm for solving it. Numerical results illustrate the effectiveness of the proposed algorithm and its superiority versus the existing approach.

4 - A collaborative approach based on DCA and VNS for solving mixed binary linear programs
Sara Samir, Hoai An Le Thi

To solve Mixed Binary Linear Programs, we propose a collaborative approach based on DCA (Difference of Convex functions Algorithm) and VNS, a metaheuristic approach. First, a constructive heuristic is applied to get an initial solution. Then, we run the algorithms in parallel. At the end of every cycle, the best found solution is ditributed to each algorithm using MPI library. The next cycle uses the previous best found solution as initial solution. Our approach is tested on instances of the Capacitated Facility Location Problem.

■ WB-49

Wednesday, 10:30-12:00 - 4D UPV B.4

Emerging Applications in Portfolio Selection

Stream: Emerging Applications in Portfolio Selection and Management Science
Chair: *John Lamb*

1 - A robust portfolio optimization model based on minimax regret
Sandra Caçador, Pedro Godinho, Joana Matos Dias

In this work a new minimax regret portfolio optimization model based on a new measure of regret is presented. Regret is defined as the utility loss for the investor resulting from choosing a given portfolio instead of choosing the optimal portfolio of the realized scenario for the uncertain parameters. The proposed approach assumes that the investor has constant relative risk aversion preferences. A genetic algorithm is applied for the computation of the relative-robust solution, allowing the transformation of a 3-level optimization problem into a 2-level optimization problem. In-sample and out-of-sample performances of relative-robust and non-robust portfolios are analyzed and compared. The results suggest that the proposed model has more value for risk-taking investors, i.e. for those who can be more affected by the methodological weakness of the classical mean-variance model, standing out as a valid alternative. The proposed model achieves better results than non-robust models in many of the considered time windows, with the exception of the global minimum variance portfolio. Its in-sample and out-of-sample robustness was confirmed concerning both deviations to its expected performance and utility loss for the investor, standing out as one of the very few optimal portfolios with no poor performances. The developed approach stands out as a valuable contribution for the assertion of robust optimization within the field of portfolio selection under uncertainty.

2 - A particle swarm optimization variant for the cardinality constraint portfolio selection problem
Ilaria Foroni, Alessandro Avellone

Since Markowitz's seminal work on the mean variance model in modern portfolio theory, many studies have been conducted on portfolio optimization problem. In the last decades, different models that include constraints representing limitations faced by real-life investors have been proposed. It is well-known that the more the model is extended to include practical constraints the more it becomes difficult to solve. For instance, the cardinality constraint, that imposes a limit on the number of assets held in the portfolio, increases significantly the computational complexity of the problem. In this case exact techniques may be inadequate to find an optimal solution in a reasonable time or computationally ineffective when applied to large-scale problems and, thus, efficient algorithms need to be investigated. In this aim, we propose a variant of the Particle Swarm Optimization for solving the cardinality constrained portfolio optimization problem. The performance qualities of this modification are compared with the penalty function method, which is a widespread approach to handle constrained problems. The efficiency and robustness of the algorithm is illustrated by solving a collection of real world portfolio optimization problems using different risk functions.

3 - Homogeneous subsets for portfolio selection
John Lamb, Elmira Mynbayeva

We call a set of data series homogeneous in a statistic such as mean or variance if we find no significant differences in the value of the statistic between any pair of series. Typically we might use a procedure like Boneferroni or Tukey's honestly significant differences to identify homogeneous subsets of a small set of series. Here we consider large sets of series and a develop a bootstrap version of Shaffer's modified sequentially rejective multiple test procedure together with the Šidák equation to identify significant differences. We then use antichains in partially ordered sets to partition the set of series into maximal homogeneous subsets.

The application is to portfolio optimisation. By identifying homogeneous subsets of means and variances, we can apply different versions of Markowitz optimisation (or equal-weight allocation) to different subsets to obtain portfolios that are more diversified than those obtained by standard Markowitz optimisation. This helps overcome the issue that Markowitz optimisation tends to produce underdiversified portfolios.

■ WB-50

Wednesday, 10:30-12:00 - 4D UPV 1.1

OR for Developing Countries V

Stream: OR for Developing Countries
Chair: *Herman Mawengkang*
Chair: *Olabode Adewoye*

1 - An optimization model to tackle health service demand problem for public hospitals
M. Irfan Fahmi, Herman Mawengkang

Due to the increase of human population, it is common that public hospitals could have more demand for health services than available capacity. One way to tackle this situation is to forecast and manage demand in order to adjust capacity or take other courses of action, for example, transfer demand to other facilities. Such a solution is commonly based on the design of a general process structure for hospitals and which defines the management processes that are needed to optimize the use of resources in doing so and to ensure a predefined service level for patients. Capacity planning decisions are important to health care management because not only it relates to the management of highly specialized and costly resources (i.e., nurses, doctors, and advanced medical equipment), but also it makes a difference between life and death in critical conditions. This paper deals with creating an optimization model to solve a capacity planning problem for a public hospital located in Medan city, Indonesia. We use a neighborhood approach for solving the model.

2 - An interactive approach for solving multi-objective model of waste management in crude palm oil industry
Meslin Silalahi, Herman Mawengkang

Crude palm oil industry is concerned with an agro-industrial commodity. The global market of this industry has experienced rapid growth in recent years, such that it has a strategic value to be developed for Indonesian economy. Despite these economic benefits, there are a number of environmental problems at the factories, such as high water consumption, the generation of a large amount of wastewater with a high organic content, and the generation of a large quantity of solid wastes and air pollution. Due to the involvement of waste in the CPO production system, it is necessary to include waste management into the system planning. How to manage waste is a socially important topic, as it deals with the unavoidable day-to-day needs of people, particularly of those who live in surrounding industrial areas. It possesses a special importance in urbanized areas due to population densities and growing rates of waste generation. In terms of waste transportation, we propose a multi-objective programming model for managing business environmental risk in a crude palm oil manufacture which gives the best possible configuration of waste management facilities and allocates wastes to these facilities. Then we develop an interactive approach for tackling logistics and environmental risk production planning problem for the crude palm oil industry.

3 - An electricity reform model for developing countries
Olabode Adewoye

Continuous power supply at required quantity remains a critical challenge for most developing countries despite the abundant energy resources. In most developing countries, generating plant availability is low and the demand- supply gap is crippling as a result of protracted mismanagement, political interference and lack of maintenance, subsidized pricing and corruption. The scale of the above listed problems and how to solve them has been studied by many authors. The objective of this work is to design a mathematical model that improve electricity supply through selection of efficient policy, combined with a Top-Down Model which creates competitive electricity markets by encouraging new entry into the generation, transmission, distribution and marketing sectors. A simple heuristic model for corruption is formulated. The combination of these models is expected to improve the electricity supply in developing countries.

4 - A mixed- integer programming model for production - distribution planning of crude palm oil industry
Hendaru Sadyadharma, Avery Boy Detinty, Herman Mawengkang

Undoubtedly crude palm oil industry plays an important role for economic development of a country, such as Indonesia. The production process of crude palm oil (CPO) can be defined as the milling process of raw materials, called fresh fruit bunch (FFB) into end products of palm oil. The process is usually through a series of steps of producing and consuming intermediate products. These raw materials, intermediate and end products are necessarily to be inventoried, allowing one to produce and consume them at different moments and rates in time. Each step of process may require several input products and may produce one or several outputs. If the milling company does not have any palm oil plantation, then, the raw materials must be purchased from suppliers, and the end products are sold to external customers. This paper considers an integrated supply - production - distribution planning of a crude palm oil milling industry. The raw material, called fresh fruit bunch (FFB) of oil palm, is supplied by several oil palm plantation. Due to the limited availability of FFB, it is necessary to choose from which plantations it would be appropriate. This paper proposes a mixed-integer linear programming model for the integrated problem. In particular, the model considers the decision about from which suppliers and to which customers such that to minimize the overall operational costs.

■ WB-51

Wednesday, 10:30-12:00 - 4D UPV 1.2

Optimization Models in Health Care

Stream: OR for Health and Care II
Chair: *Metin Turkay*
Chair: *Fadime Üney-Yüksektepe*

1 - Comparison of cervical cancer screening recommendations under different perspectives using a POMDP model
Malek Ebadi, Raha Akhavan-Tabatabaei, J.b.g. Frenk

Cost and Quality-Adjusted Life Years (QALY) are two substantial yet competing performance measures used in cancer screening decision making. Each of these measures represents a different perspective. Specifically, maximizing the expected total QALY of a certain policy refers to the patient's perspective while minimizing the corresponding cost of a policy suits the payer's perspective. Partially Observable Markov Decision Processes have become a standard modeling tool for cancer screening and treatment policies with most models considering QALY maximization as their primary objective function. On the other hand, health policymakers who develop real world screening guidelines show more interest in the tradeoff between the cost and effectiveness of a policy rather than its effectiveness only. Hence, a screening policy encompassing both factors, better reflects the real-world practice. By using a POMDP model developed for cervical cancer screening policies, we aim to highlight the differences in the screening recommendations under these two perspectives. To this end, we produce results with both performance measures and compare their corresponding frequency, follow-up intervals and ending age to quit screening. We derive important conclusions on their differences and their impact on the overall efficacy of the screening programs.

2 - Combining interventions to improve neonatal care services performance: a system dynamics model
Reda Lebcir

Neonatal services provide care to babies with medical complications and are under huge pressure due to increased demand and cuts to health funding. This has led to saturation and admission refusal to many babies. Some interventions are suggested to improve neonatal services performance including changing the treatment resources mix and allowing doctors to use their clinical judgment to reduce treatment pathways complexity. However, no evaluation of the impact of these interventions has been done and it is not clear what improvement is achieved if they are implemented. The aim of this research is to evaluate the impact of interventions involving (i) changes to treatment resources mix and (ii) allowing doctors to use their clinical judgment, on the performance of neonatal services with a focus on the babies refused admission due to services saturation. A System Dynamics model was developed in a big and saturated neonatal unit in the United Kingdom. The model was populated with data from the unit and validated successfully. The model was then used to simulate scenarios to evaluate the impact of the two interventions cited above on neonatal services performance. The results indicate that allowing doctors to use their judgment is a better intervention than changing the treatment resources mix in improving performance. Other scenarios combining the interventions was simulated and the results suggest a better performance compared to implementing the interventions individually.

3 - Markov process models in primary-care clinics

Zhimin Huang, Susan Li

Improvement of primary-care clinics has been a priority for many years. Various operations research models have been developed in the literature to improve primary-care efficiency. Primary-care clinics continue to survive and provide quality, indispensable services, only if they recover and profitably reinvest the revenue generated by the wide range of services they provide to a wide range of patients. As waiting times for elective physicians are known to be increasing and waiting queues are piling up, solutions are sought to decrease the waiting times while maintaining an acceptable quality service. For a given clinic, if it schedules too many appointments in advance, capacity shortages problem will arise. If it schedules too few appointments, the patients' wait time will increase, patients and primary care physicians will be mismatched, and the possibility of unused clinic slots is increased. We utilize Markov process and revenue management to develop an optimization model deciding how to allocate the available slots between walk-ins (same-day appointments) and regular patients (advance booking) who may have a preference for both the slot time and their primary care physicians in a given clinic. A numerical example is constructed to illustrate how to implement our model.

4 - Combining soft or methods with simulation techniques for sustainability analysis

Masoud Fakhimi, Anastasia Anagnostou, Navonil Mustafee, Lampros Stergioulas

Hybrid simulation studies have been extensively applied in various industries to gain insights into existing or proposed complicated systems of interest. However, it is rarely used to evaluate the often competing social, environmental and economic (Triple Bottom Line) metrics associated with sustainable operations management despite its potential advantages. In this research, we are investigating a new approach that helps simulation practitioners to include the underlying sustainability metrics in their simulation models. This research argues that the combination of soft OR methods with simulation techniques could reduce the challenges of developing model for analysing such complex systems. In this regards, a combined Qualitative System Dynamics (QSD) and Agent-Based Simulation (ABS) approach uses the ability of soft methods such as QSD to capture multiple perspectives on the underlying sustainability system in long term and the detailed representation of ABS models satisfies the TBL modelling requirements. This research shows the application of this approach for analysing a sustainable development issue in healthcare context.

■ WB-52

Wednesday, 10:30-12:00 - 4D UPV 1.3

Network Revenue Management

Stream: Analytics and Pricing
Chair: *Darius Walczak*

1 - Data science approach to value based pricing

David McCaffrey

For an airline or other vendor selling a set of related products (e.g., tickets for the same origin-destination) differentiated by quality attributes (e.g., booking conditions, bundled ancillaries, etc), price drives value for both customer and vendor. According to value based pricing theory, the value to the customer of choosing a given product, from a family of related products, is a trade-off between the perceived benefits and price of the product. The vendor should strive to set the price of each product in proportion to the perceived benefits of the attributes of that product. If this objective is achieved, then the products should lie on a so-called value equivalence line (VEL) where increasing price optimally captures the increasing benefit to a customer of increasing quality of product attributes. Traditionally, it has required expensive market research to estimate the relationship between product price and the perceived benefit of product attributes. In this talk, we present a data science approach to identify the attributes which drive the customer's perception of value, to statistically model the value of each product in terms of the trade-off between perceived benefits and perceived price, to build a value map and VEL representing the ideal price line-up, to define a set of ideal price changes required to achieve the ideal price line-up, and to develop practical strategies to move current prices towards the ideal line-up.

2 - Price list optimization for free-floating car sharing systems

Matthias Soppert, Claudius Steinhardt

Free-floating car sharing providers experience a strong growth of users but often struggle in generating a profitable fleet utilization. While some concepts tackle this problem at the supply side by actively relocating vehicles, demand side approaches are rather uncommon so far.

A typical pricing model in car sharing consists of a fixed minute price, generally depending on the type of vehicle. In contrast to such a fixed minute pricing, we study a car sharing provider's tactical problem of finding a revenue-maximizing price list that differentiates prices locally and temporally, with a weekly periodicity. More precisely, while prices may differ within one week depending on the day and daytime, as well as depending on the zone of the vehicle pick-up, prices remain constant on a weekly time frame for each spatio-temporal combination in our problem setting.

We formulate the car sharing system as a network flow model in which the area of operation is discretized into zones and car rentals between different zones are modeled as flows within the network. We propose an infinite-horizon quadratically constrained quadratic program (QCQP) and formulate a corresponding finite-horizon linear program by introducing a price set from which prices have to be chosen. First numerical results are presented and the feasibility of the chosen approach for practice-relevant problem sizes is discussed.

3 - Pricing in the energy field

Luce Brotcorne, Sébastien Lepaul, Léonard von Niederhäusern

Pricing models for demand side management methods are traditionally used to control electricity demand which became quite irregular recently and resulted in inefficiency in supply. In this work, we propose bilevel pricing models to explore the relationship between energy suppliers and customers who are connected to a smart grid. The smart grid technology allows customers to keep track of hourly prices and shift their demand accordingly, and allows the provider to observe the actual demand response to its pricing strategy. Moreover, we assume that the smart grid optimizes the usage of a renewable energy generation source and a storage capacity. Results over a rolling horizon are presented

4 - Dynamic programming decomposition approaches to the network revenue management and pricing problems
Darius Walczak, Ravi Kumar

We consider a dynamic programming formulation of the network revenue management problem. Due to the curse of dimensionality, various approximate dynamic programming methods based on the classical resource-based decomposition approach are used in practice. We revisit our earlier alternative idea of the product-based network decomposition and develop a novel dynamic model for the problem that relies on simultaneous solving of subproblems. We present numerical analysis to compare the revenue and computation performance of the new method with the more classical ones.

■ WB-53

Wednesday, 10:30-12:00 - 4D UPV 1.4

Renewable Energy and Storage

Stream: Stochastic Assessment of Renewable Energy
Chair: *Benjamin Böcker*

1 - Unit commitment under imperfect foresight - the impact of stochastic photovoltaic generation
Jens Weibezahn, Jan Zepter

The deployment of RES, mainly wind and PV, has strongly increased over the last years. These two technologies inherit an explicit dependency on weather conditions, making short-term system operations more challenging, as the final output is uncertain and volatile. If deviations in the production of RES are not comprehensively anticipated in short-term scheduling decisions of conventional power plants, this might lead to an inefficient use of the power system. Hence, by anticipation of forecast errors, their scheduling must account for uncertainties in the system.

This paper uses the model stELMOD, incorporating the European multi-market regime (day-ahead, intraday, real-time balancing). An approach to simulate a time-adaptive intraday forecast is presented. Uncertainty of PV generation is incorporated by numerous multi-stage scenario trees, accounting for a decreasing forecast error over time. Thereby, a comprehensive assessment of scheduling costs, redispatch costs and amounts, flexibility needs of the power system, as well as power line usage can be carried out. To comprehensively assess the impacts of fluctuating renewable generation, different cases of stochastic RES infeed are considered.

The preliminary results show an increasing need for more flexibility of the German power system in order to cover uncertain changes of both wind and PV generation.

2 - Improving deployment availability of energy storage with data-driven AGC signal models
Audun Botterud, Ying Wang, Can Wan, Zhi Zhou, Kaifeng Zhang

Energy Storage (ES) provides great flexibility and large benefits to power system operations and control. When providing ancillary services (e.g. regulation, reserve, etc.), the real time deployment of ES is uncertain, and it is important to manage state of charge (SoC) accordingly. Aiming to improve the ES performance for providing energy and regulation service in the electricity market, we propose two data-driven Automatic Generation Control (AGC) signal models. The first one is a historical-data-driven AGC signal model, which is based on the analysis of the historical AGC signals, and is designed for ES participation in the day-ahead (DA) market. The second one is a prediction-data-driven AGC signal model, which is based on the prediction of the AGC signals, and is designed for ES participation in the real-time (RT) market. We also develop a deployment availability check model and solution algorithm. The proposed framework is applied to an ES bidding problem in the DA and RT markets. The results indicate that deployment availability and operational performance of the ES are improved with the proposed data-driven AGC models compared to traditional benchmarks.

3 - A multi-stage stochastic generation capacity expansion planning model under energy policies
Heejung Park, Ross Baldick

We present a multi-stage stochastic optimization model for generation capacity expansion under energy policies affecting carbon dioxide emissions, renewable portfolio standard (RPS) and carbon tax. The optimization model minimizes total costs including building and operating costs of the generators in the test system. Uncertain parameters, wind availability and system-wide load are modeled as random variables, and scenarios are generated via Gaussian copula. A reduced multi-stage scenario tree was constructed, and a rolling-horizon method is applied to obtain one generation plan at each stage. The test system includes 243 existing generators using conventional fossil fuels and wind energy. Effects on costs and carbon dioxide emissions with different energy policy scenarios are examined.

4 - Stochastic battery valuation considering multiple value streams
Benjamin Böcker, Rudiger Kiesel, Christoph Weber

In future energy systems with a high share of renewables, matching electricity demand and supply becomes increasingly challenging. The resulting need for flexibility impacts both short-term scheduling and real-time system balancing. While different storage technologies can participate in the existing short-term markets, high technical requirements have to be met for system balancing, in particular regarding ramping and response time behavior. Especially battery systems are able to meet these high requirements, which allows them not only to provide there various system as well as grid services but also to generate revenues on different markets. The developed model makes use of the Least-Square Monte Carlo method, which allows to determine the value of batteries under uncertainties. Thereby the basic approach is extended to consider the simultaneous provision of additional services and the corresponding multiple stochastic revenue streams.

■ WB-54

Wednesday, 10:30-12:00 - 4D UPV 1.6

Logistics applications

Stream: Applied OR
Chair: *Geir Hasle*

1 - Modelling the acquisition plan of LPG cylinders with reverse logistics
Isabel Cristina Lopes, Eliana Costa e Silva, Aldina Correia, Rui Borges Lopes, Magda Monteiro

In the business of liquefied petroleum gas (LPG), the LPG cylinder is the main asset and a correct planning of its needs is critical. This work addresses an industrial challenge proposed by a Portuguese energy sector company, where the objective was to define an assets acquisition plan, i.e., to determine the amount of LPG cylinders to acquire, and when to acquire them, in order to optimize the investment. The used approach to find the solution of this problem can be divided in three phases. First, it is necessary to forecast demand, sales and the return of LPG bottles. Subsequently, this data can be used in an Economic Order Quantity (EOQ) model for inventory management. At last, because it is necessary to consider the return rate of LPG bottles, reverse logistic models and closed loop supply chain models are explored.

2 - Optimization of wave picking operations in a 3PL warehouse
Dilara Aykanat, Onur Can Saka, Erdinc Comert, Esin Altin

The problem we address originates from the real-life integration of specially designed picking carts to the retrieval processes in a cosmetics warehouse operated by a third party logistics (3PL) service provider. The 3PL company employs a wave picking approach where different types of picking carts are being used. The carts have a varying number of built-in scales and back-storage locations which facilitate validation by weight control and allow picking of multiple orders simultaneously. The aim of the study is to assign the picking orders to boxes and then to batch these boxes to finally form box groups for each picking cart. These allocations define the route of each cart that should be followed by the operator during the picking process. Given the number of picking carts available of each type, the objective becomes to minimize the total picking time of orders in a single wave.

We present a mixed integer linear programming based exact solution approach for solving the batching, tour generation and cart scheduling problems in an integrated manner. We propose a two-phase heuristic algorithm to solve the practical larger size problems. We compare the results of our heuristic against the exact approach and manual plans created by on-site planners.

3 - Materials handling application for Industry 4.0
Gizem Mullaoğlu, Sencer Yeralan

Industrial engineering practices are expected to be affected by, and most likely adapt to, the new paradigms of Industry 4.0. Early indications in practice, as well as extrapolations from the current technology trends, point toward a few fundamental features. Among these are further integration, leaner and hence more agile practices, and the use of real-time data. The final objective is to reduce complexity while striving for real-time supply- and production-chain optimization. We argue that the optimization of highly integrated production systems cannot be sought by simply aggregating the known operations management tools of industrial engineering. Specifically, we present evidence, gleaned from a recent industrial project, that indicates how as the systems become more integrated, the concept of operations optimization needs to be revisited. Our work has two distinct contributions to the literature. We develop and present a state-of-the-art optimization model for a joint materials handling, inventory, and scheduling model. The model incorporates aspects of the knapsack, bin packing, vehicle routing, and inventory control formulations. Further, we show that simply collecting existing industrial engineering models into larger aggregations, albeit in line with the current best practices of our profession, will not necessarily suffice to completely fulfill the ambitions of Industry 4.0.

4 - A comparison of different curbside waste collection systems
Sanne Wøhlk, Hani Zbib, Marcel Turkensteen

We compare the driving needed for curbside collection of household waste under different collection scenarios. We consider 'collect, then sort' and 'sort, then collect' systems using single and multi-compartment vehicles. Using different degrees of sorting, the systems are compared among themselves, and to collection for incineration. The problems are modeled as (multi-commodity) capacitated arc routing problems and are solved using a Multi-Move Chain Descent algorithm. In each iteration of the algorithm, a combination of moves (swap, cross, relocate, etc.) yielding the best improvement is identified using dynamic programming. The analysis is based on real life data from six counties in Denmark and uses 102-133 data instances for each collection scenario and the data is of large scale containing up to 8651 required edges. In this presentation, the main focus will be on the application and the analysis of the results. A main finding is that given the number of waste fractions to be collected, collection by multi-compartment vehicles requires least driving. Collection by separate vehicles requires 20% (30-60%) more driving when 2 (3) waste fractions are collected, and even more for 4 waste fractions. Collection for subsequent sorting requires 40-60% more driving for 2 fractions, but decreases to 5-20% more for 4 fractions.

■ WB-55
Wednesday, 10:30-12:00 - 4D UPV 2.1

Getting on in OR

Stream: Making an Impact I
Chair: *Ruth Kaufman*

1 - Getting on in OR
Ruth Kaufman

People with OR skills and knowledge are in great demand in industry. There are many possible career paths open to OR people outside academia, whether they are starting with no more than a first degree in a scientific subject, or with a PhD and post-doctoral experience in OR. In this session, panel members with very different career paths will briefly describe their career history and current ambitions, the skills they started with, and the important developments along the way; and then open up to discussion with the audience. The purpose of this session is for people at all stages of an OR career to explore ideas about what they may want to do in the future, and what sort of development and training may be useful.

■ WB-56
Wednesday, 10:30-12:00 - 4D UPV 2.2

Hospital Logistics

Stream: Healthcare Logistics
Chair: *Marion Rauner*
Chair: *Fermin Mallor*

1 - Solving the operating room scheduling problem maximizing patients' preferences
Ana RamonBaviera, Francisco Ballestin

One of the key elements in hospitals are operating rooms, and one of the key decisions is which patients to select from the waiting list to be operated on, and the time to operate them. Little attention has been paid in the literature to maximise the preferences of patients in the specific day to operate on them. The goals hospitals seek according to the literature can be numerous. However, when related to patients, goals focus on urgency or days in the list. In this work we study the case where the surgeries of patients are not urgent. The patients have preferences in the days of the surgery, although they want to be operated on before a certain due date (one month after their entry in the waiting list). The hospital wishes to fulfill the preferences of the patients, without forgetting the utilisation rate of the operating room. The work defines several objective functions to be optimised in one-week scheduling of patients. These functions are compared in the long term regarding the goal of the hospital, using instances randomly generated with the generator developed in Leeftink and Hans (2017). These instances try to cover an important range of possible hospitals. The second part of the work analyses if working with models that schedule patients for two weeks instead of one can improve the goal of the hospital.

Leeftink, G., and Hans, E., (2017), Case mix classification and a benchmark set for surgery scheduling, Journal of Scheduling DOI 10.1007/s10951-017-0539-8

2 - Insight into the emergency department physicians' problem about managing their patients flow
Marta Cildoz, Amaia Ibarra, Fermin Mallor

Physicians in an Emergency Department (ED) have their own portfolio of patients that is updated at the times a new patient arrives. Patients have been assigned different severities after triage upon arrival and in their process of treatment, they can be in one of the following stages: waiting for the first consultation, during the first consultation, carrying out medical tests (blood tests, Rx. . .), waiting for results, waiting for a second consultation, during the second consultation or waiting for transfer to their destination (home, hospital). After these processes, the patient is discharged (although some of them are discharged after first consultation). Furthermore there are "patient waiting time targets" for the first consultation, which depends on the patient priority. The physicians need to apply a good queue discipline (meaning to decide who is the next patient to be seen in consultation) in order to accomplish several objectives: not to exceed the first consultation waiting time limit, minimize the length of stay of each patient and minimize the number of patients in the ED (giving different importance to the patients according to their severity score). To address this problem, we have built a very detailed simulation model that is able to assess different patient flow management strategies regarding KPI aligned with the previous objectives. It is illustrated with a real case in the ED of the Hospital Compound of Navarre (Spain).

3 - Hospital resource planning for mass casuality events: a DES-based case study of a major Viennese hospital
Marion Rauner, Daniel Staribacher, Helmut Niessner

This paper presents a simulation-based policy analysis of the available resources for a major Viennese hospital in the case of a disaster with a mass casualty event. Using a Discrete Event Simulation (DES) model, the current disaster plan is simulated and then compared to an adapted version with additional changes in personnel and equipment. The results show that with the current resources of the hospital severely injured patients may have to wait up to 168.4 minutes until a life-saving operation can be performed. Assuming that the death from blood loss of severely injured patients has a peak at 2 to 2.5 hours after arrival in a hospital, this waiting time of nearly 3 hours is clearly not acceptable. A theoretical increase in staff or equipment did not lead to a sufficient reduction of this timespan. Therefore, in the short term, it is recommended that the current hospital disaster plan reduces the number of severely injured patients that can be successfully accepted and treated. In the long term, this analysis recommends expanding structural resources and improving regional disaster planning.

■ WB-57

Wednesday, 10:30-12:00 - 4D UPV 2.3

Software for Nonlinear & Parallel Optimization

Stream: Software for Optimization
Chair: *Imre Polik*

1 - Tuning the global optimization solver BARON using derivative-free optimization algorithms
Nikolaos Ploskas, Jianfeng Liu, Nikolaos Sahinidis

The global optimization solver BARON includes numerous options that allow users to control different algorithmic aspects. These options can have a significant impact on BARON's performance. Tuning these options is often necessary and may lead to significant performance improvements for specific problem classes. The aim of this work is to develop a methodology for identifying option settings that result in the best solver performance in terms of execution time and solution quality. Tuning options can be regarded as an optimization problem. This problem is hard to solve for two reasons. First, the relationship between the parameters and solver performance is not explicit. Second, some of the options may take discrete values, so the objective function is complex and non-smooth. Hence, the solver must be treated as a black-box system, whose input is values for the different options and output is a performance metric, such as the execution time. Derivative-free optimization algorithms (DFO) are attractive for this tuning problem since they do not require explicit functional representations of the objective function. We perform a computational study over a set of 126 problems from GLOBALLib and MINLPLib collections in order to identify optimal values for each one of the problems and also find a single set of options that can improve the performance of BARON across the entire test collection. A total of 27 DFO algorithms are used. We present extensive computational results.

2 - SUSPECT: MINLP special structure detector for Python
Francesco Ceccon, Ruth Misener

We present SUSPECT, an open source toolkit that symbolically analyzes optimization problems formulated using the Python algebraic modeling library Pyomo. We present the novel data structures and algorithms used to implement SUSPECT. SUSPECT works on a directed acyclic graph representation of the optimization problem to perform: bounds tightening, bound propagation, monotonicity detection, and convexity detection. We show how the tree-walking rules in SUSPECT balance the need for lightweight computation with effective special structure detection. SUSPECT can be used as a standalone tool or as a Python library to be integrated in other tools or solvers. We highlight the easy extensibility of SUSPECT with several recent convexity detection tricks from the literature. We also report experimental results on the MINLPLib 2 dataset. For each test problem, we read in the optimization problem and build a Pyomo model, then compute the special structure information for all constraints and objectives.

3 - Optimizing large-scale linear energy problems with block diagonal structure by using parallel interior-point methods
Daniel Rehfeldt

The current shift of energy systems in several European countries towards sustainable, renewable technologies comes with a massive decentralization and a concomitant increase in the size of realistic energy models. Against this backdrop the project BEAM-ME has been launched to develop methods for solving currently intractable energy optimization problems. These models are encoded as large-scale linear programs (LPs) and exhibit a block-diagonal structure with both linking constraints and linking variables. For solving these problems we have adapted and enhanced the parallel interior-point solver PIPS-IPM. In this talk we will present the new extended version of PIPS-IPM. Furthermore, (preliminary) results of solving several real-world energy system problems on the supercomputers of JSC (Juelich) and HLRS (Stuttgart) will be shown.

4 - ParaXpress - a massively parallel mixed integer linear programing solver with the potential to harness over a million CPU cores
Yuji Shinano, Timo Berthold, Stefan Heinz

Mixed integer programming (MIP) is a general form to model combinatorial optimization problems and has many industrial applications. The performance of MIP solvers, software packages to solve MIPs, has improved tremendously in the last two decades and these solvers have been used to solve many real-word problems. However, against the backdrop of modern computer technology, parallelization is of pivotal importance. In this way, ParaSCIP is the most successful parallel MIP solver in terms of solving previously unsolvable instances from the well-known benchmark instance set MIPLIB by using supercomputers. In the same way, a new implementation of ParaXpress is realized. Both parallel MIP solvers have been developed by using the Ubiquity Generator (UG) framework, which is a general software package to parallelize any state-of-the-art branch-and-bound based solvers. As for general MIP solver performance, Xpress is superior than SCIP. On top of that, the computational results of ParaSCIP imply that ParaXpress could harness over a million CPU cores. Indeed, ParaXpress solved two previously unsolved instances from MIPLIB2010 in 2017. They are the only instances which were solved in 2017. In this talk, the new implementation of ParaXpress will be presented.

■ WB-58

Wednesday, 10:30-12:00 - 4D UPV 2.4

Machine Learning and Data Analysis III

Stream: Emerging Applications of Data Analysis
Chair: *Ivan Reyer*
Chair: *Sureyya Ozogur-Akyuz*

1 - Multivariate copulas in Bayesian classification
Jan Górecki

Bayesian classifiers are attractive mainly due to their simplicity and ability to provide results better than obtained for much more complex classifiers. Considering the most popular and the simplest one, Naive Bayes, its simplicity, which is given by the (naive) assumption of the independence of the features, can also be a serious drawback in certain applications. By plugging a copula into it, Naive Bayes looses its naivety as the dependence of the features can be modeled by the underlying copula, which leads to an improvement of its classification abilities.

In the first part of the talk, we will present several classes of such copula-based Bayesian classifiers, which result from plugging in different classes of copulas, including several visualizations of such models obtained for real-world datasets. Then, we will present experimental results showing that these classifiers are able to outperform even advanced classifiers like Neural Networks, Support Vector Machines or Random Forests.

2 - Gaussian Bayesian networks and Gaussian mixture models applications of day-ahead forecast for the Spanish electricity market supply curves
Diego Gomez

Deregulation in electricity markets caused a higher interest in forecast electricity prices for generation and supply companies, which goal is to maximize their profits. This paper studies the probabilistic relationships between the Spanish electricity market supply curve of the first hour in operation day and the available forecast generations in the Spanish energy mix. We propose the Gaussian Bayesian networks and Gaussian mixture models to model these probabilistic relationships and we have used the data of the years 2015 and 2016. The existence of power generation forecasts for some technologies let us evaluate the responses of supply curve, once we have estimated the probabilistic models. Therefore, this methodology will allow market's agents advance the probable behavior of supply curve and define theirs buy or sell bidding of power generation in accordance to maximize their profits.

3 - Real-time crash prediction in an urban expressway using disaggregated data
Franco Basso, Leonardo Basso, Francisco Bravo, Raul Pezoa

We develop accident prediction models for a stretch of the urban expressway Autopista Central in Santiago, Chile, using disaggregate data captured by free-flow toll gates with Automatic Vehicle Identification (AVI) which, besides their low failure rate, have the advantage of providing disaggregated data per type of vehicle. The process includes a random forest procedure to identify the strongest precursors of accidents, and the calibration/estimation of two classification models, namely, Support Vector Machine and Logistic regression. We find that, for this stretch of the highway, vehicle composition does not play a first-order role. Our best model accurately predicts 67.89% of the accidents with a low false positive rate of 20.94%. These results are among the best in the literature even though, and as opposed to previous efforts, (i) we do not use only one partition of the data set for calibration and validation but conduct 300 repetitions of randomly selected partitions; (ii) our models are validated on the original unbalanced data set (where accidents are quite rare events), rather than on artificially balanced data.

4 - Managing uncertainty using human centric analytics (HCA): a longitudinal case study
Christina Phillips

In 2015 Forbes predicted that embedded analytics could save US companies $60 B by 2020 but, in order for companies to leverage the full capabilities of analytics in their organisations, the human analytics interface must be robust and fit for purpose. This is especially so in uncertain environments where the reliance on human decision making and management is high. Models which only capture process and data can fall short of expectations and miss nuances which are held implicitly by the organisation. Action Research together with contextualised explanatory models derived through grounded analysis can enhance engagement and create new organisational pathways to understanding. In this talk you will hear about; • Multiple analytics interventions in a complex healthcare environment over 4.5yrs • Successful ways to couple soft and hard methods so that contextualised models can be developed • A cultural shift in an organisation around demand, production planning and forecast use

■ WB-59

Wednesday, 10:30-12:00 - 4D UPV 2.5

Stochastic Aspects of Energy Management

Stream: Technical and Financial Aspects of Energy Problems
Chair: *Raimund Kovacevic*

1 - Explicit solutions of stochastic energy storage problems
Martin Densing

We consider stochastic optimization of the dispatch of energy storage against exogenous, stochastic prices. Arbitrarily many periods are considered, and also continuous time solutions. A common application is hydropower storage, but other energy storage with an interchange between reservoirs apply, too. In addition, explicit solution of an ancillary service of balancing power supply is shown in a simplified setup. In both cases, we provide numerical examples related to hydropower, and we hint to limits of the approach.

2 - Multi-scale scenario generation for a power plant valuation problem
Martin Glanzer, Debora Daniela Escobar, Georg Pflug, Wim van Ackooij

In this talk, we address two issues appearing in the context of the valuation of a coal-fired power plant. First, it is a multistage stochastic optimization problem where there are two different time scales inherent in the problem: while decisions can be made on a weekly basis, the multi-dimensional underlying process (prices of electricity, coal, and CO2 certificates) needs to be monitored every four hours in order to determine the profit and loss associated with a decision. The evolution of the underlying price process is modelled by a three-dimensional two-factor model. In order to discretize the distribution of the value of this multi-dimensional process at each decision stage, we use a lattice structure. We generate this lattice based on optimal quantization of the given probability distribution w.r.t. the Wasserstein distance. On the other hand, we derive and simulate the stochastic bridge process linking a pair of values given at the beginning and at the end of a week, respectively, in order to compute expected costs during the week. The problem is finally solved by dynamic programming. The second issue we discuss is model ambiguity. This is joint work with Daniela Escobar, Georg Pflug, and Wim van Ackooij.

3 - Dynamic stochastic programming. applications for the valuation of a coal power plant
Debora Daniela Escobar, Martin Glanzer, Georg Pflug, Wim van Ackooij

The aim of this project is to find the optimal profiles of production for every week during a year that maximizes the expected profit of the correspondent power plant. For this case, the random disturbances will refer to prices of electricity, fuel and allowances of CO2. The stochastic process will be defined in groups of hours and the decisions on profiles will be taken at the end of every week for the upcoming week. Therefore, we are talking about a multi-scale stochastic optimization problem. The problem will be solved by using the Bellman principle. Regarding the stochastic process, we use a lattice to approximate it. The evolution of the electricity prices will contain a seasonal pattern in addition to previous models of this problem. Finally, the profit function, set of decisions, states and updating functions are applied to a real problem for the valuation of a coal power plant. This project is a joint work with the company Electricité de France (EDF).

4 - Arbitrage conditions on a market with electricity production from fuel
Raimund Kovacevic

We consider a market at which electricity is produced from fuel. Several generators and fuel storage (costs) are considered. In this situation we derive no-arbitrage conditions. For a large class of statistical models, it is found that arbitrage can be achieved only under unrealistic assumptions. We analyze further the consequences for parameter estimation, contract valuation and tree construction for stochastic optimization.

■ WB-60

Wednesday, 10:30-12:00 - 4D UPV B.5

Vendor Sessions

Stream: EURO Special Sessions
Chair: *Simon Jones*

1 - Model-based optimization with AMPL: From prototyping to deployment
Robert Fourer

Optimization is the most widely adopted technology of Prescriptive Analytics, but also the most challenging to implement. Thus model-based optimization has become a key approach to streamlining the optimization modeling cycle and taking applications from prototyping and development through integration and deployment. Using a few simple but nontrivial examples, this presentation demonstrates how AMPL's design of a language and system for model-based optimization is able to combine power of expression with ease of use to get projects going quickly and bring them to conclusion successfully.

2 - What's new in Gurobi 8.0
Kostja Siefen

Gurobi Optimizer is the engine used by more than 1600 companies in over 40 industries to turn data into smarter decisions. Recognized as the state-of-the-art solver for mathematical programming, Gurobi was designed from the ground up to exploit modern architectures and multi-core processors, using the latest implementations of the latest algorithms. The recently released version 8.0 improved the overall performance of Gurobi Optimizer again, while significantly enhancing the features of Gurobi Instant Cloud and Gurobi Compute Server. Meet our team and learn about the latest features and improvements in Gurobi 8.0.

3 - How to get published in research journals
Simon Jones

How to get published in research journals addresses how to prepare and submit a manuscript using correct manuscript language, and how to structure an article.

Wednesday, 12:30-14:00

■ WC-01

Wednesday, 12:30-14:00 - UPV Nexus

Online Optimization for Dynamic Matching Markets

Stream: Keynotes
Chair: *Bernard Fortz*

1 - Online Optimization for Dynamic Matching Markets
Patrick Jaillet

There are many situations in which present actions must be made and resources allocated with incomplete knowledge of the future. It is not clear in this setting how to measure the quality of a proposed decision strategy. Online optimization compares the performance of a strategy that operates with no knowledge of the future (on-line) with the performance of an optimal strategy that has complete knowledge of the future (off-line). In some cases, some probabilistic information about the future may be available. In this talk, we provide an overview of results obtained from that perspective on problems arising from dynamic matching markets such as (i) online auctions, (ii) display advertisements, (iii) kidney exchange programs, and (iv) ride-hailing platforms.

■ WC-02

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S101

Innovative Applications I

Stream: DEA: Applications
Chair: *José Dulá*

1 - Performance evaluation of mobile network operators in Japan
Norihiro Hayakawa, Yasufumi Saruwatari

The performance of mobile network operators (MNOs) in Japan has been analyzed and compared. The Japanese mobile telecommunications market is said to have distinctive characteristics. Every MNO delivers its own mobile network service combined with cellular phones (devices). The "enclosure strategy" for customers is successful in protecting new entrants. In addition, the basic monthly charge for the mobile network service is almost the same between MNOs. By the "cooperative oligopoly," this market has lost liquidity. The Japanese government demands they improve their business practices.

The performance of MNOs has been examined by employing a variant of data envelopment analysis. The financial statements of MNOs during 2014 and 2016 have been collected. The findings show deterioration of efficiency of MNOs performance and changes in MNOs business strategies. The costs for customer retention implies excessive amounts in every year. It can be seen as the evidence of excessive price reduction for their own devices. The results support the government awareness on the Japanese mobile telecommunications market issue. The conflict of strategies between MNOs becomes one of the factors for the MNOs to review their own strategies, and as a result, each MNO would adopt a "differentiation strategy." An MNO competes with others through the differentiation strategy, and therefore tries to avoid competitions for the basic monthly charge reduction.

2 - Applying DEA on accounting data to assess Spanish chemical companies: an analysis based on size and region
Amalia Rodrigo-González, Amparo Ruiz-Llopis

This paper studies the efficiency and productivity of Spanish chemical companies in the 2008-15 period. This sector is the second in exportation and leads R+D+I in the Spanish industry. It applies DEA and Malmquist index, using accounting data of 1,202 companies, 16 sub-sectors, 3 sizes, and 15 regions. The relationship between efficiency/productivity and some financial ratios and the economic cycle is investigated by Tobit regression and generalized least square regression with panel data. As main findings, Valencian large chemical firms are leaders in efficiency: the 71% of them reach the rate of 0.7, at least. In contrast, the 55% of Valencian small chemical companies record rates equal or less than 0.5. Regarding productivity, most regions show a Malmquist index slightly below 1, being that of Valencian Community slightly over 1. In Spain, the overall Malmquist index is 0.98, and the overall efficiency change increases the 4.7%. Tobit regressions reveal IGDP growth, ROA, TURNOVER, MEDIUM, LARGE, and LEVERAGE as significant variables, but the last shows a negative coefficient. The regression analysis on technological change shows a negative (positive) and significant effect of medium (large) companies. Additionally, ROA and TURNOVER exhibit a negative and significant coefficient. As general conclusion, within the Spanish industrial sector, chemical companies reveal as a strong industry, being able to face 2008-15 crisis with efficiency levels well above 0.8.

3 - Assessing performance in international mathematics competitions

Stella Sofianopoulou

The current study investigates the determinants of success in the performance of nations at the International Mathematical Olympiads (IMO). To measure the performance of nations in terms of their mathletes' achievements, the data for year 2015, published by IMO.org have been utilized to compare the relative performance via Data Envelopment Analysis (DEA) approach. As measures for the inputs, two macro-level determinants that are representative of the effort made by a country are considered: population size and Gross Domestic Product (GDP) per capita. A nation's success at the IMO is judged in the present study by the number of gold, silver and bronze medals awarded. As however all inputs and outputs may not be equally important to the decision maker, this study reports an application where weight restrictions are imposed on the outputs in the DEA model utilised in order to overcome the above problem. The results from this study provide information concerning the technical efficiency of the nations analysed and indicate that further training for targeting realistic objectives for future events can become a plan to pursue.

4 - Post-modern DEA: DEA knowledge and skills for novel and innovative applications

José Dulá

DEA is about identifying and locating points in a polyhedral hull defined by a finite, multi-dimensional, non-parametric, point set. To know DEA is to know linear algebra, LP, duality, algorithms, computations, and high-dimensional geometry. There are many ways to understand and interpret DEA. One is as an application of computational geometry: the convex hull problem. Another is as a data mining tool to extract information from massive data sets. This opens the door to many novel and innovative applications for DEA. DEA is a factorization of the data into two non-negative matrices. Non-negative Matrix Factorization (NMF) under a "separability" assumption is a rapidly evolving topic with a myriad of applications including facial recognition, document clustering, signal processing, and feature selection. DEA as a convex hull problem can be used in procedures for the recommender problem. DEA is closely linked with the L1 norm. This norm is the focus of recent work on robust data analysis. We talk about such applications and about how knowing DEA uniquely prepares a researcher to expand into new fields.

■ WC-03

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S103

Stochastic Modeling of Production Systems

Stream: Production and Operations Management

Chair: *Çerkez Ağayeva*

1 - Optimal harvesting policies to reduce the number of setups in biomanufacturing

Yesim Koca, Tugce Martagan, Lisa Maillart, Ivo Adan

Fermentation processes in biomanufacturing use viable cells, like bacteria, to produce proteins used in drug manufacturing. After the viable cells reach a specific growth rate during the fermentation process, the batch is discharged and a new batch is set up. These change overs are time-consuming and expensive. Also, using viable cells causes the fermentation processes to proceed in a stochastic behavior. Therefore, the aim of this study is to develop a stochastic decision making model to reduce total number of change overs in the fermentation processes and maximize the yield (desired proteins) obtained in a single setup. To address this, we develop a Markov decision model to determine the optimal harvesting policies and maximize the total revenue obtained from a batch. We analyze the structural characteristics of optimal policies, and illustrate the industry use of the model through a case study.

2 - Exploiting random lead times for significant inventory cost savings

Qiong Wang, Alexander Stolyar

We study the classical single-item inventory system with backlogs, random replenishment lead times and order crossovers. We propose a new inventory policy that exploits the lead time randomness. Deviating from conventional approaches, our policy does not keep the inventory position within a fixed range, but uses the net inventory level to set a dynamic target for inventory in-transit, and places orders to follow that target. Our policy provides a potentially infinite inventory cost reduction compared with Constant Base Stock (CBS) policy. In the case of exponentially distributed lead times, we prove that, as the demand rate becomes large, the expected (absolute) inventory level under our policy vanishes relatively to that under CBS policy. Simulations show that the advantage of our policy remains substantial under non-exponential lead times as well.

3 - A production queueing system in which product quality may deteriorates during processing.

Kuo-Hwa Chang

A customer evaluates her perception quality of service by considering the quality of the service she receives, the way server treats her and how long she waits. In production system, the quality of the semi-product is certainly affected by machine' working condition and it may also deteriorate as it waits in the production process. We study a production queueing system considering quality of product that deteriorates as waiting time increases and it also depends on the service quality of the server, which degrades gradually as the accumulated service time increases. We define the framework of the corresponding queueing system of single stage and implement the cumulative negative quality(CNQ) measure. By utilizing absorbing time analysis, we estimate the final quality of the current product given the state of the system and we estimate the steady-state distribution of final quality and hence the yield of the end products. To estimate the yield of a two-stage system, we propose a bridging method to simplify the computation of absorbing time on a multiple dimensional state space into the computation on a series of 2-dimensional space that it can be extended to the multiple-stage system. For the application in practice, our model based results can be used to predict the final yield of a current semi-product and this will help us to determine whether further action should be done or to design proper settings of the production line in order to achieve the final quality goal.

4 - Problems of singularity for stochastic switching systems with restrictions

Çerkez Ağayeva

This paper considers the investigation problems of optimality for stochastic switching control systems. Switching systems form the kind of hybrid systems and play the important role for the studies of process with continuous dynamics. Switching systems have a wide engineering background and can be used to described many kinds of practical systems, such as flight control systems, network control systems, power electronics, and so on. It is well known that the first order necessary conditions of optimality are not always effective to research the optimal control problems in singular cases. To investigate the optimal control problem in mentioned cases is required additional information. Present research is devoted to the stochastic optimal control problemof switching system along singular controls. The concept of singularity for stochastic switching systems with restrictions in form of qualities at right ends of intervals is introduced. Second order necessary condition of optimality for singular stochastic control systems with uncontrolled diffusion coeffcients is proved. Finally, the transversality conditions for switching points corresponding to optimal control are obtained.

■ WC-04

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S104

Optimal Control Applications II

Stream: Optimal Control Applications
Chair: *Fabricio Oliveira*

1 - Analysis of serial production lines with phase-type processing times
Özgün Öztürk, Onder Bulut

In this study, we consider serial production lines with intermediate buffers between stations in a make-to-stock environment. Demand arrives according to a Poisson process and unsatisfied demands are backordered. In general, we assume independent two-phase Coxian processing times at each station. Such a setting is also equivalent to the settings having independent Exponential processing, time-to-failure and repair times. We first characterize the optimal policy for a two-station line having one reliable and one unreliable station. The optimal control analysis of such a two-station with Exponential (a special form of Coxian) and Coxian processing times is missing in the literature. We also discuss the effects of the position of the unreliable machine (at the up or down stream) on the several performance measures. Furthermore, we evaluate the performance of the classical policies (Kanban, CONWIP etc.). For such a setting, for the optimal control approach, the state-action space grows exponentially with the number of stations. Due to this, we also study the buffer size allocation problem under given control policies. This approach would provide approximate policies without finding the optimal policy but determining the buffer sizes for the lines having several stations and all have general Coxian processing times. We also aim to extend our findings to the settings having multiple-parallel machines at each station.

2 - Managing logical constraints in 4D optimal trajectory planning for multiple aircraft
Dinesh Babu Seenivasan, Alberto Olivares, Ernesto Staffetti

In this talk an approach is described to numerically solve optimal control problems with multiple aircraft with logical constraints in disjunctive form. These constraints are enforcing separation between aircraft, passage through waypoints, and obstacle avoidance and are especially demanding in modelling efforts. Standard modelling techniques can tackle constraints in disjunctive form using binary variables. The trajectory planning problem for multiple aircraft with logical constraints in disjunctive form can be solved as an optimal control problem for a hybrid dynamical system and a common approach for solving this class of problems is to formulate them as a mixed-integer programming problem. In this talk logical constraints in disjunctive form are included in the model using continuous auxiliary variables. Moreover, transition constraints through way-points are enforced by defining a rectangular window in the airspace around the way-point avoiding the multi-phase model of the hybrid optimal control problem. The resulting hybrid optimal control problem is converted to a smooth optimal control problem which is solved using traditional nonlinear programming methods, thereby reducing the computational complexity of finding the solution. The effectiveness of the approach is demonstrated planning the continuous descent approach of multiple aircraft in converging arrival routes in which the optimal sequencing and the optimal trajectories of each aircraft must be computed.

3 - Refining replenishment policies with the internet of things: a control-theoretic approach
Christos Papanagnou

Manufacturing companies are constantly looking ways to optimise their supply chain performance by improving their relationship with the suppliers, investing on new data while minimising the bullwhip effect. Internet of Things (IoT) provides a new platform where the flow of information is reinforced by integrated systems throughout the chain, which may improve order decision-making. In this research replenishment policies are enhanced by IoT and are modelled with the aid of a proportional controller. Then, a state space model is derived to capture the dynamics across all supply chain nodes as a function of information (orders) and inventory levels. Customer demand is represented by a stochastic sequence while the model is analysed under stationarity conditions with the aid of a covariance matrix.

The main objective of the study - inspired by chemical manufacturing companies - is not only to gain a comprehensive in-depth understanding of IoT and supply chain management but also to offer managers an insightful model to tackle (1) inventory fluctuations and associated management, which is currently predominantly manual with heavy reliance on human input to update the inventory status, (2) lack of in-transit visibility and logistics transparency when receiving orders from customers, and (3) limited flow of information both internally and externally.

4 - Revisiting inventory control using stochastic programming
Fabricio Oliveira

Traditional methods for solving inventory control problems have their roots in tools such as queueing theory and dynamic programming. Despite being powerful tools in several contexts, particular characteristics of real-world inventory control problem might render these techniques unsuitable to deal with aspects such as multiple products, perishability, variable lead times, or randomness of the input parameters. This talk will present recent developments that show how optimal control policies can be obtained using stochastic programming (SP), which is a powerful framework that allows the consideration of uncertainty using mathematical programming tools.

Due to the discrete nature of the scenario-based representation used in SP, there is an inherent trade-off between the quality of the representation of the uncertainty and the size of deterministic equivalent problems. We show that, for benchmark cases to which a closed-form optimal solution can be calculated, the approximation using SP is often very close to the optimal for an adequate number of scenarios.

We present recent developments showing that several aspects of inventory control problems can be easily modelled using SP and that optimal solutions can be obtained very efficiently even for large-scale problems. We illustrate these ideas showing applications related to the management of blood unit inventories in a network of hospitals served by a central blood bank.

■ WC-05

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S105

Heuristics for Vehicle Routing Problems I

Stream: Vehicle Routing and Logistics Optimization I
Chair: *Daniele Vigo*

1 - Fleet composition for last-mile delivery service
Frédéric Semet, Ekaterina Alekseeva, Luce Brotcorne

In this presentation, we address a fleet composition problem for last-mile delivery service. This problem occurs at a tactical level when the composition of the fleet has to be decided in advance. It is the case for companies that offer last-mile delivery service. Most of them sub-contract the transportation part to local carriers and have to decide the day before which vehicles will be needed to cover a partially known demand. Here we assume that the distribution area is divided into a limited number of delivery zones and the time horizon into time-slots. The demand is characterized by packages to be transported from pick-up zones to delivery zones given a delivery time slot. First, we introduce an integer programming model which aims to minimize the total delivery cost while ensuring that the demand is covered, the capacity of each vehicle is not violated, the working time for each period is not exceeded and the total working of each delivery respects the social regulations. Then we present a column-generation based approach, which is able to solve real-life instances in reasonable CPU times.

2 - SISRs - slack induction by string removals for vehicle routing problems
Jan Christiaens

Multiple decades of research have led to a multitude of solution methods for Vehicle Routing Problems (VRP). Exact methods are now capable of solving some CVRP's (capacitated vehicle routing problem) up to 650 customers. However, their practical applicability is limited by excessive computation times incurred. Therefore, heuristics are still preferred when dealing with large scale real-world problems. Such methods which have proven to be very effective include, but are not limited to: memetic algorithms and ruin and recreate strategies. Generality of solution approaches is proven by way of application to a multitude of problem variants. As such, memetic algorithms may require problem specific crossover processes while ruin and recreate strategies rely on a number of ruin and recreate methods which are selected by way of an adaptive learning mechanism. In this research a general applicable ruin and recreate method - SISRs - is proposed. SISRs (Slack Induction by String Removals) relies on a single ruin and recreate method which is guided by Simulated Annealing for distance minimisation and guided by an absences-based acceptance criterion for fleet minimisation. Performance and general applicability of the presented solution approach is demonstrated on VRP variants such as the CVRP, VRP with Time Windows and the Pickup and Delivery with Time Windows for which many of the best known results are improved.

3 - A static move descriptor-based heuristic for the vehicle routing problem
Daniele Vigo, Luca Accorsi, Wout Dullaert, Birger Raa

We consider several strategies for the efficient implementation of Static Move Descriptors (SMDs), a recently developed technique that significantly speeds up Local Search-based algorithms. SMDs exploit the fact that each local search step affects only a small part of the solution and allow for efficient tracking of changes at each iteration, such that unnecessary reevaluations can be avoided. Despite its significant advantages, the design proposed in the literature suffers from high overhead and considerable implementation difficulty. We developed a simpler implementation that offers better extendibility and significant further speedups of local search algorithms. We also explore the hybridization of SMD with the granular sparsification concept to achieve a possibly larger computational efficiency. We experimentally evaluate our findings by applying them to the Capacitated Vehicle Routing Problem (CVRP).

4 - A two-phase solution algorithm for the flexible periodic vehicle routing problem
Claudia Archetti, Elena Fernandez, Diana Lucia Huerta Muñoz

The Flexible Periodic Vehicle Routing Problem is the problem of visiting a given set of customers considering a certain periodicity to attend their demands. It is a generalization of the Periodic Vehicle Routing Problem (PVRP) where the fixed schedule constraint is relaxed and the quantity to deliver to each customer at each visit is a decision variable. This flexibility leads to remarkable savings in total costs and this explains the interest in studying the problem and developing effective solution approaches. The problem was first studied in a previous paper by the same authors where the maximum benefits with respect to the PVRP were shown and a mathematical formulation of the problem was proposed. In addition, an exact algorithm, based on branch-and-cut, was developed which is able to solve small to medium size instances. In this work, an iterative two-phase matheuristic is developed to solve medium and large instances of the problem. Computational tests are made on benchmark instances and on newly generated instances. The matheuristic is compared with optimal solutions, on small-size instances, and with lower bounds on larger instances. Computational results show that good quality solutions are obtained in a reasonable amount of time.

■ WC-06
Wednesday, 12:30-14:00 - SOUTH BUILDING UV S106

Stochastic Modeling in Queuing Systems

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Chair: *Hiroshi Toyoizumi*

1 - Cost-benefit analysis of four availability retrial models with warm standby components and general repair times
Kuo-Hsiung Wang

This paper presents a cost-benefit analysis of four availability retrial models with warm standby components and arbitrary repair times. The time to failure and time to repair of the primary and standby components are assumed to be exponentially and generally distributed, respectively. The failed components join the retrial orbit if the server is busy or are repaired immediately. The time to retrial is assumed to be exponentially distributed. We adopt a recursive method that involves using the supplementary variable technique with the remaining repair time treated as the supplementary variable to develop expressions of the steady-state availability Av, for the four availability retrial models. For each availability retrial model, the explicit expressions of Av were developed for the three repair time distributions, namely exponential, three-stage Erlang, and deterministic distributions. The specific values of the distribution parameters and component costs are compared among the four availability retrial models. The four availability retrial models are ranked on the basis of Av and the cost-benefit ratio for three repair time distributions, where Av represents the benefit.

2 - Modelling of Bernoulli arrival process subject to binomial catastrophes
Nitin Kumar, Umesh Gupta

In recent years study of catastrophe model has picked up much interest due to their wide application in computer-communication networks and digital telecommunication systems where interruptions due to various types of virus attacks are referred to as catastrophe. The occurrence of a virus (catastrophe) may cause immediate removal of all or some packets (elements) from the system. Such type of situations can be modelled under discrete-time catastrophe setup. More specifically we consider a discrete-time model in which population (packets) grows according to Bernoulli process and viruses (catastrophes) occur according to renewal process. When a catastrophe occurs, an element of the population remains in the system with probability p or gets removed from the system with probability 1-p. The analysis of the model has been carried out using supplementary variable technique and steady-state distribution of the population size at post-catastrophe, arbitrary and pre-catastrophe epochs are obtained. A step-wise computing procedure has been given for easy implementation of the analytical results.

3 - M/M/? stochastic dynamic networks with joins and leaves
Hiroshi Toyoizumi

Break-ups in the scale-free network are studied. We study the basic features such as the dynamics of the number of break-ups, and the size of the fragments. We also discuss the extension of our toy model to M/M/ stochastic dynamic networks with joins and leaves.

Most of the current network models are focused on gen- erating connected graphs, which is ideal for studying spread dynamics. However, the focus is shifting to the seg- regation or how closed communities arise in the network. We use a simple toy model of network with preferential attachment to study the segregation phenomena. In scale-free networks, nodes join the network and attach to the existing nodes preferentially with their degree, and the network evolves progressively. We use a particular type of scale-free networks so that it may have break-ups.

■ WC-07

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S107

Scheduling with Resource Constraints II

Stream: Scheduling with Resource Constraints
Chair: *Pedro Alfaro-Fernandez*

1 - A novel disruptive innovation-like algorithm for single machine scheduling with sequence-dependent setup times

Chun-Lung Chen

This research proposes a novel Disruptive Innovation-like Algorithm to solve the problem of single machine scheduling with sequence-dependent setup times for minimizing the total weighted tardiness of jobs. The presented algorithm is derived from the theory of disruptive innovation proposed by Christensen (1997). Based on the theory of disruptive innovation, four Disruptive Innovation-Like Algorithms (DILA1, DILA2, DILA3, and DILA4) are proposed and several mechanisms built in DILA will be examined. To evaluate the performance of DILA, 120 benchmark instances are chosen from the literature. Computational results confirm that DILA is an efficient and competitive algorithm compared with the state-of-the-art algorithms.

2 - Minimizing the weighted tardiness penalties for parallel machines scheduling based on ATC dispatching rule

Gen-han Wu, Wang-Xian Li

The ATC dispatching rules are originally developed for solving the single machine scheduling problem with minimum tardiness penalties. In recent years the ATC rules are successively applied to the parallel machine scheduling but the current studies still rely on the thinking of single machine scheduling to choose the earliest available machine as the processing machine. Even though they can avoid the machine idleness, they might not obtain the best solutions due to the different machine efficiencies. This highlights the limits of the ATC rules. We consider machine release times, job-ready times, and sequence-dependent setup times and develops the ATC dispatching rules for the parallel machine scheduling problem. The design of reducing the variable time's interference on the denominator is proposed and three approaches for selecting the best processing machine is developed. In experiment analysis, a series of random problems designed by grid approach is utilized to obtain the best scheduling and are compared to the existing literature on the identical parallel machine scheduling problems. As to the unrelated parallel machine scheduling, we consider the mechanism of the different machine available processing time points in order to improve the mechanism of the original the earliest available processing time. The results show that our adjusted ATC dispatching rule is better than the approaches on the existing literature.

3 - Hybrid flow shop to minimize makespan: efficient constructive heuristics

Victor Fernandez-Viagas, Jose M. Molina-Pariente, Manuel Burgos, Paz Perez Gonzalez, Jose M Framinan

In this study, we analyse the hybrid flow shop scheduling problem to minimize makespan, where each stage in the shop is composed of identical machines. In the existing literature, several heuristics have been proposed to obtain good solutions in reasonable computational times. We analyse and compare them in this study, by carrying out a computational evaluation. More specifically, a total of 18 heuristics have been recoded and compared under the same conditions on a set of 360 instances. In addition, we propose two new heuristics to solve the problem. These heuristics use a memory approach to repeat in each iteration the best moves of previous iterations. The computational results show the efficiency of the proposed heuristics.

4 - Flow shop scheduling problem with additional resources

Pedro Alfaro-Fernandez, Ruben Ruiz

Scheduling is a well-known Operations Research problem for both: industry and research community. It can improve or optimize industry processes in many forms. However, too often two issues stand in the way: research lacks the detail that industry demands while industry lacks from the deep knowledge required. This is the well-known gap between theory and practice. Studying real shop production as a scheduling problem from the Industry perspective results in many issues. Machinery is indeed a crucial and scarce resource, but so it is the plant personnel that makes it work. Consequently, we can see an increase in the research effort to include additional resources in scheduling problems. In this work, we introduce the consideration of additional resources in the well-known flow shop to minimize the makespan. Resources are renewable and flexible. Given a maximum amount of resources, which is fixed during the production horizon, jobs use a given amount of resources during their processing. The objective is not only to schedule jobs as in the regular flow shop but not to exceed the maximum amount of resources in the plant. In this ongoing work, we can already show some promising results in mathematical models, simple heuristics and powerful metaheuristics.

■ WC-08

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S108

Topics in Combinatorial Optimization

Stream: Combinatorial Optimization I
Chair: *Valentina Cacchiani*

1 - Approximating the incremental knapsack problem

Ulrich Pferschy, Federico Della Croce, Rosario Scatamacchia

We consider the 0-1 Incremental Knapsack Problem (IKP) where the capacity grows over time periods and if an item is placed in the knapsack in a certain period, it cannot be removed afterwards. The contribution of a packed item in each time period depends on its profit as well as on a time factor which reflects the importance of the period in the objective function. The problem calls for maximizing the weighted sum of the profits over the whole time horizon.

In this work, we provide approximation results for IKP and its restricted variants. In some results, we rely on Linear Programming (LP) to derive approximation bounds. We first manage to prove the tightness of some approximation ratios of a general purpose algorithm currently available in the literature and originally applied to a time-invariant version of the problem. We also devise a Polynomial Time Approximation Scheme (PTAS) when the input value indicating the number of periods is considered as a constant. Then, we add the mild and natural assumption that each item can be packed in the first time period. For this variant, we discuss different approximation algorithms suited for any number of time periods and for the special case with two periods.

2 - Fractional knapsack problem with penalties: models and algorithms
Michele Monaci, Enrico Malaguti, Paolo Paronuzzi, Ulrich Pferschy

Given a set of items, each one having positive profit and weight, and a knapsack of fixed capacity, the objective of the classical 01 Knapsack Problem is to select the subset of maximum profit that does not exceed the knapsack capacity. When considering fractional items, the problem can be easily solved through the well-known algorithm of Dantzig. In this talk, we consider the case in which items can be fractionated at cost of a penalty, so that a given fraction of an item brings a smaller fraction of profit. The problem is denoted as Fractional Knapsack Problem with Penalties (FKPP). We show that, when the penalty for fractionated items is described by a concave function, there exists an optimal solution for the FKPP that has at most one fractional item. We present alternative mathematical models for the problem and describe a solution algorithm based on Dynamic Programming for the case of concave penalty functions. All models and algorithms are compared through computational experiments on instances derived from the literature.

3 - A path-based formulation for the 2-reservoir hydro unit commitment problem
Dimitri Thomopulos, Wim van Ackooij, Pascal Benchimol, Claudia D'Ambrosio

Managing the hydroelectricity produced by the plants in hydro valleys is called the hydro unit commitment problem (HUCP). Solving efficiently and rapidly HUCP, especially when considering the optimization of cascaded reservoirs, is particularly difficult. The main reason for this mostly arises from the need to model reality as accurately as possible. One particular way of dealing with this difficulty is by disposing of an a priori discretization, i.e., considering a specific set of operational points, typically chosen in order to have maximal efficiency (highest derivatives). It is intuitive that a decomposition method is a valid strategy to tackle the hydro valley HUCP problem. However, it is also clear that the effectiveness of the method is subject to the efficiency of solving the obtained sub-problems. Our main postulate is that a two-reservoir single turbine hydro unit commitment problem (2RST-HUCP) is the essential building stone of these subproblems and can be handled efficiently. We focus on the deterministic price-taker model with a two-reservoirs and potentially many discrete operational points for the underlying units. We extend a path formulation for the single reservoir hydro unit commitment problem presented in van Ackooij et al. (2018). In particular, we propose a path formulation, a dynamic programming approach to handle the 2RST-HUCP, and some pruning techniques in order to reduce the size of the graph.

4 - On the value of integration in supply chain planning
Martin Kidd, Maryam Darvish, Leandro Coelho

It is well known that a lack of coordination and information sharing among facilities with conflicting objectives is a major cause of large logistic inefficiencies in a supply chain. It is therefore often emphasized that a shift from the traditional approach of localized planning to a global, integrated solution is one way in which systemwide costs can be greatly reduced. Subsequently, a large body of research exists on integrated optimization problems in logistics and supply chain management that integrate the decisions of production, inventory, distribution and facility location in different ways. In practice, however, integration significantly increases the complexity of the entire decision making process as more coordination and information sharing is needed. The question naturally arises: how can we quantify the value of integration in order to support the strategic decision to shift from localized planning to integrated planning? In this talk we will present some initial results on quantifying the value of integration using realistic data from different industries. We compare the cost-savings of several possible levels of integration, where we use mixed integer programming (MIP) formulations to solve the resulting planning problems. We will address the question of whether or not there is a relationship between a good way of integrating decisions and certain features of the supply chain.

■ WC-09

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S109

Integrating Machine Learning in Optimization Methods

Stream: European Working Group: Data Science Meets Optimization
Chair: *Kevin Tierney*

1 - A data science approach for OD matrix analysis in transportation modelling
Lídia Montero, Jaume Barceló, Xavier Ros-Roca

Origin-Destination (OD) matrices are a main input to most of the transport analysis procedures. Travel demand analysis is the first step in the traditional 4 steps Transport Models, and it is usually based on a well-established methodology, traditionally consisting on detailed travel household surveys, accurately designed, supported by careful sampling procedures, whose results are combined with socioeconomic census data. However, the resulting matrices still need to go through additional checking and validation processes before being used for transport analysis, especially when they will become a major input to transport models. A variety of checking and validation process have been proposed, nevertheless there still remain many alternatives to explore. The first objective of the research reported is to propose a methodological approach to systematically analyze the spatio-temporal structure of the trip patterns represented by modal OD matrices based on the use of Principal Components Analysis and Correspondence Analysis. The main methodological contribution in the validation process consists on considering analysis of similarities in the global mobility pattern inter-districts and/or inter-neighborhoods of common knowledge among mobility analysts. To do this a Correspondence Analysis (CA) is applied to the daily modal mobility matrix in the city of Barcelona. Hourly pattern analysis is addressed using Principal Component Analysis (PCA).

2 - Optimization of Shows Schedules on Linear Television
Sebastian Souyris, Jaime Miranda

The hyper-competitive live and video entertainment industry offers to consumers an array of high-quality products to choose from like never before. At the same time, content providers must make decisions carefully in order to grow or maintain a profitable position. At a tactical level, decision makers must decide what shows to create and acquire in order to maximize the medium-term ratings. At an operational level, schedulers must program the shows in order to maximize the short-term target demographic viewership. In this talk, we present rating forecasting and show scheduling models that in conjunction lift network audience. We use gradient boosting trees to predict audience and an integer programming model that use patterns to schedule shows. Our models are used by leading US television networks. We present the approach and results.

3 - Online algorithm selection for operational-level combinatorial optimisation problems
Hans Degroote, Lars Kotthoff, Jose Luis Gonzalez-Velarde, Bernd Bischl, Patrick De Causmaecker

The classic approach to solving an NP-HARD problem is to develop a specialised algorithm. We apply a more high-level approach: to collect a portfolio of algorithms that solve the problem well and to learn when to use which algorithm while solving problem instances. This is called online algorithm selection. The core idea is to use a supervised learning method to create a regression model for each algorithm, predicting its performance. To do so, a set of descriptive features is required. For each new instance, the predicted best algorithm is selected. Its performance is then observed and used to further refine its regression model, resulting in better selections over time. An advantage of online algorithm selection is that no time must be spent on developing and fine-tuning new algorithms: it automatically learns to combine the algorithms already developed. Furthermore, new algorithms can be added to the portfolio, and the method can learn when to use them. Online algorithm selection is most useful for problems at the operational level, as those must be solved often (generating a lot of new performance data) and in a short time (if much time is available, all algorithms can simply be run in parallel). Simulations on the ASlib algorithm selection benchmark show that the proposed method consistently manages to learn over time. It performs especially well when starting from some initial training data (warm start), but can also outperform the single best algorithm without.

4 - Deep learning assisted heuristic tree search for the container pre-marshalling problem
André Hottung, Shunji Tanaka, Kevin Tierney

One of the key challenges for operations researchers solving real-world problems is designing and implementing high-quality heuristics to guide their search procedures. In the past, machine learning techniques have failed to play a major role in operations research approaches, especially in terms of guiding branching and pruning decisions. We integrate deep neural networks into a heuristic tree search procedure to decide which branch to choose next and to estimate a bound for pruning the search tree of an optimization problem. We call our approach Deep Learning assisted heuristic Tree Search (DLTS) and apply it to a well-known problem from the container terminals literature, the container pre-marshalling problem (CPMP). Our approach is able to learn heuristics customized to the CPMP solely through analyzing the solutions to CPMP instances, and applies this knowledge within a heuristic tree search to produce the highest quality heuristic solutions to the CPMP to date.

■ WC-10

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S110

MCDA and Environmental Management II

Stream: Multiple Criteria Decision Aiding
Chair: *Luisa Paolotti*
Chair: *Filippo Fiume Fagioli*

1 - A multi-criteria decision framework for the selection of biomass separation equipment
Pablo Brito-Parada, Junko Hutahaean, Jan Cilliers

Bioseparations are essential in a wide range of industrial applications and make use of a variety of techniques and unit operations for efficient processing. A typical bioseparation process include the removal of biomass before further purification stages. The selection of a biomass separation technique and the equipment required will depend on a number of criteria that are often complex and challenging. Despite its complexity, little attention has been paid to develop and implement decision analysis frameworks to support the selection of bioseparation equipment.

This paper presents a decision support system that has been developed to select equipment for the separation of biomass. The framework evaluates the requirements of the process and applies the Analytic Hierarchy Process to perform the multi-criteria decision analysis to select among six different equipment alternatives. This approach systematically considers the relative importance of those different alternatives and selection criteria, based on separation performance and energy consumption, to evaluate the weighting for each criterion and alternative.

The output of the framework is a ranking of equipment as well as a sensitivity analysis of the results for different weighting of the criteria. These results can be used to equip practitioners and engineers in the field of bioseparations with a tool for making a more consistent and better-informed equipment selection decisions.

2 - Towards the generation of social entrepreneurial impact in the traditional wood and biomass sector: a multi-criteria decision aid perspective
Olga Porro, Nuria Agell, Mónica Sánchez

Social entrepreneurship (SE) is a multidimensional concept (including many aspects, such as economic sustainability, social impact, innovation or leadership vision) with an imprecise nature. We are concerned with how this phenomenon can be applied to the traditional small and medium enterprises (SMEs). Our goal is to compare SE initiatives and devise an integrative overall indicator of the attractiveness, potential and impact of its social entrepreneurial activity.

Multi-criteria decision aid (MCDA) techniques are adequate tools for this analysis. At a first stage, based on literature research and expert's knowledge gathering, we will identify key attributes affecting the decision process of social entrepreneurial opportunities in the SMEs. Secondly, data from a wood pellet production plant, owned by a traditional family business, whose vision is to contribute to mitigate climate change, will be analyzed. Different alternatives are considered (i.e., implementing a district heating and cooling system, installing a cogeneration plant or setting up a cooperative of biomass providers). The analysis involves many criteria that may be intangible, and all the initiatives have an impact to the agro-forestry management and practice of the surrounding community. Many stakeholders are influenced by this sector, such as public agents, private investors, forest landowners, biomass users, villagers or wood transformation industries

3 - The Willingness to Pay for Sustainable Supplier Selection
Mehrnoosh Enjelasi, Behnam Fahimnia, Andrew Collins

Sustainable Supplier Selection has not been broadly explored in the literature from a behavioural viewpoint. This study aims to understand how supply chain or procurement managers balance environmental and economic goals when making supplier selection decisions under different scenarios. Several quantitative optimisation models have been developed to analytically and numerically explore possible trade off solutions. We aim to study this topic from a practical viewpoint and understand the situations upon which a supply chain or procurement manager choose one supplier over another. In particular, we analyse a range of behavioural factors influencing sustainable supplier selection in the Fast-Moving Consumer Goods (FMCG) industry. A discrete choice experiment was designed to investigate this topic. Data has been collected from supplier chain and procurement managers in the FMCG industry to address the following questions a) to what extent supply chain/procurement professionals compromise costs to achieve better environmental performance when making supplier selection decisions, b) which dimensions of environmental sustainability (waste management, carbon equivalent emission efficiency, green product and process design, and organisational support toward sustainability) play more dominant roles in supplier selection decisions, and c) to what extent the environmental attitudes of individuals influence their supplier selection decisions.

4 - MCDA approach to the internal migration of regions: case of Serbia
Mladen Stamenković, Salvatore Corrente, Maja Jandric

Internal migration is one of the most fundamental responses to different development dynamics of regions. In the most advanced societies, inter-regional migration is a major mechanism through which labor resources are redistributed geographically in response to changing economic and demographic forces. A vast literature in economic development sees internal migration as the central feature of future economic growth. When it comes to migration, only around three percent of the world's population, about 210 million people, are international migrants and that most migratory flows happen within the country.

The aim of the paper is to apply sorting approach in order to determine internal migration potential for Serbian regions and provide public policy recommendations how to mitigate the bad effects of such process. The classification will be conducted by using the extension of the ELECTRE Tri method to the case of criteria structured in a hierarchical way. The novelty of the approach will be within modeling of imprecise weight structure of such a problem. Imprecise SRF method will be used as the methodological support. Final classification will not be unique, and it will depend on the choice of the weights of criteria. Consequently, a frequency of classification will be obtained by applying Stochastic Multicriteria Acceptability Analysis.

■ WC-11

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S111

Dynamic Games in Operations Research

Stream: Applications of Dynamical Models
Chair: *Margarida Lopes*

1 - Price, time, and reliability competition for service delivery
Ata Jalili Marand, Hongyan Li, Anders Thorstenson

A firm's delivery performance has significant impacts on satisfaction and purchase behavior of its customers. It has been shown that customers are willing to pay higher prices for a faster and more reliable service. In this study, we address the interactions between price, delivery time, and delivery-reliability level, in a competitive setting. We model the problem as the competition among an arbitrary number of profit-maximizing firms facing boundedly rational customers who can choose to buy service from one of the firms or balk. We show the existence of a unique Nash equilibrium and propose a simple iterative method that converges to this equilibrium. Furthermore, we compare our results with those in the existing literature and show that, contrary to the literature, a firm with a capacity advantage is not always better off in a more reliability-sensitive market, and even a firm that is in a capacity disadvantage may benefit from a more time-sensitive market.

2 - A bi-level optimization formulation of priority service pricing
Yuting Mou, Anthony Papavasiliou, Philippe Chevalier

Priority service pricing is a promising approach for mobilizing residential demand response, by offering electricity as a service with various levels of reliability. Higher levels of reliability correspond to higher prices. The proper pricing guarantees that consumers self-select a level of reliability that corresponds to the reliability that the system can offer. However, traditional theory for menu design is based on numerous stringent assumptions, which may not be respected in practice, such as a well-behaved (convex) cost functions. In addition, the objective of the menu design is to maximize social welfare, while the profit requirement of the aggregator is not accounted for. Moreover, no guidelines are provided regarding how to discretize the menu into finite options. In this study, we design a priority service menu as the equilibrium solution to a Stackelberg game where an aggregator moves first with a menu offering, and residential consumers react by selecting menu options and revealing their valuation. The Stackelberg game is modelled as a bi-level optimization problem involving the aggregator and consumers, and then reformulated as a mixed-integer problem. As a consequence of this approach, the menu design problem can be integrated within a day-ahead unit commitment model, and profit requirements of the aggregator can be modeled explicitly. The approach is illustrated on a toy numerical example as well as a large-scale model of the Belgian power market.

3 - Optimization of lot size flow with linking cost and individual profit of bargaining players of various tier wise purchasing capacities in supply chain network
Prem Prakash Mishra

An attempt has been made to optimize the lot size flow passing through various nodes of successive tiers with sequentially decreasing stock capacity and simultaneously increasing prices of commodity with respect to time. The bilateral link of flow is formed from source to sink through bargain. There exists linking cost between the nodes of different tiers for making cooperation. The cooperative lot size game theoretic approach has been employed to obtain the profit of individual player of different tiers and optimum cost of system under the cobweb phenomenon of demand and supply.

4 - Post-merger internal organization in multitier decentralized supply chains
Margarida Lopes, Duarte Brito

Firm mergers usually provide cost savings, with full integration of the participants (traditional merger). The creation of divisions within the firm that results from the merger is an alternative possibility, in which the merger resulting firm obtains a strategic advantage over its rivals (multidivisional merger). This second possibility involves at least some foregone cost savings or synergies, but provides a Stackelberg behavioural advantage. The owners of a merged firm may thus face a trade-off between operating as a single firm, or operating with independent divisions. Many industries present a vertically desintegrated structure across a supply chain composed by several tiers, each one with many competing firms. To what extent does a merger in one tier impact on firms in other tiers and on final consumers? These questions have been answered considering both upstream and downstream mergers, in environments where mergers bring cost savings and firms compete à la Cournot within each tier. The possibility of firms opting for a strategic behaviour advantage inducing merger, however, has not yet been considered. In this paper, we make this decision across a multitier decentralized supply chain endogenous. We find under which conditions each structure (traditional or multidivisional) occurs in equilibrium, and analyse the effects upon consumers (final price) and firms (profits), to find out parameter ranges for which consumer welfare is not maximized by firms' choices.

■ WC-12

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S112

Port Operations

Stream: Maritime Transportation
Chair: *Eva Vallada*

1 - A new lower bound and an iterative deepening hash-based branch-and-bound algorithm for container premarshalling
Consuelo Parreño Torres, Shunji Tanaka, Kevin Tierney, Ramon Alvarez-Valdes, Ruben Ruiz

Container terminals around the world strive to reduce the berthing times of the ships to improve their efficiency. A way of achieving this objective consists of re-sorting the containers according to their retrieval times before the arrival of the ship, when the workload at the terminal is at a minimum. This is known as the container pre-marshalling problem. Academic work in this field has been intense in recent years, with algorithms nearing the goal of finding optimal solutions in low times even for real-world sized problems. To this end, we present an iterative deepening branch and bound search that includes a novel lower bound computation, new branching and symmetry breaking rules and a new greedy partial solution completion heuristic. Moreover, by using hash functions, we introduce an effective way to skip already visited configurations during the branching, effectively avoiding stack permutations. Several computational experiments have been carried out over difficult pre-marshalling datasets, obtaining a greater number of optimal solutions than the state-of-the-art algorithms and also obtaining feasible solutions in instances not yet solved by these algorithms.

2 - A fast heuristic for the container pre-marshalling problem
Noemí Elizabeth Castañeda, Gerardo Minella, Ruben Ruiz

In the Pre-Marshalling Problem the objective is to rearrange shipping containers in a given bay of a block of containers placed in the port storage yard so that their retrieval is carried out without unproductive moves. This way, containers can be swiftly retrieved without unwanted waiting, resulting in higher throughout of the terminal. Ideally, the pre-marshalling is carried out when the terminal is not at peak capacity and/or when there is no ship waiting at the berthing line. The goal is to find the sequence with minimal number of movements to arrange the containers in the requested order. In this short presentation, we show a fast heuristic that gives such a solution and that it compares favorably against existing methods from the literature. The proposed heuristic consists of a greedy randomized adaptive search procedure to build solutions to problems and a subroutine to correctly locate containers saving movements. The computational experiments carried out so far are promising when compared to existing methods.

3 - Yard crane scheduling in Valencia's largest container terminal
Gerardo Minella

This work presents a real-life yard crane scheduling problem solution approach developed for the largest terminal operator in Valencia port. In a first step, we study and characterize the actual real problem. More specifically, the container yard studied has a very specific and particular layout. Blocks of containers are parallel to the quay similar to an Asian layout but with some particularities. The terminal employs Rubber Tyred Gantry (RTG) cranes that can move from one set of blocks to another. We discuss the enormous challenges that we faced when collecting, cleaning and organizing the gargantuan data sets needed to model and solve the real problem. We briefly discuss the proposed methods in the form of simple heuristic and metaheuristic techniques based on dispatching rules, genetic algorithms and simple local search-based iterated greedy methods. All these methods are compared to the real working conditions and algorithms employed at the terminal. Results, opportunities and future research directions are discussed.

4 - Metaheuristics for the yard crane scheduling problem in a port container terminal
Eva Vallada, Fulgencia Villa, Ramon Alvarez-Valdes, Jose M. Belenguer

An iterated greedy method and a genetic algorithm are proposed to schedule the movements of a yard crane in a port container terminal. An automated terminal is studied, with input/output points in each block of the yard where the crane loads/unloads containers. Congestion in input/output points is considered. Therefore, four types of operation requests related to containers are analysed: arrival of a container from a vessel to be stored in the yard, arrival of a container from land to be stored in the yard, retrieval of a container from the yard to be loaded in a vessel, and retrieval of a container from the yard to be loaded in a truck. The optimization objective is to minimize the total weighted delay with respect to a time parameter related to each container and to reduce the time each container stays at the input/output point. A benchmark of problems is also proposed, with small, medium and large instances, varying the time parameter ranges. Computational experiments are carried out together with a statistical analysis in order to compare the performance of both methods.

■ WC-13
Wednesday, 12:30-14:00 - SOUTH BUILDING UV S201

Credit Card Risk Management

Stream: Financial Modeling, Risk Management and Managerial Accounting
Chair: *Jonathan Crook*

1 - Optimal model selection in credit risk modeling
Marta Galvani, Silvia Figini

The aim of this paper is to present novel approaches for model selection and assessment in credit risk prediction models. More precisely the idea is to derive the optimal model taking into account complexity, predictive power and discriminatory ability. In this paper we introduce a comparison for a wide range of supervised learning models introducing the concept of stochastic dominance and optimality. Empirical evidence are obtained using literature and real data sets.

2 - Predicting credit card debt recovery rates: an empirical study using generalised additive models
Christophe Mues, Raffaella Calabrese, Mee Chi (Meko) So
After the introduction of the Basel accords, and with the recent adoption of the new accounting standard IFRS 9, which considers expected credit losses, a growing body of work within the credit risk modelling literature considers the problem of estimating recovery rates in the event of a loan default. The recovery rate is the proportion of the outstanding balance at default that will be paid back by the creditor as part of the recovery or collections process. However, relatively few studies have thus far appeared on credit card data and they did not yet consider the extent to which the explanatory variables in these models may be non-linearly related to the dependent variable. We propose a generalised additive model to produce recovery rate estimates for credit card accounts in default. This model is capable of dealing with the bimodal nature of the recovery rate distribution, allowing for different drivers for the probability of zero recovery, a full recovery, or the size of a partial recovery. Furthermore, the model is able to capture any non-linear relationships that may exist between those and the explanatory variables. By fitting the model to an example dataset from a Hong Kong lender, we find that the method compares well against other methods and it produces well-calibrated estimates. Moreover, several non-linearities are identified, many which are intuitive and would risk being overlooked or misinterpreted using a traditional parametric approach.

3 - Regulatory policy to mitigate potential risks arising from contingent convertibles
Masaaki Kijima
A contingent convertible (CoCo) bond is an instrument that converts into equity when the issuing bank is in financial distress. In practice, a trigger event of CoCo takes place when the capital ratio of the bank falls to a pre-defined level or when the national authority declares a trigger at its discretion. The aims of this study are to model CoCos having such triggers and to find effective regulatory policies to handle them. A model for banks issuing CoCos is built within the framework of a structural-default approach. The trigger mechanisms are expressed both in a first-passage-time model and in a Merton type model. CoCo investor is also included in our model as CoCos are designed to enhance the bank's resilience while shifting their risks to investors. Through numerical examples, we study the impact of regulatory policy, which is intended to mitigate both banks and investors' default risks, on the price of CoCo and default probabilities of both bank and investor.

4 - Survival models for credit cards with time varying coefficients
Jonathan Crook, Viani Djeundje
Survival models applied to credit loan data predict the probability that an account will default in the next month given that she/he has not defaulted before. Earlier work (Loew & Crook 2016) suggests that the parameters survival models for credit card accounts changed after, compared with before, the financial crisis. In this paper, rather than having two sets of parameters we estimate survival models with parameters that are allowed to vary continuously over time, in addition to time varying covariates. We use different specifications as to how the parameters are related to time including a highly non-linear function and cubic B-splines. We allow the parameters on a subset of covariates and then on all of the variables themselves to vary. Using a large sample of credit card accounts, we compare the effects on the significance of included covariates and the effects on predictive performance. We find noticeable uplift in predictive performance when the parameters of all of the variables are time varying and that the spline functions give slightly better performance than the highly non-linear specification.

■ WC-14
Wednesday, 12:30-14:00 - SOUTH BUILDING UV S202

ETHOR III Ethics and OR

Stream: OR and Ethics

Chair: *Pierre Kunsch*
Chair: *Cathal Brugha*
Chair: *Dorien DeTombe*

1 - Modelling ethical level in financial entity performance appraisal: assessment in a multi-dimensional framework using data envelopment analysis
Don Galagedera

When appraising performance of financial entities such as ethical mutual funds (MFs), it is important to recognise that MF portfolio construction and management may be conditional upon corporate policy on ethical issues. Appraising performance incorporating multiple financial and economic performance measures together with measures of commitment to ethical issues such as environment, sustainability and governance (ESG) score is essentially an undertaking in a multi-dimensional framework. We develop data envelopment analysis (DEA) models to assess MF performance recognising that (i) ESG score reflects medium- to long-term corporate policy on ethical issues and (ii) MF portfolio construction and management may be conditional upon such corporate policy. We model this issue by conceptualising MF overall management process as a serially linked two-stage process (operational management and portfolio management) and treating ESG score as a fixed output at the first stage. DEA models assess overall and stage-level performance and thereby reflect relative performance from two different aspects of MF management. For MFs deemed inefficient, we propose a procedure that provides information as to how inefficient MFs may reach the frontier of best performance. We highlight our procedure as a methodological advancement in ethical MF performance appraisal using DEA. We demonstrate application of the proposed models using a sample of large U.S. equity MFs as a case study.

2 - Ethical investment performance: evidence from the portfolio theory perspective
Noureddine Kouaissah, Sergio Ortobelli

This paper explores and examines the performance of socially responsible investments (SRI), frequently called ethical investments or sustainable investments, from the portfolio theory perspective. In particular, we use three different portfolio strategies to compare the financial performance of SRI and conventional investments. In this context, we propose a new portfolio strategy that maximizes the Sharpe ratio under the third-order stochastic dominance constraints. Applying the portfolio optimization methods to different ethical funds/indexes, we can answer several questions that arise with SRI opportunities. Thus, we first consider the Italian ethical market and then we strengthen our analysis on SRI to the international market using MSCI KLD 400 social index. Initial empirical results from Italian market are in contrast with the corporate social responsibility (CSR) theory conclusion, which confirms that SRI are performing much better than their conventional counterparts. This may well be linked to the characteristics and the peculiarity of the Italian market, e.g., recentness and dimensionality. International ethical indexes, on the other hand, give the best results and conforming to the CSR theory. The proposed empirical analysis allows us to understand the complexity and dynamics of the SRI and to evaluate their performance.

3 - Optimization problems in designing a post-disaster relief system
Bela Vizvari

There are many metropolitan cities such that disaster, for example earthquake, can be expected in the city. Part of the preparedness for disaster can be that authorities establish, maintain, and train a relief organization. After selecting the proper technology, the parts of the system are to be optimized. Optimization problems arise both before and after the disaster. Pre-disaster optimization is again part of the preparedness. These kinds of problems are static. It is enough to solve them only once after any significant change in the system. Optimization in the post-disaster period is part the disaster response. These problems are dynamic as the situation and its known description can be changed very fast. The aim of these optimization problems is to find the proper answers for the disaster to save human life and property. This talk discusses several optimization problems as follows: 1. Assignment of surgeons and anesthetists to operating rooms including both static and dynamic version. The objective is to maximize the number of working operating rooms. Only the expected value can be maximized in the static case. 2. Finding shortest path for emergency vehicles in a partially destroyed city; dynamic version. Computational analysis of the existing methods is provided. 3. Emergency transportation of injured people to hospitals including mathematical analysis of the problem, models, and ethical considerations.

4 - Using soft systems methodology to incorporate ecological ethics and systems thinking in education
Lady Johanna Peñaloza-Farfán, Alberto Paucar-Caceres

Higher Education Institutions (HEI) are committed to promote sustainable development/regional development (SD/RD). Over the last years, HEIs have been involved in providing education for SD/RD. These include critical thinking, creative thinking, systems thinking (ST), and leadership. HEIs have embedded some of the above elements in the curricula of its programmes. This paper argues that the principles and practice of ecological ethics (EE) need to be incorporated. EE are moral principles governing the human attitude towards the environment, and rules of conduct for environmental care and preservation. EE advances a way of life practicing a set of skills and abilities, based on mutual acceptance and equal (horizontal) co-existence among human beings. Furthermore, we also argue that ST skills need more prominence in current HEIs programmes. The paper aims to explore strategies among lecturers and students for incorporating ST and EE principles into current programs at the Universidad de Ibague (Colombia) and Manchester Metropolitan University (UK). We regard educational setting as problematic situations where improvements can be facilitated by the use of soft systems methodology (SSM). We report in the use of SSM for analysing students and lecturers' views on the specific benefits and systemic advantages of using ST and EE when promoting SD/RD. The paper proposes a re-designed course structure in which ST skills and EE principles for SD/RD awareness are incorporated.

■ WC-15

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S203

Scheduling Theory II

Stream: Scheduling Theory
Chair: *Rafael Moras*

1 - Maximizing the weighted number of just-in-time jobs in a two-machine flow-shop system with scenario dependent job parameters
Miri Gilenson, Dvir Shabtay

We study a set of multi-scenario two-machine flow-shop scheduling problems, where the objective is to maximize the weighted number of just-in-time (JIT) jobs. In each of the problems in this set, a given subset of the job parameters is scenario-dependent. We first focus on the case where the processing times are scenario-dependent. As the single-scenario counterpart of this problem is hard for arbitrary weights, we study the unweighted version of the problem. We prove that if only the processing times on the first machine are scenario-dependent the problem is NP-hard, even with two scenarios. However, if only the processing times on the second machine are scenario-dependent the problem is solvable in polynomial time, even if the number of scenarios is arbitrary. Moreover, the case where the processing times on both machines are scenario-dependent while the weights are arbitrary, is solvable in a pseudo-polynomial time. Then, we study the case where only the weights are scenario-dependent. As different weight values yield different objective values, we used a multi-criteria approach to analyze four different variations of the problem. We show that three out of the four variations are hard, even if the scheduling is done on a single machine. Lastly, we provide a pseudo-polynomial time algorithm to solve the most general variation of the problem, where we need to construct the entire set of Pareto-optimal solutions. We also show how this algorithm can be converted into FPTAS.

2 - Relationship between common objective functions, idle time and waiting time in permutation flowshop scheduling
Kathrin Maassen, Paz Perez Gonzalez, Jose M Framinan

The objectives of makespan and total flowtime have been often addressed in permutation flow shop scheduling. Instead, core idle time and core waiting time are rarely studied as objectives. Core idle time occurs as soon as a machine has to wait for the processing of a job and can be interpreted as a capacity buffer. Since makespan is defined as a utilization-oriented objective function, core idle time and makespan might be aligned. Core waiting time defines the time where a job has to wait for an occupied machine and refers to an inventory buffer. On the other hand, flowtime is known to be a throughput-oriented indicator and might be aligned to the minimization of core waiting time. A test bed with small problem instances for optimization models (processing times chosen from a uniform distribution U[1,99]) is used to show the relationship between these four performance measures (makespan, flowtime, core idle time and core waiting time). The test instances are solved optimally for each objective function. Moreover, for each optimal sequence, the corresponding values for the other performance measures are computed as well as its deviation with respect to the optimal solution value. The results show that the alignment between flowtime and core waiting time is stronger compared to core idle time and makespan. Furthermore, it seems that a strong goal conflict between core idle time and core waiting time exists.

3 - Spectrum allocation problem in OFDM networks
Yash Aneja, R. Chandrasekaran, Xiangyong Li

The spectrum allocation problem can be viewed as the following generic scheduling problem. We are given a set K of jobs with their processing times. Certain pairs of jobs cannot be done simultaneously (arising out of spectrum clash constraints). The objective is to minimize the makespan. First, we show that the problem is NP-complete. Second, we present a Mixed Integer Programming formulation for the problem. We study the facial structure of the projection polytope in the space of binary variables. Making use of these results, we develop a computationally effective approach based on Benders Decomposition.

4 - Antithetic sequences in flowshop scheduling: special cases of monster cell dominance
Rafael Moras, Gopalakrishnan Easwaran, Paul Uhlig

We describe the effects of monster cell in flow shop scheduling with minimization of mean lateness. In the simplest case of this type of dominance, a job has a "monster cell" if its processing time on a given machine is much larger than any other processing time in the system. Other cases of monster cell dominance may include, among others, (1) having two monster cells of similar processing times that are much larger than any other, and (2) having two monster cells, one having a time much larger than the other, and both times dominating the rest of the processing times by a considerable amount. A pair of sequences is antithetic when the jobs of one are processed in the reverse order of the other. Insight into this type of dominance and its effect on antithetic sequences in flow shops is provided.

■ WC-16

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S115

Graphs and Networks

Stream: Graphs and Networks
Chair: *Reinhardt Euler*

1 - A dynamic programming approach for computing all-terminal reliability of small networks with uniform probability
Naoya Makiishi, Natsumi Takahashi, Shao-Chin Sung

We are concerned with the problem of computing all-terminal reliability of networks with uniform probability. This problem is known to be #P-complete. When all edges have the same reliability, all-terminal reliability of a given network can be obtained based on the number of connected spanning subgraphs in terms of number of edges in those subgraphs. Based on this fact, we propose a dynamic programming based algorithm for computing all-terminal reliability. Moreover, we have implemented the proposed algorithm, and obtained the number of connected spanning subgraphs in terms of number of edges for all networks with up to 9 vertices. According to this result, the networks with the largest all-terminal reliability among all networks consists of given numbers of vertices and edges are identified.

2 - Models and algorithms for transmission line route planning
Bernhard Primas, Natalia Shakhlevich

Transmission line routing plays a crucial role in satisfying energy demands. Given two locations in a geographic region and terrain characteristics, the problem consists in finding a path connecting both locations such that the cost of constructing a transmission line along that path is minimized. In its most general setting, the problem does not have a well-defined underlying graph due to the infinite possibilities for selecting tower locations. Another difficulty is related to the multiple components of the cost function such as (a) wires' costs, (b) towers' costs dependent on the terrain, the spans between consecutive towers and the angles between consecutive segments, and (c) environmental costs.

A widely accepted approach to planning transmission lines consists in solving first a macro-level problem for identifying the transmission corridor, followed by solving a micro-level problem for fixing the precise route within the corridor. The presentation will focus on modeling and algorithmic challenges of the macro-level problem. The main contributions are (1) the introduction of the network model for the minimum-cost path analysis and (2) developing an efficient algorithm capable of handling large-scale instances. The results are evaluated on two case studies formulated for North England and Scotland.

This research is carried out in collaboration with NM Group, a British network company that optimizes the performance of electricity networks.

3 - Distributed leader election in wireless and IoT networks
Ahcene Bounceur, Madani Bezoui, Reinhardt Euler, Loic Lagadec, Mohammad Hammoudeh

The Leader Election is a real challenge in Wireless Sensor and IoT networks since it depends on the nature of the application domain and the energy consumption. In the case of real time applications, the choice will be based on the speed of election, and in the case where the time is not important, the choice will be based on the energy consumption. The Minimum Finding Algorithm is one of the classical algorithms allowing to elect such a node. In this algorithm, each node sends its value in a broadcast mode each time a better value is received. This process is very energy consuming and not reliable since it may be subject to an important number of collisions and lost messages. In this talk, we propose four new algorithms: 1) LOGO (Local Minima to Global Minimum), 2) BROGO (Branch Optima to Global Optimum), 3) DoTRo (Dominating Tree Routing) and 4) WBS (Wait-Before-Starting). These algorithms are based on simple routing protocols and they are more reliable since they require a small number of broadcast messages and a reduced number of nodes that send broadcast messages at the same time. The obtained results show that the proposed algorithms can reduce the energy consumption with rates that can exceed 94% compared with the classical Minimum Finding Algorithm. Finally, we will demonstrate on the CupCarbon simulator how to use the proposed algorithms to determine the starting node of a network required to run the D-LPCN algorithm.

4 - Boundary detection in wireless sensor networks by means of linear programming
Reinhardt Euler, Mohand Bentobache, Ahcene Bounceur

We apply linear programming techniques to model and solve the problem of boundary detection in Euclidean graphs associated with Wireless Sensor Networks and we compare our numerical results with those obtained by applying the LPCN (Least Polar angle Connected Node) algorithm as implemented on the simulator CupCarbon.

■ WC-17

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S205

Simulations and Queueing Systems

Stream: Stochastic and Robust Optimization
Chair: *Anders Reenberg Andersen*

1 - Development of a bushfire evacuation support tool using workspace
Leorey Marquez, Vincent Lemiale, Rajesh Subramanian, Joel Robertson, Tim Gazzard, Peter Ashton

Bushfires are a serious and growing threat to Victorian communities. At present, more than 433,500 Victorians live in 146,750 dwellings in areas impacted by bushfires over the last 50 years. The bushfire risk is increasing due to growing populations in high-risk, rural-urban interface areas and a trend to hotter, drier summers with more extreme fire-weather days. The seriousness of the current situation has brought about the Great Ocean Road Decision Support System (DSS) Pilot project that will develop a software tool to support emergency management organisations assess evacuation and risk mitigation options in the Barwon-Otways region, one of the highest-risk areas in the country. The software tool integrates a bushfire hazard model, an evacuation traffic model and a behavioural response model using Workspace, CSIRO's own workflow-based development framework. The Workspace GUI provides a catalogue of pre-built Workspace operations featuring basic and enhanced capabilities in flow control, visualisation, modularisation, database access, scripting and parallel execution in order to implement rapid application development. Preliminary results will be presented that indicate a reasonably robust and responsive tool capable of meeting most of the initial performance requirements. With additional workshops to exchange expertise between stakeholders and surveys to obtain new data, the model capabilities are being expanded to deal with new use-cases and behavioural issues.

2 - A comprehensive comparison of confidence lower bound estimation methods for Weibull lower percentiles in small samples
Burak Birgoren, Meryem YalÇinkaya

In component reliability studies, confidence lower bound estimation of Weibull lower percentiles has been a recent concern, particularly for modeling behavior of advanced materials, namely ceramics and composites. There is limited literature on this topic in classical and Bayesian estimation theory and there has been no comprehensive comparison of the methods proposed in the literature. In this study, confidence lower bound estimation algorithms have been developed for several methods such as the maximum likelihood method, linear and weighted linear regression methods with various weighting schemes, the Bayesian Weibull method with different prior elicitation or by using specific prior distributions for the Weibull parameters. Monte Carlo simulations have been designed and run in the C++ language for the comparisons. The results showed that the Bayesian Weibull method showed the best performance with the largest confidence lower bounds and the maximum likelihood method produced the second best; the simulations was performed for the first and tenth percentiles with a 95% confidence level, which are of particular interest in materials science.

3 - Heuristic room type allocation for nursing wards
Anders Reenberg Andersen, Wim Vancroonenburg, Greet Vanden Berghe

An increasing number of hospitals are governed by the number of patients they are able to attract and the corresponding services they provide for patients. One such service, which is often of significant importance for patients, is the option to choose their room type.

In this study, we provide hospital decision makers with a strategic method for optimizing the configuration of room types by distinguishing between patients who prefer private rooms and those who have no preference concerning whether they are assigned to a private or shared room.

Specifically, we employ a heuristic search procedure that sample from a gradually improved interpolation of the objective function, where we evaluate the resulting patient flow using a continuous-time Markov chain. Based on patient data the performance and robustness of the proposed approach is validated through various numerical experiments, showing that solutions within a relative gap of 1% from the optimum can be attained in most cases.

■ WC-18

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S206

Traffic Flow and Control

Stream: Transportation
Chair: *Paulina Reina*

1 - Estimating a spatiotemporal network of urban traffic flows
Dmitry Pavlyuk

A structure of the spatiotemporal network (STN) plays an important role in urban traffic modelling and forecasting. In contrast to the classical macroscopic approach, real-world spatial dependencies are not limited by the road network structure, but also appear between remote road segments simultaneously or with a temporal delay. In this research we applied modern data-driven methodologies (graphical lasso and sparse vector autoregressive models) for identifying STN of traffic flows and analysing its dynamics. The research data set includes sensor-based information for traffic flows in a large highly interconnected real-world urban network. Obtained STNs are compared to classical network weight matrices, constructed on the base of road network graph characteristics (connectivity, betweenness centrality and link vulnerability). A special attention is paid to dynamics of the STN to discover daily patterns and utilise them for forecasting. Finally, we validated the importance of STN for short-term traffic forecasting accuracy and made practical recommendations for estimating and utilising STN of urban traffic flows. Acknowledgements: this work is funded by the post-doctoral research aid programme of the Republic of Latvia (1.1.1.2/VIAA/1/16/112).

2 - Data-driven spatio-temporal analysis of public transport usage in a metropolitan area
Merve Bakar, Gultekin Kuyzu

Smart card automated fare collection systems facilitate efficient and accurate fare collection in public transport systems. These systems enable the planners to implement more flexible pricing structures compared to traditional fare collection methods. Smart card systems record several pieces of data about the passengers, which can be used to improve the overall efficiency and service quality of the public transport network. In this work, we focus on analyzing smart card transaction data to understand spatial and temporal travel patterns of public transport passengers in Ankara, Turkey. One of our primary goals is to identify origin-destination pairs where the passengers are required to transfer through one or more intermediate points because of the lack of a direct service. We use a data set of about 30 million records corresponding to a one-month period. The data include records from bus and light rail transportation modes. Each record includes the smart card number, the transport mode, the bus/rail line, the boarding location, the boarding date and time, and the fare class of the passenger; but lacks the alighting location of the passenger. We first create a model to estimate the alighting location of each passenger. Then, we estimate origin-destination flows and their breakdown by several dimensions such as fare class, day of week, and time of day. We propose possible improvement strategies based on the results of our analyses.

3 - Unfairness constrained system optimal routing of traffic flows on road networks
Valentina Morandi, Enrico Angelelli, M. Grazia Speranza

In static traffic assignment problems, the user experienced travel time in a system optimum solution can be much higher than the user experienced travel time in a user equilibrium solution. On the other hand, the total travel time in a user equilibrium solution can be significantly higher than the total travel time in a system optimum solution. A compromise solution between the two assignment seems to be the right choice for traffic regulators aiming at improving the network performance while satisfying users needs. In this paper, an MILP based approach is proposed to efficiently obtain a solution that balances system and user objectives focusing on the unfairness experienced by each driver. Computational results show that the obtained total travel time is very close to the system optimum one while guaranteeing a low level of experienced unfairness. The underlying idea is to bound the experienced travel time of each user to a fixed threshold, representing the maximum level of unfairness the regulator decides to allow. The MILP formulation requires the enumeration of all feasible paths from each origin to each destination and, hence, it becomes computationally intractable even considering small road networks. To this aim an efficient and accurate heuristic algorithm will be also presented.

4 - Spatio-temporal characteristics of freeway traffic state transitions
Paulina Reina, George Saman

Empirical data at two freeway sites were analyzed to investigate features of traffic state transitions from free-flow to congested state. It was observed that transition durations range approximately from 15 to 35 minutes on average during congestion onset and clearance. Results also suggest that the rate of transition growth increases as the transition zone travels upstream of the bottleneck and that merges and diverges have no effect on the transition mechanism. Findings from this research can have significant implications on traffic operations and the effectiveness of traffic control measures around transition zones.

■ WC-19

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S207

Exploring Production/Inventory Systems via Probability Models

Stream: Supply Chain Management I
Chair: *Barış Balcıoğlu*

1 - Condition-based production planning: adjusting production rates to balance output and failure risk
Ruud Teunter, Michiel uit het Broek, Bram de Jonge, Nicky Van Foreest

Many production systems deteriorate over time and the deterioration rate typically increases with the production rate. Although the system condition may be monitored real-time, planning maintenance (personnel, parts and tools) takes considerable time. We analyze how to adjust the production rate, based on condition information, until planned maintenance takes place. We first derive the optimal policy for any possible condition state, if the system always deteriorates as expected. We then show that key insights from that policy carry over to the more realistic setting with uncertain deterioration. Furthermore, our numerical results show that the optimal condition-based production rate policy performs much better then simpler policies that fix the production rate or turn off the system when some deterioration threshold is reached.

2 - Joint pricing and replenishment decisions for an inventory system with a randomly fluctuating supply price process
Fikri Karaesmen, Caner Canyakmaz, Suleyman Ozekici

We consider a joint inventory management and pricing problem of a retailer selling an item that has purchase price uncertainties. We assume that the price uncertainty is governed by a stochastic price process as is the case in commodity markets. The customer demand is price dependent and the retailer determines a markup to maximize the expected profit. The motivation for this problem comes from environments where fluctuating raw material prices can impact the overall price of the product. For this setting, we characterize both the optimal inventory replenishment and dynamic markup policy and present monotonicity properties of the expected profit function with respect to each decision.

3 - Performance analysis of the extended-two-critical-number policy in different make-to-stock systems
Onder Bulut, Sinem Özkan

This study considers a single-item make-to-stock production environment with start-up costs. We conduct the performance analysis of the Extended-Two-Critical-Number Policy, which is a well-performing one proposed by the authors for multi-channel make-to-stock systems, in different settings. The first contribution of this research is to calculate the average cost per unit time for M/G/1 make-to-stock queues in lost sales environment. In this single-server setting the proposed policy is the optimal one and the analysis for the backordering case is already available in the literature. We then extend the analysis to M/M/s make-to-stock queues for both lost sales and backordering cases. To the best of our knowledge, such an analysis for multi-channel systems is missing in the literature. Our approach, providing the results in a very short amount of time, borrows some results from Renewal and Queueing theories. This study can be also extended to the systems with different service time distributions such as Erlangian and Phase-type. The most challenging extension would be developing such an analysis for M/G/s make-to-stock systems.

4 - Dynamic pricing and lead time quotation in a make-to-stock queue
Barış Balcıoğlu

We study two make-to-stock queues for which we explore how profit can be maximized by dynamic pricing and lead time quotation policies. In the first model, customers pay more if their demand is instantaneously satisfied. If they need to wait, the manufacturer announces a dynamically quoted lead-time and lower prices to be jointly considered by the customers to make their decision in placing the order. With this mechanism, the manufacturer aims at preventing demand loss. In the second model, we assume customers can form two classes, namely, those who are willing to pay more for instantaneous delivery and those who can opt to wait in return for being charged lower prices. We extend the application of the multilevel inventory rationing policy for the manufacturer to serve these different types of customer classes. For both systems, we obtain the steady-state system size distributions of the queues modeling the production line and via numerical examples, we assess if elaborate dynamic policies determining which price and lead-time to quote can increase the profit significantly when compared to simpler policies.

■ WC-20

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S301

Decision Support for Medical Applications and Health Policy

Stream: Decision Analysis and Decision Support Systems

Chair: *Aron Larsson*

1 - A data-based decision analytic approach for designing optimal testing and treatment strategies
Lauri Neuvonen

Diagnostic testing is most useful when the right test is carried out at the right time, and the same applies for treatment actions. Unnecessary testing and treatment can cause discomfort to the patients, and consume resources that could be better used elsewhere. The probability of making correct testing and treatment decisions could be increased by utilizing the large amounts of patient data stored in electronic health records. These data make it possible to predict the development of a patient's state of health, and thereby to design optimal testing and treatment plans for highly specific patient segments.

We develop a data-based model for optimizing testing and treatment strategies that maximize the expected health outcome for a patient based on predictions about the patient's development of health. Our model helps understand the value of designing patient-specific testing and treatment strategies, and provides a tool for studying the cost-effectiveness of such strategies over time.

2 - A decision support system for Parkinson disease management: models for suggesting medication change
Marko Bohanec, Dragana Miljković, Anita Valmarska, Biljana Mileva-Boshkoska, Elisabetta Gasparoli, Giovanni Gentile, Konstantinos Koutsikos, Andrea Marcante, Angelo Antonini, Dimitrios Gatsios, George Rigas, Dimitrios Fotiadis, Kostas Tsiouris, Spiros Konitsiotis

Parkinson's disease (PD) is a degenerative disorder of the central nervous system that causes numerous symptoms, such as tremor, rigidity, impulsivity, and depression. PD requires a long-term, interdisciplinary disease management. The EU Horizon2020 project PD_manager (http://www.parkinson-manager.eu/) was aimed at developing a decision support system for PD management. As part of this task, we have developed decision-support models that identify situations in which the disease has progressed to the point which requires a change of medical therapy. The assessment is based on data collected from a patient using unobtrusive devices: smartphone, sensor insole (Moticon), and wristband. The data includes motor symptoms (bradykinesia, tremor, gait, dyskinesia, on/off fluctuations), non-motor symptoms (daytime sleepiness, cognitive disorder, impulsivity, depression, hallucinations) and epidemiologic data (patient's age, employment status, disease duration, living alone). The models are developed by combining data mining and expert modelling. For data mining, we employ parts of the data set PPMI (Parkinson's Progression Markers Initiative, http://www.ppmi-info.org/about-ppmi/). For expert modelling, we use a qualitative multi-criteria method DEX. We will describe the developed models, assess their quality in terms of classification accuracy, transparency, correctness, and completenes, and demonstrate the use of models in the PD_manager decision support system.

3 - Do healthcare workers need cognitive-computing technologies?
Arthur Carvalho

Cognitive-computing systems are be able to learn from structured and unstructured data, discover important correlations, create hypotheses for those correlations, and suggest actions that produce better outcomes. Instead of replacing a subject-matter expert, those systems behave as decision support systems that can collaborate with humans by gathering huge amounts of data related to a specific topic and, eventually, provide new insights on that topic.

Healthcare is one of the most promising domains one can apply cognitive-computing systems to. For example, a cognitive system can examine the existence of several relationships between symptoms and disorders and suggest the most promising ones to be further investigated by a researcher, thus working in close collaboration with and improving the productivity of the latter.

IBM has been at the forefront of the development of cognitive systems with IBM Watson. Since IBM Watson is a relatively new technology, it is important to understand whether there exists a natural acceptance/demand for its services. Focusing on the healthcare domain, we seek to understand the type of professionals and organizations that can benefit most from using IBM Watson. To do so, we guide our efforts through the Technology Acceptance Model and investigate the perceived usefulness, ease of use, and other variables regarding IBM Watson. Our analysis and conclusion are based on qualitative data collected from interviews with Dutch healthcare workers.

4 - Decision appraisal framework for pandemic influenza interventions
Tobias Fasth, Anton Talantsev, Aron Larsson, Lisa Brouwers

The pandemic potential of influenza is a major public health concern. Choosing intervention in advance is impractical, as it is unknown when the next pandemic will occur, what characteristics the virus will have, and what impact it will impose on society. There are alternative interventions, e.g., vaccination, antiviral drug treatment, prophylaxis, along with a set of non-medical interventions. The interventions have to satisfy some constraints such as the general feasibility, cost-effectiveness, safety, and it is not obvious how to trade-offs must be made. As non-medical interventions affect multiple stakeholders, this also requires considering diverging perceptions and interests of public actors and stakeholder groups. Herein we incorporate MCDA, scenario analysis, pandemic influenza simulations, and multi-stakeholder preferences modelling into an intervention appraisal framework.

■ WC-21

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S303

Applications of Smooth Nonconvex Programming

Stream: Nonlinear Programming: Theory
Chair: *Hector Ramirez*

1 - Feasibility and cost minimisation for a lithium extraction problem
Paul Bosch, Juan Pablo Contreras, José Saavedra-Rosas

In this work we address the problem of allocating extraction pumps involved on the exploitation of lithium rich brines as part of the processing of lithium salts. The problem of choosing the location of extraction wells is defined using a transportation network structure. Using this network, the lithium rich brines are extracted from each well and then mixed. The quality of the blend will be based on the chemical concentrations of the different brines originating in different wells. The objective of the problem is then to determine a pumping plan such that the final products have predetermined concentrations and the process is operated in the cheapest possible way. The problem is modeled as a combinatorial optimisation problem and a potential solution to it is sought using a genetic algorithm. The evaluation function of the genetic algorithm requires a method to determine feasible minimum cost flows, this leads to the formulation of a blending model in a flow network for which an iterative nonconvex optimisation algorithm is proposed. The model was implemented and tested on a simulated instance to measure the algorithms' efficiency.

2 - An interior algorithm for nonlinear conic programs: application to classification problems
Julio López, Miguel Carrasco, Alfredo Canelas

We present a new feasible direction algorithm for solving smooth nonlinear second-order cone programming problems. Given an interior point to the feasible set defined by the conic constraints, the proposed approach computes a feasible and descent direction, for the objective function, by solving two linear systems which result of applying the Newton method to the Karush-Kuhn-Tucker conditions of the nonlinear conic problem. Then, a line search along the search direction finds a new feasible point that has a lower value of the objective function. Repeating this process, the algorithm generates a feasible sequence with monotone decreasing values of the objective function. Under mild assumptions, we prove the global convergence of the algorithm. Numerical results are presented. Finally, we apply our approach for solving new support vector classification formulations.

3 - Double regularization methods for robust feature selection and SVM classification via DC programming
Miguel Carrasco, Julio López, Sebastian Maldonado

In this work, two novel formulations for embedded feature selection are presented. A second-order cone programming approach for Support Vector Machines is extended by adding a second regularizer to encourage feature elimination. The one- and the zero-norm penalties are used in combination with the Tikhonov regularization under a robust setting designed to correctly classify instances, up to a predefined error rate, even for the worst data distribution. The use of the zero norm leads to a nonconvex formulation, which is solved by using Difference of Convex (DC) functions, extending DC programming to second-order cones. Experiments on high-dimensional microarray datasets were performed, and the best performance was obtained with our approaches compared with well-known feature selection methods for Support Vector Machines.

4 - Subdifferential characterization of Gaussian probability functions
Pedro Perez-Aros, Abderrahim Hantoute, Rene Henrion

This work provides formulae for the subdifferential of Gaussian the probability function. Applications for this class of functions can be found in water management, telecommunications, electricity network expansion, mineral blending, chemical engineering, where the penalization in the optimization problem is represented by a chance constraint formulation.

■ WC-22

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S304

Evolutionary Multiobjective Optimization Methods

Stream: Multiobjective Optimization
Chair: *Ernestas Filatovas*

1 - Decomposition-based interactive evolutionary optimization guided by multiple search directions compatible with indirect preference information
Michał Tomczyk, Milosz Kadzinski

We propose a decomposition-based interactive evolutionary algorithm for Multiple Objective Optimization, called IEMO/D. During an evolutionary search a Decision Maker (DM) is asked to provide holistic decision examples such as pairwise comparisons, intensities of preference, a partial or a complete pre-order of a subset of solutions from the current population. Using the Monte Carlo simulation, the proposed algorithm generates a set uniformly distributed instances of the L-norms compatible with such an indirect preference information. These instances are incorporated as the search directions with the aim of systematically converging a population toward the DM's most preferred region of the Pareto front. The experimental comparison proves that the proposed decomposition-based method outperforms the state-of-the-art interactive evolutionary algorithms, called NEMO, driven by the dominance principle. We also show that the quality of constructed solutions is highly affected by the forms of accepted holistic information and incorporated preference model. In this regard, we demonstrate that the results are vastly improved when the DM compares solutions pairwise by means of different intensities of preference, and the employed L-norm aligns with the DM's judgement policy.

2 - An evolutionary approach to constrained many-objective combinatorial optimization
Mert Sahinkoc, Ümit Bilge

Many real-world optimization problems include constraints and they attempt to optimize multiple objectives concurrently. When solving constrained multi-objective optimization problems, various constraint handling techniques have been proposed and they have been integrated with the most popular approach used for multi-objective problems: multi-objective evolutionary algorithms. On the other hand, it has been shown in the literature that the conventional methods for multi-objective optimization often suffer scalability issues when number of objectives is high. This fact has lead into a new research area called many-objective optimization where number of objective functions are higher than three. The associated studies try to characterize and overcome the challenges posed by the high number of objectives. This study proposes a successful many-objective evolutionary algorithm in which different constraint handling techniques are implemented. Our algorithm also includes a combination of features that can contribute to the present methodologies. It uses elitist non-dominated sorting based on reference points that are mapped onto a "fixed hyperplane" integrated with path relinking recombination scheme and complementing selection mechanisms. Numerical experiments are conducted through some well-known constrained combinatorial optimization problems and the comparison of the performance of different constraint handling techniques will be demonstrated.

3 - An integrated approach for evaluation of facility layout alternatives
Esra Duygu Durmaz, Ramazan Sahin

Facility layout is one of the strategic areas that significantly influences the performance of a manufacturing system. It has been extensively investigated by researchers and many exact and heuristic solution methods have been proposed. Most of these studies focus on minimizing material handling cost or time. However, these methods are insufficient for solving real world layout problems. In practice, there are many qualitative performance measures as well as the quantitative ones. In this study, an integrated solution approach is proposed for solving a facility layout problem. Firstly, an evolutionary algorithm for minimizing the total material handling cost is utilized to obtain layout alternatives. Then, an AHP-VIKOR hybrid decision making method is implemented by using decision makers' subjective judgements based on qualitative criteria. The proposed method employs AHP to determine the criteria weights and VIKOR method to choose the best layout.

4 - A preference-based multiobjective evolutionary algorithm with controllable approximation accuracy
Ernestas Filatovas, Ignacy Kaliszewski, Olga Kurasova, Janusz Miroforidis

Evolutionary Multiobjective Optimization (EMO) algorithms aim to find a set of well-distributed points on objective space that approximate the entire Pareto front. However, they are computationally expensive, and an analysis of the obtained solutions is cumbersome for the Decision Maker (DM). This is why EMO algorithms that incorporate the DM's preference information have gained in popularity during the last decade. Preference-based EMO (PEMO) algorithms aim to find an approximation of the Pareto front whose elements are scattered according to the preference information provided by the DM. However, nor EMO nor PEMO are not capable to ensure the approximation accuracy, which makes their usefulness questionable especially for real-world problems (where the true Pareto front is not known). In our recent works, it was proposed to approximate Pareto fronts by two-sided approximations, one from inside and another from outside of the feasible objective set, called, respectively, lower shell and upper shell. Accuracies of Pareto front approximations by such pairs can be measured and controlled with respect to the distance between such approximations. Here, we propose a PEMO algorithm based on lower shell and upper shell paradigm. The algorithm was experimentally investigated by solving a set of benchmark problems and has shown promising results. Moreover, the algorithm was tested large-scale multiobjective problems with data stemming from cancer radiotherapy planning.

■ WC-23

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S305

Lot Sizing IV - Integrated Models

Stream: Lot Sizing, Lot Scheduling and Production Planning
Chair: *Nabil Absi*

1 - A mathematical programming approach to product line decisions
Xavier Andrade, Luis Guimarães, Gonçalo Figueira

Given the difficulty of the managerial trade-offs involved in product-line management, the significance of the impacts, and the lack of accountability resulting from product proliferation strategies, we find that there is a real-world need for quantitative models to support these decisions. In the literature, when product-line management is tackled in marketing research, the cost structure is oversimplified, and sometimes even ignored. When operations research assumes demand uncontrollable, and unresponsive to the assortment. We develop a mixed integer linear programming model for product-line decisions capable of dealing with demand responsive to assortment, while still accounting for manufacturing considerations. By nesting an attraction model within an exogenous one, we manage to circumvent the independence of irrelevant alternatives, and by integrating this structure into a multiple-product lot-sizing model, we include the specificities of manufacturing into the problem. The model allows the handling of trade-offs such as that of revenue with complexity costs, of market-share with product profitability. By managing these trade-offs we assess if it is worth to produce a product in a given planning horizon.

2 - Decomposition of sequence dependent setup times in simultaneous lot sizing, scheduling, workforce, overtime and shift planning
Gorkem Yilmaz, Cevdet Utku Şafak

The operational level capacity planning concentrates on the short term decisions such as the lot-sizing, product scheduling and available workforce planning. Operational level decisions cannot be taken without considering capacity utilization decisions brought by the tactical level capacity plans where the production levels of the facilities are decided. This study focuses on the extensions of the simultaneous lot sizing and scheduling MIP models in literature by the overtime, shift decisions and available workforce decisions including production environments of parallel non identical sets of machines using multiple sets of non-identical tools attached and sequence dependent setups between the tools. 2 types of setups are considered: major setups due to the interchange of the tools and minor setups due to the minor revisions on the tools to produce different versions of the products or the raw material changes. A MIP based decomposition technique will be presented to solve industry size problems. The developed models are tested in a TV manufacturer in Europe, Vestel Electronics's production planning of the plastic injection plant. The results show that the developed heuristics solve the large size problems in a reasonable time.

3 - A simple heuristic for the supply vehicle routing and lot sizing problem enhanced by genetic programming
Fanny Hein, Christian Almeder

The supply routing and production planning problem integrates the collection of input materials from suppliers situated at different locations (vehicle routing) and the planning of the conversion of those input materials into final products (capacitated lot sizing). Due to the complexity of the problem, an efficient algorithm is needed to be able to solve large instances which does not yet exist. For the counterpart, the production and distribution routing problem, various heuristic algorithms have been developed. However, so far no constructive heuristic has been proposed though the benefits of such heuristics are manifold, e.g., the computation time is extremely low, no commercial solver is needed, it can be easily integrated into existing software, and it is usually better understood and accepted by practitioners. The aim of this work is to provide a constructive heuristic for this planning problem which relies on simple priority rules automatically evolved by means of genetic programming.

4 - Comparing sequential and integrated approaches for the production routing problem
Nabil Absi, Claudia Archetti, Stéphane Dauzere-Peres, Dominique Feillet, M. Grazia Speranza

In this presentation, we consider the Production Routing Problem where production planning, inventory management and distribution planning decisions must be taken. We compare two sequential approaches, one in which production decisions are optimized first and one in which distribution decisions are optimized first, with an integrated approach where all decisions are simultaneously optimized. Some properties of the solutions obtained with the different approaches are shown. Computational experiments are performed on instances of different size which are generated using two critical parameters. The numerical results illustrate the properties and show that the benefits of the integrated approach over the two sequential ones depend on the trade-off between production and distribution costs and on the trade-off between setup and inventory costs in production.

■ WC-24

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S306

Convexity and Global Optimization

Stream: Global Optimization
Chair: *Janos D. Pinter*

1 - Necessary optimality conditions for some nonconvex facility location problems
Marcus Hillmann

The problem of locating a new facility with simultaneous consideration of existing attraction and repulsion points is a problem with great practical relevance e.g. in the fields of economy, city planning or industrial design. Unfortunately, the consideration of negative weights makes this problem in general a nonconvex one, so that none of the established algorithms for location problems are able to solve it.

We will therefore present a new approach to derive necessary optimality conditions for such problems using the nonconvex subdifferentials by Ioffe and Kruger/Mordukhovich. After giving a brief review on definition, properties and calculus of the mentioned subdifferentials we will show, that for certain distance functions it is possible to precisely calculate the corresponding subdifferentials.

Thus, by taking advantage of their special structure we can derive necessary optimality conditions for some scalar semi-obnoxious facility location problems. Furthermore, we will present some new scalarization results and use them to establish necessary optimality conditions for multicriteria semi-obnoxious facility location problems.

2 - Conditions on optimality and non-optimality in global optimiztaion
Pál Burai

In this talk some results are shown dealing with optimality and non-optimality conditions in global optimization using tools from convex analysis.

3 - A global minimization algorithm for concave quadratic programming
Mohand Bentobache, Mohamed Telli, Abdelkader Mokhtari

In this work, first we prove a new necessary and sufficient condition for local optimality of the minimization problem of a concave quadratic function subject to linear equalities and nonnegativity constraints. Then, we suggest an algorithm which moves from one extreme point to an adjacent one, until finding a local minimal extreme point which satisfies the suggested local optimality conditions. Using the global optimality criterion suggested in [Strekalovsky, A. S. (1998). Global optimality conditions for nonconvex optimization. Journal of Global

Optimization, 12(4), 415-434], the global optimization algorithm presented in [Chinchuluun, A., Pardalos, P. M., and Enkhbat, R. (2005). Global minimization algorithms for concave quadratic programming problems. Optimization, 54(6), 627-639], and the suggested local optimization algorithm, we propose an algorithm which finds a global optimal solution of the problem in a finite number of steps. Finally, we conduct numerical experiments on randomly generated test problems. The obtained numerical results are very encouraging. Indeed, our algorithm finds the global optimal solution for all the generated test problems with dimension up to 250 constraints and 400 variables in reasonable CPU time. In future work, we improve our implementation by using efficient matrix inverse updating techniques in order to reduce the CPU time of the suggested local optimization algorithm and solve large-scale concave quadratic programs.

4 - Packing general convex sets into polygons
Janos D. Pinter, Frank Kampas, Ignacio Castillo

The optimized packing of convex objects has a range of important industrial and scientific applications. We consider generalized "egg-shaped" sets in R2 defined by boundary curves of the form (x/a)p + exp(t*x)*(y/b)p =1. Here a and b are the (generalized) semi-major and semi-minor axes of the "egg", the exponent p>0 is an even number, and t>=0 is a distortion factor. Such an "egg" can be further specified by (additional) orientation parameters: hence, this flexible model subsumes a broad range of instances, including general circle and ellipse packings. Our objective is to pack collections of generalized "eggs" into convex polygons. The model development is based on our embedded Lagrange multiplier approach; this is followed by numerical (global-local) optimization. We present summary results based on solving several hundred test problems, reporting optimized container sizes and packing fractions. Our numerical results support the development of regression based optimum estimates for well-defined families of general "egg" packings. The visual representation of these results consistently shows credible "tight" packings; the corresponding run times vary from seconds to several hours, clearly depending on the "egg" model parameters.

■ WC-25

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S307

Combinatorial Optimization in Assembly Systems

Stream: Combinatorial Optimization II
Chair: *Olga Battaïa*
Chair: *Erwin Pesch*

1 - An exact approach for sequencing assembly lines to facilitate just-in-time part feeding
Simon Emde, Lukas Polten

The problem of sequencing assembly lines consists of determining the order in which a given set of products is launched down the line. Since individual products may require different parts in different quantities, the production sequence has a big influence on line-side inventory. Classically, sequences are often optimized with the goal of attaining level schedules, i.e., the part demand should be smooth during the planning horizon. However, this approach does not necessarily work well if parts are delivered at discrete points in time in bulk quantities. In this paper, we consider a production system where bins of parts are delivered periodically by a tow train from a central depot at fixed times. Due to the limited space at the assembly line, the maximum number of bins in stock at any time at any station should be minimal. We propose an exact solution method based on combinatorial Benders decomposition as well as bounding procedures and heuristics for this problem. The algorithms are shown to perform well both on instances from the literature and on new data sets. We also investigate whether classic level scheduling methods are effective at reducing line-side stock in an assembly system supplied by tow train, and to what degree line-side stock can be traded off for more frequent deliveries.

2 - An improved mathematical formulation for the production planning problem in additive manufacturing and 3D printing
F. Tevhide Altekin

Advances in material science as well as manufacturing technologies have given rise to the use of additive manufacturing and 3D printing in not only production of prototypes but also for direct parts production in industries such as defense, aerospace and automotive. This paper deals with the production planning problem in such an environment. The problem involves the assignment of parts to jobs and assignment of jobs to distributed additive machines in order to minimize the average production cost per volume of material. We improve the initial formulation of this problem by providing a linear mixed integer programming formulation and employing a pre-processing step to fix variables for dedicated assignments of parts to jobs and/or machines. The efficiency and effectiveness of the improved model is demonstrated for small and medium sized problems.

3 - Task assignment in assembly lines with physical and cognitive ergonomic constraints
Olga Battaïa, Dmitry Arkhipov

This research addresses the problem of work assignment to operators in paced manual aircraft assembly lines. In such assembly lines, in contrast to the intensively studied automotive assembly lines, a relatively high number of operators can be assigned to the same workstation. Therefore, a Resource Constrained Project Scheduling Problem (RCPSP) should be solved for each workstation in order to schedule the assembly tasks under the takt time constraint. In addition to precedence, resource and skill constraints, which are common for the RCPSP formulations, this study considers ergonomic constraints. We develop new mathematical models for physical and cognitive ergonomic constraints for operators and show first results for several industrial applications.

■ WC-26

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S308

Bike Sharing and Demand Prediction

Stream: Public Transportation I
Chair: *Dalila Fontes*

1 - Setting incentives for user based relocation in free floating bike sharing systems
Christoph Heitz, Roman Etschmann, Thomas Bachmann, Raoul Stoeckle

Relocation of bikes is a central operational problem for bike sharing systems. It is necessary for ensuring a high service level, but extremely costly. In recent years, the question if and how users can be engaged for relocation has attracted much attention. We address this question in a context of a free floating (stationless) bike sharing system. Free floating systems lead to complex spatio-temporal distribution patterns. We investigate some basic properties of the bike distribution under stochastic demand, and we study the relationship of number of bikes and service level under various demand and usage patterns. Setting incentives for dropping off bikes at, or picking up bikes from, specific locations changes the bike distribution and may increase the service level. We develop a general methodology for dynamical setting of incentives, based on the current bike distribution and a forecast of pick up and drop off distribution. The methodology can be applied to pick up as well as drop off incentives in various settings. Simulations studies show that, under optimum user incentivization, the number of bikes needed for achieving a service level of 95% can be reduced by about 30%, resulting in substantial cost reduction for the operator. We show how the methodology has been implemented in the new e-bike sharing system "smide" in Zurich, launched in 2016 by the insurance company Mobiliar.

2 - A mathematical model to evaluate balancing strategies of bicycle sharing systems
Pablo Andrés Maya Duque, Diana Marcela Perez, Miguel Angel Arroyave

The Bicycle sharing systems offer a mobility service in which public bicycles are available for shared use. This talk addresses the problem of balancing the operation of bicycle sharing systems in order to ensure bicycles and parking docks availability at the stations. Strategies and insights to face this problematic are identified from the literature and interviews with operators of five different systems in Latin America. Six strategies are pointed out which involve not only operational decisions, but also tactical and strategical concerns. We propose a mathematical model to evaluate the impact of some of the identified strategies and point out challenges and gaps to be addressed in future researches.

3 - Incentives as a balancing mechanism in bike-sharing systems
Dalila Fontes, Ehsan Ali Askari, Sergiy Butenko

Bike-Sharing Systems (BSSs) can be used to facilitate transportation and, at the same time, provide some health benefits. In a BSS the users pick up bicycles at a station near their location and ride them to a station near their destination. Depending on the systems, users may have to pay for using the bicycles. BBSs have been introduced all over the world, following on the pioneering experience in the 1960s in Amsterdam. System imbalances constitute the major problem to overcome; since often there are stations (nearly) full, while some other stations are (nearly) empty. Re-balancing can be done during the day and/or during night; the former is considered a dynamic problem and the latter a static one. In this work, we go one step back and try to obviate the aforementioned problem by providing the users with incentives. A bi-level bi-objective mathematical model is proposed and, since the problem is NP-Hard, solutions are found by resorting to a greedy hybrid heuristic method based on a NSGA-II algorithm. In the upper level we consider the urban planners' point of view that offers incentives to the users to encourage them to choose stations with more bicycles; while in the lower level, it takes the users' point of view and based on these incentives selects the routes that minimize the transportation cost. We solve some numerical examples, which show the effectiveness and efficiency of the proposed approach.

4 - Prediction methods improve bus services profitability
George Kireulishvili, Wolfgang Garn, James Aitken, Jane Hemsley-Brown

Since the bus deregulation (Transport Act 1985) the patronage for bus services has been decreasing in a county in South of England. Hence, methods that increase patronage, focus subsidies and stimulate the bus industry are required. Our surveys and market research identified and quantified essential factors. The top three factors are price, frequency, and dependability. The model was further enhanced by taking into account real time passenger information (RTPI), socio-demographics and ticket machine data along targeted bus routes. These allowed the design of predictive models. Here, feature engineering was essential to boost the solution quality. We compared several models such as regression, decision tress and random forest. Additionally, traditional price elasticity formulas have been confirmed. Our results indicate that more accuracy can be gained using prediction methods based on the engineered features. This allows to identify routes that have the potential to increase in profitability - allowing a more focused subsidy strategy.

■ WC-27

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S309

Reverse Logistics / Remanufacturing

Stream: Production, Service and Supply Chain Management
Chair: *Sandeep Mondal*

1 - A robust mathematical model to optimize an electronic reverse logistics network
Saman Hassanzadeh Amin, Babak Mohamadpour Tosarkani

Electronic reverse logistics activities are important due to both environmental and economic effects. In Canada, the province of Ontario has regulations regarding to recycling of electrical and electronic equipment. The objective of this study is to develop a novel robust possibilistic approach to optimize and configure an electronic reverse logistics network by considering the uncertainty in the parameters. The proposed model is extended to the multi-objective one for the purpose of minimizing the environmental impacts in addition to maximizing the profit. A fuzzy TOPSIS is developed and applied to convert the qualitative factors related to green practices of the third parties to the quantitative parameters. The application of the mathematical model is shown in this research.

2 - Revenue management in remanufacturing under competition, cannibalization, and customer behavior
Nughthoh Arfawi Kurdhi, Shaunak Dabadghao, Jan Fransoo

Although remanufacturing has good economic potential, many firms are worried about the effects of cannibalization and competition. Cannibalization leads to issues in the optimal pricing decision since it affects the new product market. At the same time, the presence of another firm selling the same primary product as well as its remanufactured version is also an issue for firms, since the firms face external competition and also strive to evolve a reasonable remanufacturing strategy where the collection of used product is also a factor. Further, customer behavior towards new and remanufactured products determine the degree of cannibalization and thus affect the optimal prices. Two kinds of customer behavior are observed - an inverted-U-shaped function where customers get suspicious when the price is too low, and the other is a linear function which behaves according to willingness to pay. In this study, we develop models to help firms make the strategic decisions concerning remanufacturing policies under cannibalization and different customer behavior in a competitive setting. We consider duopoly environments with two firms in direct competition selling their new and remanufactured products in the same market. We identify the equilibrium decisions and profits for both the firms. We provide sensitivity analyses and derive general managerial insights.

3 - Mixture reliability analysis of a product consisting of new and remanufactured components
Sandeep Mondal, Kampan Mukherjee, Kaustov Chakraborty

Remanufacturing operations are becoming popular, globally, not only because of its ability to retrieve a significant portion of the reusable value retained in end-of-life products hence reducing production costs, but also its role in preventing environmental degradation by avoiding landfilling and incinerations of used products. The economic, environmental and social benefits of remanufacturing enthral the manufacturers to incorporate it seriously in their business propositions. In terms on product quality, remanufactured products are though considered as good as the original product, however, reliability of the remanufactured product is still an area of concern for both customers and remanufacturers. Generally, a remanufactured product is an assembly of parts and components comprising both new as well as remanufactured ones, thus it is expected that the failure distribution of a new and a remanufactured product may not be same. With this backdrop, this research paper basically intend to study and analyse the behaviour of mixture failure rates of remanufactured products at different mixture proportions between new and remanufactured components and then to determine the condition under which the mean time to failure of the system is maximized. A case example is also illustrated here to explain the above methodology.

■ WC-28

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S310

Tabu Search

Stream: Memory-based Heuristics

Chair: *Rafael Marti*

1 - New advanced heuristic methods for the VRP problem family
Piotr Sielski, Piotr Cybula, Marek Rogalski, Piotr Beling, Andrzej Jaszkiewicz

We introduce new general algorithms and metaheuristics for various types of Vehicle Routing Problem including capacitated VRP with time windows, multiple depots, heterogeneous fleet, pickup and delivery. Proposed methods improved more than 30% of 800- and 1000-customer instances of Gehring-Homberger published on www.sintef.no/vrptw (as of February 28th, 2018) - arguably the most competitive benchmark for the VRP family. Moreover some solutions were improved by more than 1%, a magnitude of improvement unseen for many years. Interestingly these performances were achieved with a small (desktop PC level) computational effort. Equally good results were observed on real world instances with heterogeneous fleet and 1-M-1 PDP problems. The progress has been obtained through a combination of several mechanisms described shortly below. Our methods include new local minima management processing with probabilistic tabu memory, diverse solution pools and minima graphs. We have developed fast approximate search methods, which allowed us to combine functionality of the Large Neighbourhood Search and Iterated Local Search metaheuristics. Moreover new efficient pruning techniques that allowed a very deep neighbourhood search were implemented. This combined with new penalty oscillation and recombination algorithms has led us to many record breaking performances.

2 - Tabu search for hub location with modular links
Juanjo Peiró, Fred Glover, Angel Corberan, Rafael Marti

The capacitated single assignment hub location problem with modular link capacities is a variant of the classical hub location problem in which the cost of using edges is not linear but stepwise, and the hubs are restricted in terms of transit capacity rather than in the incoming traffic. We propose a tabu search algorithm based on strategic oscillation. Our method incorporates several designs for constructive and destructive algorithms, together with associated local search procedures, to balance diversification and intensification for an efficient search. Computational results on a large set of instances show that, in contrast to exact methods that can only solve small instances optimally, our metaheuristic is able to obtain high-quality solutions on larger instances in short computing times.

3 - Heuristics for the bi-objective diversity problem
J. Manuel Colmenar, Abraham Duarte, Rafael Marti

The max-sum and max-min diversity problems are two well-known optimization models that capture the notion of selecting a subset of diverse points from a given set. The resolution of their associated optimization problems provides solutions of different structures, in both cases with desirable characteristics. They have been extensively studied and we can find many metaheuristic methodologies, such as GRASP, Tabu Search, Iterated Greedy, VNS, and Genetic algorithms applied to them. We consider now the bi-objective problem in which both models are simultaneously optimized. No previous effort has been devoted to study the combined problem from a multi-objective perspective.

In this talk, we adapt the mono-objective methodologies applied to these problem to the resolution of the bi-objective model, obtaining approximations to its efficient frontier. In particular, we propose six algorithms belonging to three classes of heuristic methodologies: NSGA-II and SPEA2 (population-based methods), GRASP and Iterated Greedy (construction-based methods), and Tabu Search and VNS (trajectory-based methods).

The assessment of the results in our computational experience has been done with three quality measures typically considered in multi-objective evaluation: hypervolume, set coverage and epsilon indicator. These metrics have shown that the best algorithm is Tabu Search, in both quality and execution time.

4 - Diversity, dispersion, and equity models
Rafael Marti, Abraham Duarte, Anna Martínez-Gavara

The challenge of maximizing the diversity or dispersion in a collection of points arises in a variety of settings, and the growing interest of dealing with equity resulted in an effort to study the management of diversity with many different mathematical models. While the terms diversity and dispersion can be found in many optimization problems indistinguishable, we explore the different mathematical programming models proposed in the last few years to deal with them. In particular, in this talk we describe the mathematical models for the Max-Sum, Max-Min, Max-Mean, MaxMin-Sum, and Differential-Dispersion. Additionally, we also review related models that have recently received special attention, such as capacitated clustering and grouping variants. Especial emphasis is given to metaheuristics for finding near-optimal solutions for these problems, where constructive and local search based methods, such as GRASP and Tabu Search, play a key role.

■ WC-29

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S311

Cutting and Packing III

Stream: Cutting and Packing
Chair: *Maria Teresa Alonso Martínez*

1 - An approach for the pallet building problem and subsequent loading in a heterogeneous fleet of vehicles considering practical packing constraints
Daniel Cuellar-Usaquen, Guillermo Camacho, David Álvarez-Martínez

This article presents a metaheuristic algorithm to solve the pallet building problem and the loading of these in trucks. This approach is used to solve a real application of a Colombian logistics company. From the integrated problem, different practical requirements of goods loading and unloading operations were modeled. The optimization algorithm consists of a two-phase approach, the first is responsible for the construction of pallets and the second considers the optimal location of the pallets into the selected vehicles. The two phases present a search strategy type GRASP. The proposed methodology was validated through the comparison of the performance of the solutions obtained for deliveries of the logistics company whit the solutions obtained using a highly accepted commercial packing tool that uses two different algorithms. In addition to this, the pro-posed methodology was compared in equal conditions whit different previous works that considered the same restrictions of the integrated problem or at least one of the problems separately. For this, we used the test of sets of cases published in the literature for each of the previous Works. The results allow to conclude that the proposed algorithm has a better performance than the commercial tool for real cases (instances of large size). Also the proposed algorithm manages to match most of the test instances, improving the performance of some previous works that only involve decisions of one of the two problems.

2 - MultiCapableWarehousePackagingOperators in vegetable and fruit warehouses
Wim De Bruyn

Flexible short term workload scheduling of warehouse-operators and packaging operators in the vegetable and fruit business. Goal is to optimize reception of vegetables and fruits from the farmers, conditioning and packaging for supermarkets and shops and keeping the food safe, ecological and fresh during the logistic chain towards the customers. We can simulate or execute (in reality) the packaging, labeling (traceability), palletizing (including labeling) and conditioning with MES (Manufacturing Execution System) software, the warehouse actions (reception, delivery to the packaging and conditioning units, preparing the outgoing stock and the optimization of the loads in the reefer containers or trucks using the WMS (Warehouse Management System software and keep the items (pallets and packages) traceable during these warehouse activities and further in the logistic chain. Due to the high variations in workload and tasks, we investigate the capability and impact of having multi-functional Warehouse and Packaging - Conditioning operators in combination with reactive scheduling will result in a more fluid supply chain and a more enjoyable work organization for the operators.

3 - Beam search for the 2D-single knapsack problem
Marta Cabo Nodar, Julia Bennell, Antonio Martinez Sykora, Carlos Alegría

The Two-Dimensional Single Knapsack Problem is a well-known problem in the cutting and packing literature. It is an output maximization problem, where the decision maker must choose between a finite set of rectangular pieces to be placed in a rectangular bin, so that the profit of the selected pieces is maximized.

We present a beam search heuristic for this problem. Beam search is a heuristic that acts as a tree search, where each node represents a partial solution to the problem. At each level, all partial solutions will have the same number of pieces placed, and all nodes emanating from the same parent will only differ in one piece. Beam search uses two evaluation functions to prune branches. The first one is made locally and help decide which children will remain from a given parent node. The rationale behind this evaluation is to allow the creation of multiple child nodes, and quickly evaluate which ones may be immediately discarded. The second evaluation is made globally over all the child nodes from each level. The goal of this evaluation is to perform a drastic prune on the branches that will potentially lead to bad solutions at the end of the algorithm. This evaluation is needed due to the greediness of the local evaluation, who does not take into account future decisions to keep one child node over the others.

During this talk, we will explain in detail the two selected heuristic and how they are embedded into the beam search framework.

4 - Solving the pallet-loading vehicle routing problem with stability constraints
Maria Teresa Alonso Martínez, Antonio Martinez-sykora, Julia Bennell, Ramon Alvarez-Valdes, Francisco Parreño

We will present our mathematical model and results for a distribution problem that includes both the packing and routing of customer orders. The model needs to determine the packing of products onto pallets, assign pallets to trucks, decide the position of the pallets on the trucks so that a customer's pallets are together and finally the route the trucks will take. The demand of a customer can exceed the truck capacity and, therefore, we allow solutions that split the delivery of a given customer across several trucks. Each truck can carry a maximum weight and there is also a weight limit on each axle. In addition, the load inside each truck must be stable when the truck is moving to avoid displacement during the journey. All these routing and packing constraints are included into an integer linear model where the objective is to minimize the total travel distance. We present an extensive computational study, varying the number and locations of the customers and the number and weight of the demanded pallets, which shows the performance and the limits of the proposed model. Since the model becomes intractable with even small instances, we propose a decomposition algorithm in which some of the packing constraints are relaxed in the model and then considered by a heuristic packing algorithm. If the heuristic fails, an auxiliary model is then used to ensure the optimality of the solution obtained.

■ WC-30

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S312

Sharing in Transportation

Stream: Transportation and Logistics
Chair: *Francesca Maggioni*
Chair: *Rossana Cavagnini*

1 - Pricing strategy for ride-sourcing platforms
Luoyi Sun, Ruud Teunter, Guowei Hua

Online car hailing platforms are rapidly gaining popularity. Unlike most two-sided markets, these platforms have pricing power. The price for a specific customer ride request affects the number of interested drivers and the likelihood that a customer will accept a selected driver (and not opt for a regular taxi service). This paper is the first to take ride details and driver locations into account, and assuming that drivers and customers maximize utility, studying the optimal pricing strategy for ride-sourcing platforms. We consider two popular types of matching: the platform selects either the first driver to respond or the one closest to the customer. Under selection of the first driver to respond, we find that the platform price consists of a ride length based fare (set relative to the competing regular taxi fare) and a rush hour congestion fee, and increases with the customer waiting cost. Furthermore, the platform price if low relative to the regular taxi fare if traffic conditions are good, drivers have low profit expectations, and the platform commission is low. We also discuss the effects on price and profit if the platform switches to selecting the closest driver. A numerical study based on the Beijing market illustrates the findings.

2 - Optimal rebalancing for bike sharing systems with information-assisted riders
Mohammad Javad Feizollahi, Xinchang Wang

We consider a bike sharing system with riders who are well informed of the number of available bikes and dockers at each docking station through smartphone apps. Meanwhile, the released availability information affects the likelihood of riders choosing a station to pick up or drop off bikes. A fleet of homogeneous trucks is employed to reposition bikes between the stations. The objective is to minimize the sum of the bike rebalancing cost and the penalty cost caused by the lost demand accounting for riders who give up visiting any station based on the information released. We focus on the static version of the problem and formulate it as a mixed-integer nonlinear program. To solve the program, we develop solution approaches leveraging techniques from both dynamic programming and discrete optimization. Our solutions are tested with numerical studies.

3 - Locating take-off and landing sites for a VTOL-based ridesharing network in urban areas
Nitin Ahuja, Melanie Reuter-Oppermann

Demand for efficient mobility is increasing steadily in ever growing urban areas. Therefore, numerous initiatives have been launched recently to develop innovative transportation solutions. One of them is based on vertical take-off and landing aircrafts (VTOLs), capable of carrying up to four passengers. Lilium and Uber are two of the companies trying to make this possible.

To create and operate a VTOL-based transport network, a few technological, regulatory and logistical hurdles need to be taken. In this talk we present a solution for one of the logistical hurdles, namely, where to place the take-off and landing sites in an urban area. One of the aims here is to minimize travel times of medium to long journeys. A customer would then travel to a take-off site nearby, fly to a site near her destination, and then travel to her destination.

An operator of such a network also wants to keep an eye on fixed costs for building or renting a site, flexible costs per trip, and its profitability. Some other factors that play a key role are the underlying urban topology and expected demand for rides. Our method takes these factors into consideration and suggests a small or optimal number of locations at which the take-off and landing sites can be placed. We verify our method for New York with the help of openly available historic taxi data.

4 - Multi-objective stochastic optimization models for managing a bike sharing system
Rossana Cavagnini, Luca Bertazzi, Francesca Maggioni, Mike Hewitt

In this talk, we consider stochastic optimization-based approaches for managing a bike sharing system. Specifically, we focus on determining the initial daily allocation of bikes to stations, while recognizing the opportunity to rebalance bikes amongst stations at a point in time later in the day. We present both a stochastic programming model and heuristics based on a Newsvendor model type analysis for making these decisions. We perform a computational study of these approaches with a simulation of the bike sharing system in San Francisco. With this study, we assess the relative effectiveness of the stochastic programming (SP) and Newsvendor-based approaches. We show that modeling uncertainty with a SP leads to much better solutions, since a decision-maker can obtain a saving of the 41% than not doing so. Nevertheless, we show that the deterministic model solution can be used to speed up the solution of the SP of the 10%. Moreover, we find out that the plan prescribed by the SP out-performs the heuristics. On average, through the SP, the frequency of which stations are empty and the travelled miles reduce both by 14%, while the inventory quantities reduce by 2% with respect to the heuristics. These results can be attributed to a better allocation of bikes at stations and to the recognition of rebalancing. Finally, we prove the efficiency of our SP with respect to what we estimate to be the plan implemented in practice.

■ WC-31

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S313

Academic OR and Approaches

Stream: Soft OR, Problem Structuring Methods and Behavioural OR
Chair: *Cigdem Kadaifci*
Chair: *Ilker Gölcük*

1 - Analysis of factors affecting the choice of academic conferences to participate
Cigdem Kadaifci, Umut Asan, Y. Ilker Topcu

Academic conferences are preferable platforms for academicians to share their research with colleagues, get feedback for improving their research and stay up to date on recent academic studies. Besides the contributions to academic research, these conferences also provide opportunities for the participants to improve their qualifications, expand their network and become socialized. However, academicians are forced to choose a limited number of conferences to participate due to several different reasons such as time required for preparing a research, conference fees, and other expenses. To address this issue, this study suggests a Fuzzy Cognitive Mapping (FCM) approach to analyze factors affecting the choice of academic conferences to participate. In order to decide which factors should be included in the model, the Delphi technique is employed. After finalizing the list of factors, the causal relationships between the factors are determined by four experts. These assessments are aggregated to form the adjacency matrix. Then, with respect to the determined factors, 22 academicians are asked for assessing two conferences, which one of them they participated in and the other one they did not. By using FCM, simulations are performed for each assessment separately and 44 individual results are obtained. Finally, aggregating the individual results and comparing them provide a basis for determining the most influential factors on the choice of academic conference to participate.

2 - Problem-structuring method for safety analysis in the laboratory of injection systems for liquid propellants
Moacyr Machado Cardoso Junior, Marco Antonio Albuquerque, Luís Eduardo Loures da Costa, Sarah Francisca de Souza Borges, Mischel Carmen N. Belderrain

Brazil has invested in projects that enable the development and launch of satellites with different purposes, minimizing dependence on supplier countries and increasing national knowledge. The studies and tests in the laboratories of the Technological Institute of Aeronautics (ITA) in São Paulo, will contribute to launch satellites in its territory and the intellectual property of the products generated will overcome technological barriers. Due to scenario and existing dangers, the objective of this study is to evaluate control and mitigation barriers in this academic laboratory. For that, the Soft System Methodology (SSM) method was used to broaden the horizon and understanding of the problem in a holistic way, analysis of the academic segments involved and actors responsible for the process of teaching and research activity. Stands out the motivation to guarantee necessary safety, without people, environment, assets and reputation's damages, besides the fulfillment of the legal requirements in force. Some of the results obtained in addition to the identification, analysis and evaluation of potential risks in relation to the activities of the Laboratory were the suggestion of the adoption of barriers such as: emergency response plan, access controls, laboratory technicians safety training, preventive equipment, safety signs and a virtual management program for laboratory operations.

3 - Command and control (C2) enhancement in the management of air force logistic projects using multimethodology
Thiago Dias, Daniel Pamplona, Tadeu Vale, Mischel Carmen N. Belderrain

The purpose of a Command and Control (C') system is to create the necessary conditions for success in accomplishing a mission or a task. The design of an efficient logistics system is a matter of survival for a military organization. A C' system must have the ability to plan and predict situations that may affect the progress of operations, as well as assist in the appropriate use of the resources in order to accomplish the mission. The objective of this article is to support C' in the management of logistic projects of the Brazilian Air Force (FAB) using Problem Structuring Methods (PSM). It is necessary a better understanding of C' used in the FAB and its logistics management problems using conceptual maps and Soft System Methodology (SSM) in order to make clear the systemic deficiencies existing in the current management. Finally, after structuring the problem, corrective measures are proposed to improve the current C' system. The results show that the use of Multimetodology facilitates the understanding of the problematic situation and provide solutions not yet considered in the C' system in use by Air Force.

■ WC-32

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S314

Dynamic Models in Game Theory I

Stream: Dynamic Models in Game Theory
Chair: *Anton Bondarev*

1 - Repeated games for analysis of agreements on protection of the environment
Alexander Vasin, Anastasiia Divtsova

We consider repeated games with sliding planning horizons. The initial game includes two stages: the first is a game that generalizes the known model "The Tragedy of the Commons". At the second one the players redistribute the payoffs by means of side payments. Our purpose is to find conditions for existence in the repeated game of a subgame perfect equilibrium (SPE) realizing some Pareto-optimal outcome. The problem is of interest in context of the study of international agreements on limitation of environmental pollution. Existence of the SPE means the possibility for a stable and efficient agreement of such sort. This concept takes into account a possibility of unexpected breaking the agreement by some country and assumes that only endogenous economic mechanisms in frame of the agreement prevent such breaking. Note that in the one-short game there is a "bad" Nash equilibrium in dominant strategies corresponding to a high pollution level. We examine two types of SPE realizing some Pareto-optimal outcome: 1) after any deviation, all players start playing dominant strategies; 2) if one player deviates, the rest continue cooperation maximizing their total payoff under the dominant strategy of the disturber; after the second deviation everybody plays his dominant strategy. For each type, we determine the set of Pareto-optimal SPE outcomes and examine how maximal and minimal SPE payoffs of a player depend on planning horizons.

2 - Feedback strategies first-order zero-sum mean field type differential games
Yurii Averboukh

We study a large system of identical agents governed by two players with the opposite purposes. We assume the mean field interaction between the agents. Moreover, the dynamics of each player is given by ODE. We study this control problem in the limit when the number of agents tends to infinity. The limiting system is a control system in the space of probabilities. We extend the feedback methodology developed by Krasovskii and Subbotin for the finite dimensional differentiation games to the mean field type differential games. It is assumed that the players are informed about the state of the game and form their control stepwise. The main results are as follows. - We construct near optimal strategies of the first and the second players. - We prove the existence theorem for the value function.

3 - Due date quotations in an observable make-to-order system with strategic customers and the effects of customer risk-aversion
Myron Benioudakis, George Ioannou, Apostolos Burnetas

We consider mathematical models for pricing, due date quotations and delay compensations in production and service systems with strategic customers. Methodologically it lies on the interface between Game theory and Queuing theory. The application framework is a make-to-order production system with lead-time quotations and strategic customers with risk neutrality or risk aversion to delay. Specifically, we consider a make-to-order system where customers arrive according to a Poisson process, and the production/service times are i.i.d. exponential random variables. This gives rise to an M/M/1 queuing model. Customers place a value on the service they receive and a cost per unit of time of delay. The risk aversion is modeled by a concave utility function of the net benefit. Based on this utility customers make individual decision to join the system or seek an alternative service with fixed value. Customers know the potential arrival rate and the economic parameters are common to all. They observe the actual state of the queue upon arrival. The individual decisions of arriving customers result in a symmetric join/balk game, for which a Nash equilibrium can be identified using game theory methodology. We have identified threshold and due date quotation policies that guarantee a given entrance rate and examine the profit maximizing policies. We also consider extensions

4 - How optimal control may avoid chaotic dynamics: market inefficiency in asymmetric multi-modal differential games
Anton Bondarev

In this paper I study the potential consequences of the combined multi-modality and asymmetry for dynamic games. It turns out that once the asymmetry in payoffs or investment strategies across varying leaders in the game is sufficiently high, the game at hand may exhibit the so-called non-deterministic chaotic behavior, leading to the fully unpredictable behavior. Still if one considers the optimal program for the social planner, this dynamics can be sometime avoided because of aggregation and the resulting lower dimensionality of the cooperative outcome. Moreover it is demonstrated, that for a certain simple class of games the cooperative solution is topologically equivalent with respect to the increase in the number of players, whereas the decentralized solution is not.

I explore what structures are necessary to be included into the model to observe this non-deterministic chaos and other types of complex behavior on the example of the R&D game with spillovers and imitation. It turns out that while mathematically this type of dynamics appears to be generic for at least 3-dimensional systems, economic structure has to be very specific. In this case the fully centralized regulation appears to be necessary whereas in simpler cases it still can be limited to conventional subsidies.

■ WC-33
Wednesday, 12:30-14:00 - SOUTH BUILDING UV S315

New Applications and Perspectives II

Stream: Data Mining and Statistics
Chair: *Pakize Taylan*

1 - Time series forecasting of driving patterns using LSTM recurrent neural networks for energy management of plug-in vehicles
Orkun Karabasoglu, Damla Kesikburun, Deniz Türsel Eliiyi

Plug-in electric vehicles might be an effective solution to reduce gasoline consumption, greenhouse gas emissions, and dependency on foreign oil. Economical and environmental benefits of plug-in vehicles depends significantly on their energy management strategy which basically dictates under what type of driving conditions gasoline engine and electric motor to be used. Many types of control strategies that have been proposed in the literature require some knowledge of the driving patterns. In this study, we present a time series forecasting method for driving patterns using recurrent neural networks with Long-Short Term Memory (LSTM) approach. The performance of the forecasting model has been analyzed using various statistical performance metrics. Increased accuracy regarding driving pattern forecasting might help improve the fuel efficiency of plug-in vehicles and reduce emissions.

2 - Network methods for fraud detection in the anti-fraud database
Michele Tumminello, Andrea Consiglio, Fabio Farabullini, Riccardo Cesari

The Anti-Fraud database is a proprietary database managed by the IVASS. It includes detailed information about all of the car accidents that have been notified to any insurance company operating in Italy. The objective of the study is to analyze the database by taking a network approach, and develop a score of potential fraudulence that is grounded on the statistical anomalies of sub-networks of subjects and/or vehicles. We look at the system of subjects and car crashes (events) as a bipartite network, where elements of one set (subjects or vehicles) link to elements of the second set (events) and no direct connection occurs between elements of the same set. This network allows one to construct a projected weighted network of subjects, the co-occurrence network, where a link is set between any two subjects who have been involved in at least one event together. "Irrelevant" links, or "noise" links, in this network, which includes professionals, are filtered out by using the method of Statistically Validated Networks [Tumminello 2011]. Besides one-to-one connections, three-node motifs, triangles in particular, might be useful to unveil frauds, since frauds require a high degree of cooperation and trust among fraudsters [Tumminello 2013]. Therefore, a specific statistical method has been devised to test if a three-node motif in the projected network is statistically anomalous with respect to a null hypothesis of random connectivity in the original bipartite network.

3 - An assessment of the use of machine learning in modern ERP systems to provide competitive advantage for manufacturing companies
Mahmoud Abdelrahman, Christian Askvik-Hansen, Jamie Dyer, Carl McLaughlin, Aaron Wilcock

With the boom in computing power and complementary technological advances, businesses are increasingly searching for competitive advantage. As ERP is now considered an order qualifier for manufacturing companies, Machine Learning-enabled ERP software could present an opportunity for businesses to break free from a commoditised ERP offering. There are, however, several challenges ahead, with the key challenge being how to allocate resources in the development of Machine Learning (ML) to create customer value. Due to the exploratory nature of the research, semi-structured interviews were conducted with participants who are working with ERP systems in manufacturing industries and participants from an ERP software vendor. The qualitative analysis have lead to the development of a new conceptual framework: The Supply Chain Management, Planning, User Interaction and Data Management (SPUD-Framework). Interviewees provided a significant amount of detailed insight into the use of ERP systems within manufacturing operations, highlighting several key themes for further investigation. Participants have expert knowledge of their processes and identified areas that would benefit from optimisation through the use of ML. SPUD-Framework will help users finding out how ERP providers can implement ML in a way that can allow their customers to gain competitive advantage through strengthening user utilisation and offer small and medium enterprises (SMEs) enhanced data analysis capabilities.

4 - The refugee game: blame thy neighbor for terrorism
Andreas Novak, Joao Faria, Aniruddha Bagchi, Timothy Mathews

This paper studies a three player hierarchical differential game (with a Large country, a Small country, and terrorist organization), to analyze the actual European refugee situation. Terrorists may enter Europe as refugees, taking advantage of the Open Doors Policy, to attack both countries. There are two scenarios: myopia and full awareness. Countries are myopic when they ignore each other's security efforts, and the terrorist group only considers the weakest link's security efforts. A comparison between the scenarios shows that for an extremely impatient Large country, full awareness yields a greater level of security effort for the Large country, a greater level of security effort for the Small country, and, because of backlash, more terrorist attacks. One predicable result is that both countries will blame each other for their failures in curbing terrorist activities. Stability analysis, however, shows that this is an unstable equilibrium. Continental safety is higher in the myopic model than in the full awareness model.

■ WC-34

Wednesday, 12:30-14:00 - SOUTH BUILDING UV S113

Game Theory and Mathematical Economics

Stream: Game Theory and Mathematical Economics
Chair: *Alper Nakkas*

1 - The impact of valuation heterogeneity on equilibrium prices in supply chain networks
Alper Nakkas

This paper studies bargaining in two-sided supply chain networks where heterogeneous manufacturers on the demand side can purchase an input from homogeneous suppliers on the supply side only if they have a business relationship or "link" to bargain and trade with each other. We show that valuation heterogeneity among manufacturers can mitigate unfavorable supply and demand balance to protect some surplus for the manufacturers and leads to higher price dispersion in the supply chain network. We also demonstrate that bargaining effectively takes place in smaller subnetworks in a general supply chain network and develop an algorithm to decompose the general network into these smaller subnetworks, which simplifies the analysis of the general supply chain network significantly.

2 - Retiree decision making and parameter interchangeability under Epstein-Zin preferences
Asiye Aydilek, Harun Aydilek

We investigate the interchangeability of the two central elements of most macroeconomic models, the parameter of intertemporal substitution and discount rate. We use a recursive utility model during retirement with housing, uncertain life time and risky stock prices since recursive utility is more general and includes expected utility as a special case. We provide the analytical solution of retiree decisions. We realistically calibrate our model and simulate stock returns. Our model mimics consumption data for homeowners well and qualitatively explains retirees' decreasing stock and bond holdings. We investigate the interchangeability of intertemporal substitution and discount rate parameters since they have similar effects on retiree decisions. We show that those two parameters are not interchangeable analytically. Exploring the interchangeability is important since interchangeability will ease the estimation of parameters and simplify the solution. Providing the analytical solution is important to see the effects of different retiree related policies on household decisions.

3 - Dominance in game theory: new concepts
Gabriel Solari Carbajal

Game Theory is the formal study of conflicting situations between rational agents through the use of mathematical models. The agents or contenders have different strategies, among which they must select those that are more favorable. Game theory allows us to structure the problem, determine the different strategies and select the best one for each contenders.

The origin of the Theory of the game is uncertain, but it is considered that its study begins with the work of Cournot. Subsequently, the works of Borel, Neumann-Morgenstern and Nash contributed to its development. The Game Theory is used to solve conflict problems in Economic and Social Sciences.

Of the strategies available to a contender, not all offer the best benefit. Using the dominance technique, it is possible to discard those strategies that offer the worst benefit, facilitating decision making.

In the present investigation, the domance is studied from another perspective, expanding the concept. Now the interest is not to discard the worst strategies but to locate those strategies of greater benefit that will not be discarded, this diminishes the later search facilitating the solution of the problem.

The present investigation has been used to solve problems of different schemes that come to the solution. The results obtained give us the idea that the present proposal is very promising.

4 - Price zones and investment incentives in electricity markets: an application of multi-level optimization with graph partitioning
Mirjam Ambrosius, Veronika Grimm, Thomas Kleinert, Frauke Liers, Martin Schmidt, Gregor Zöttl

With a growing share of renewables, regional price signals become more important as a possible remedy for dealing with network congestion. Additional bidding zones within the countries could enable better signaling of scarcities induced by the transmission network and are therefore under discussion. Still, it is not clear how many bidding zones would be beneficial and how exactly a market should be split in order to maximize overall welfare. This paper addresses the problem of determining the welfare-optimal bidding zone configuration for the German electricity market, and its impact on investment incentives. We use a multilevel optimization model, which determines the optimal configuration of price zones via graph partitioning. It incorporates the optimal determination of interzonal transmission capacities, generation capacity investment, spot market trading, and redispatch. The model is solved to global optimality, using a Benders decomposition approach that is specifically tailored for the effective solution of the resulting optimization problem. Our results show that market splitting with the right zonal configuration can lead to high welfare gains when compared to the case of a single price zone. Here, 2 and 3 zones lead to the highest marginal welfare gains as compared to 4 or more zones. Further, it can be beneficial to restrict inter-zonal transfer capacity in order to increase price signals for spot market trading.

■ WC-48

Wednesday, 12:30-14:00 - 4D UPV B.3

OR in Water Management

Stream: OR in Water and Hydro Energy Management

Chair: *Corinna Hallmann*

1 - Optimization of booster disinfection stations in water distribution networks
Caglayan Sert, A. Burcu Altan-Sakarya

The main goal of this research is the investigation of the efficiency of booster disinfection stations on minimizing the total disinfectant mass applied to the water distribution networks while maintaining an adequate amount of residual concentrations at all consumer demand nodes as well as providing more uniform chlorine concentrations throughout the network. Existing initial concentration effects are also included in the formulation. A C++ code interfacing with EPANET is developed to find optimum scheduling and injection rates of the booster disinfection stations.

2 - A model for optimal water resources allocation: a special application to the Lake Chad Basin
Noe Careme Fouotsa Manfouo

The transboundary Lake Chad basin, situated between Cameroon, Chad, Nigeria and Niger, has experienced a decreasing trend of the surface water resources, due to climate change and unsustainable irrigation policies. Concerns are increasing about its future ability to sustain agricultural production, for both upstream and downstream users. This situation may lead to conflicts on the usage of the remaining water. As a result, riparian countries have ratified a water charter agreement in 2014 that highlights the necessity to develop a water resources allocation model that can define precise and fair water rights allocation for each user, and propose an optimal management of such water rights over time. Results from a research study attempting to address the above-mentioned issue are presented. Firstly, a comparison between stochastic approaches to predict future water availability is given. Secondly, the estimation of future water demand is discussed. This estimation includes a combination of the regression based statistical downscaling technique for climate variable forecasts, Cropwat8.0 to estimate the per hectare monthly crop water demand, a coupled Long-Short-Term neural network and space competition model for future crop land-use and livestock population patterns. Thirdly, a pre-emptive goal programming model is developed for water right allocation. Finally, a combined hydroeconomics, stochastic dynamic programming and game theory, helps for water right management strategy.

3 - Sparse polynomial optimization for water networks
Bissan Ghaddar, Mathieu Claeys, Martin Mevissen, Bradley Eck

In this talk, we explore polynomial optimization techniques for the valve setting problem in water networks. The sparse hierarchy of semidefinite programing relaxations is used to derive globally optimal bounds for an existing cubic and a new quadratic problem formulation. The formulations use an approximation for friction loss that has an accuracy consistent with the experimental error of the classical equations. Solutions using the proposed approach are reported on four water networks ranging in size from 4 to 2000 nodes.

4 - Generating models for water distribution systems
Corinna Hallmann, Stefan Kuhlemann

In recent years, the optimization of water distribution systems has gained more and more attention. Different optimization problems were explored in the literature, such as water network design, tank optimization, pipe optimization, energy minimization or pump scheduling. For all these problems there exist many mathematical optimization models and a variety of different solution methods. The numerical experiments are performed either on realistic networks only available for the corresponding use case or on those few test networks available in the literature. These networks are mostly very small and often lack in realistic properties. To evaluate models and solution methods and compare them to other research work, it is inevitable to have many different water network models. These models require to be of realistic size and to have realistic properties. In this work, we present a model generator for water distribution systems. With this generator it is possible to create network models with realistic properties and arbitrary size. The generator can also control the structure of the network to guarantee a realistic reflection of a water distribution system. To ensure the hydraulic properties in the network we use a hydraulic simulation tool in our generator. Details about the generation process and the application of different use cases will be shown in this talk.

■ WC-49
Wednesday, 12:30-14:00 - 4D UPV B.4

Emerging Applications in Management Science

Stream: Emerging Applications in Portfolio Selection and Management Science
Chair: *Juana-Maria Vivo-Molina*

1 - Evaluating risks in agri-food value chain in developed and developing economies: a multi-stakeholder perspective
Sonal Choudhary, Manish Shukla, Mike Simpson, Rakesh Nayak

Identification and evaluation of risks impacting agri-food supply chains, from multi-stakeholder perspective, are the fundamental prerequisites for developing a resilient agri-food supply chain. In order to achieve a thorough identification of the risks occurring along a supply chain, developing an in-depth understanding of the context in which they occur is crucial. To do so, going from a supply chain perspective to a value chain one is necessary, as it allows to assess relationships, level of collaboration and information exchange amongst supply chain's entities, developing an understanding of the way in which value-creating activities are conducted. To obtain an in-depth understanding of the research context and differences between the developed and developing country, this research focuses on a case study approach of onion value chain risk analysis in the UK and India, respectively. Our results highlight the risk profile using Failure Mode Effect Analysis (FMEA) within three different onion value chains (within UK, UK-Europe and within India), from a multi-stakeholder perspective. We also discuss how variety of stakeholders in the value chain in different economies are affected by some of the key vulnerabilities such as market price uncertainty, cash flow, food quality standards, food safety, information uncertainty, regulations and customer demand fluctuation. Results are useful for practitioners for developing capabilities for risk mitigation strategies.

2 - Attribution and timing for revenue growth in knowledge-intensive organizations
A. D. Amar, Januj Juneja

Taking growth as an outcome of the firm's conscious resource allocation behavior, we study the outcomes of the firm's major decisions, R&D budget; capital expenses; budget for property, plant & equipment; and selling, general & administrative. The outcomes of their decisions are reflected in the variables of revenue growth, earnings before interest and taxes, gross profit margin, times interest earned, and cost of sales. We analyze these outcomes to help guide management's behavior for the firm's better financial performance. Our analysis comes from a study of 18,000 cases of conscious behavior of S&P 500 firms covering a period of 36 years, from 1980-2016, wrapping periods of several economic cycles. We apply principal components analysis to demonstrate the impact of conscious decision behavior on the firm's performance. The management conscious decisions are implemented using a Monte Carlo simulation experiment to recommend a behavior for achieving superior financial performance.

3 - Estimation of a load-sharing model for two-component parallel systems
Juana-Maria Vivo-Molina, Manuel Franco

Motivated by reliability parallel systems whose components share a common load, Freund introduced a bivariate exponential (FBE) model based on the lifetime distributions of the two-component parallel redundant systems. This stochastic model is a two-component load-sharing system which is repaired whenever a component fails, and then its two-dimensional lifetime distributions is modified, being of interest in maintenance and stress-strength reliability modelling. A number of papers have been addressed to extend the FBE model, overcoming for example its restrictive assumption of a constant failure rate, like the extension given by Lu 1989 through Weibull components. Recently, the extended Freund's bivariate (EFB) distribution has been provided by Asha et al. 2016 allowing components to have proportional failure rate models with a common underlying distribution. In this work, a generalization of the EFB (GFB) distribution is proposed deeming how failure rates change after the first failure occurs. Furthermore, a genetic algorithm is employed in order to estimate this GFB stochastic model, encouraging the usefulness of this emerging application of evolutionary techniques. Ref. Asha et al. 2016 An extension of the Freund's bivariate distribution to model load sharing systems. AJMMS 35:207-26 Freund 1961 A bivariate extension of the exponential distribution. JASA 56:971-7 Lu 1989 Weibull extensions of the Freund and Marshall-Olkin exponential models. IEEE Tr Reliab 38:615-20

4 - Analyzing the effects of health policies on the public benefit through simulation
Aydin Teymourifar, Onur Kaya, Gurkan Ozturk

Authors: Aydin Teymourifar, Onur Kaya, Gurkan Ozturk Industrial Engineering, University of Anadolu

Public and private hospitals with different features generally co-exist in healthcare systems. It is observed that the price of healthcare service at most of the public hospitals are low but the average waiting times of the patients are high and service quality is low. On the contrary, at the private hospitals, the quality levels and prices are often high, while the average waiting times are low. These differences affect patients' choice in hospital selection and therefore the satisfaction level of the community and also the public expenditure. In this study, we analyze the impact of different public policies and decisions of the governments on such systems. For this aim, a simulation model of a region in Turkey is designed, considering the public and private hospitals in that region and the preferences of the patients depending on the prices and service qualities. Effects of various scenarios based on different policies and contract mechanisms are analyzed. The proposed scenarios are compared according to a multi-objective definition of the public benefit, which consists of the public expenses, the average waiting times of the patients and the total service quality level obtained. The results obtained through detailed numerical experiments propose that the public benefit can be increased significantly through the efficient use of the proposed policies.

■ WC-51

Wednesday, 12:30-14:00 - 4D UPV 1.2

Health Informatics and Modeling

Stream: OR for Health and Care II
Chair: *Joel Joris Van de Klundert*

1 - Improving trauma outcome prediction models using patients' vital signs
Fatima Almaghrabi, Dong-Ling Xu, Jian-Bo Yang

Traditional vital signs are an essential part of triage assessment in emergency departments (ED), and have been widely used in trauma prediction models. Due to a number of factors related to patients' characteristics and the environment, many medical records have missing data or incomplete information regarding patients' vital signs. This prevents the application of prediction methods that cannot handle missing data, and affect patient care in the ED. Moreover, previous researchers have studied the effect of differences in certain vital signs measured in the prehospital stage and in the ED, and have found that the differences significantly affect outcomes. This research consists of two stages. Firstly, the missing vital signs data are represented using intervals; the evidence has been aggregated and the evidential reasoning rule applied to predict trauma patients' outcomes. Secondly, it investigates different prediction models that have been proposed based on vital sign variables, and how they can improve prediction accuracy. This would help in the early identification of trauma patients at risk of mortality. At this stage, patients' data have been recoded using the National Early Warning System (NEWS) scoring criteria. Based on the changes in the scores for pulse rate, systolic blood pressure, and respiratory rate, a number of prediction models have been constructed and compared.

2 - Screening for breast cancer: the role of supplemental tests and breast density information
Burhaneddin Sandikci

The imperfect nature of mammography led to increased consideration of supplemental ultrasound and Magnetic Resonance Imaging (MRI) screening for timely detection of breast cancer, particularly for high-risk women including those with dense breasts. Breast density not only impairs screening accuracy, but also significantly increases risk of developing breast cancer, resulting in disproportionate risk of death from breast cancer for millions of women with dense breasts. We formulate the optimal breast cancer screening problem using a partially observable Markov decision process model. We compare its results to mass screening guidelines and quantify the value of supplemental screening.

3 - Investigative study on using standardized implants for knee and hip joint replacement and its effect on lifestyle post surgery in India
Rashmi Shahu

: As per the latest news in Times of India estimates show that over 1,20,000 knee replacement procedures, and about 70,000 hip procedures, take place every year in India. It has been more than 50 years that the process of knee and hip joint replacement is carried out successfully. But is very lately understood that there are more complexities post surgery specially in the routine lifestyle of the patients. Various studies in the past have shown that there are differences in the anthropometric data of the Indian population and the western world. In India most of the implants which are used for knee and hip joint replacement are standardized and imported from western countries. This paper tries to study the anthropometric dimension difference between the implants used for the surgeries and the anthropometric data of patients. The paper also tries to analyze the effect of such implants on the lifestyles of the patients post surgery. The methodology consists of empirical data of patients undergone total knee and hip joint replacements between 2010 to 2017. The study consists of data of around 250 patients. The result shows that there is a mismatch between the implants used for surgeries and the anthropometric dimensions of patients. The study also reveals that due to this mismatch there are routine problems which are caused in the lifestyles of patients which includes changes in their walking style and pain in the affected area.

4 - Modelling why and when Chinese citizens bypass primary care
Joel Joris Van de Klundert, Qingxia Kong

Despite sustained policy efforts to improve access to primary care, Chinese citizens increasingly bypass primary care and choose to access the health system at the level of secondary and tertiary hospitals. Given the difficulty to design effective policy measures, and the considerable investments they require, it is important to better understand the choice processes Chinese citizens adopt when selecting healthcare facilities. We collected systematic evidence on the factors influencing the patient choice from the scientific literature, and validated these in in extensive focus group discussions. Based on these collected data we mapped the choice models, and conducted Discrete Choice Experiments to estimate the parameters of the descriptive choice models. We present the model results, and preview future policy optimization problems.

■ WC-52

Wednesday, 12:30-14:00 - 4D UPV 1.3

Pricing and Revenue Management II

Stream: Analytics and Pricing
Chair: *Luce Brotcorne*

1 - Choice of mixed opaque marketing strategy of OTA
Zhaofang Mao, Xiaomei Li

More and more large Online Travel Agents (OTA) are adopting opaque marketing strategies to achieve price discrimination. Using such a strategy can not only increase profits from high-valuation consumers but from low-valuation consumers. There are two kinds of opaque marketing strategies: Posted Price (PP) and Name Your Own Price (NYOP). Different opaque marketing strategies both influence consumers' decisions and the profit of OTA. Therefore, it is particularly important to study the effect of different opaque marketing strategies on the OTA's profit. This paper analyzes the profit of OTA with a single opaque marketing strategy (PP or NYOP) or a mixed opaque marketing strategy (PP and NYOP) with the consideration of consumers' valuation discounts, and concludes that the single opaque marketing strategy is not a special case of the mixed one. When consumers'NYOP valuation discount is smaller and their probability of winning the bid is lower, PP strategy is better than the mixed strategy. With increasing the probability of winning the bid or the NYOP valuation discount, the advantages of the mixed strategy appear, OTA tends to adopt the mixed strategy. The conclusions of this paper are useful to support OTA to select opaque marketing strategies.

2 - Consumers' willingness to pay and firms' cost differentiation on price competition for multiple bundles
Juan Perez, Héctor López-Ospina, Álvaro Flores

We analyze price competition for multiple bundles when including consumers' willingness to pay. It has been studied that pricing is affected by the willingness to pay, but the analysis in competition requires more research effort for sales in bundles. Our results indicate that willingness to pay affects the price competition equilibria and in addition, the mathematical framework proposed, allow us to analyze the relationship among bundles' composition (or attributes), bundles' prices, costs and consumers' willingness to pay. These aspects play also a central role in price competition and affect firm's profit depending on competitors' costs and consumers' preferences. We consider firms in price competition selling multiple bundles in an oligopolistic market, we determined the conditions to have unique price competition (Nash) and analyzed it by means of introducing consumers' maximum willingness to pay as a penalized (cut-off) soft-constraint into the firms' profit maximization function. We show some results for a mobile communications market selling services in bundles (voice and data).

3 - Optimizing conditional value-at-risk in dynamic pricing
Jochen Gönsch, Michael Hassler, Rouven Schur

Many industries use dynamic pricing on an operational level to maximize revenue from selling a fixed capacity over a finite horizon. Classical risk-neutral approaches do not accommodate the risk aversion often encountered in practice. We add to the scarce literature on risk aversion by considering the risk measure Conditional Value-at-Risk (CVaR), which recently became popular in areas like finance, energy or supply chain management. A key aspect of this talk is selling a single unit of capacity, which is highly relevant in, for example, the real estate market. We analytically derive the optimal policy and obtain structural results. The most important managerial implication is that the risk-averse optimal price is constant over large parts of the selling horizon, whereas the price continuously declines in the standard setting of risk-neutral dynamic pricing. This offers a completely new explanation for the price-setting behavior often observed in practice. For arbitrary capacity, we develop two algorithms to efficiently compute the value function and evaluate them in a numerical study. Our results show that applying a risk-averse policy, even a static one, often yields a higher CVaR than applying a dynamic, but risk-neutral, policy.

4 - From revenue management to profit management: capacity control via dynamic stochastic programming
Giovanni Giallombardo, Francesca Guerriero, Giovanna Miglionico

The quantity-based revenue management decision for multiple-resource capacity-control problems is about accepting/rejecting the product request issued at the current period, given the residual capacity of each resource and the random future demand of each product. A relevant underlying assumption is that operational costs are essentially fixed with respect to the resource consumption; hence, they do not depend on the accept/reject decision. In several applications, service providers, upon acceptance of a product request, have to bear non-negligible additional operational costs, still having the chance of optimally rearranging operations (i.e., resource-consumption). In order to account also for variable costs we introduce a dynamic stochastic optimization framework for profit management, focusing in particular on multiple-resource capacity control problems. We propose a deterministic approximation formulation, whose solution allows to define primal and dual approximate control policies, and we explore the practical role of the framework by presenting a vehicle-routing based application.

■ WC-53

Wednesday, 12:30-14:00 - 4D UPV 1.4

Energy Management

Stream: Stochastic Assessment of Renewable Energy
Chair: *John Boland*

1 - Computing energy system transformation pathways with high spatial and temporal resolution
Manuel Wetzel

Decarbonisation of the energy system requires substantial efforts along all sectors. This necessitates the allocation of carbon budgets among both energy sectors as well as the years along the transformation pathway. Additionally state-of-the-art energy system models need to represent the increasing complexity of the energy system from decentralized generation, increasing electrification in the heating and transport sector and demand for flexibility options. The downside of this additional complexity shows itself in the numerical difficulties making these models computational intractable for most solvers.

The BEAM-ME project addresses this need for efficient solution strategies for complex energy system models. This goal is achieved by bringing energy system model to high performance computers, a process that requires interdisciplinary expertise from the fields of energy systems analysis, mathematics, operations research, and informatics. By using a specialized solver adapted to the specific problem structure of energy system models the parallel computation power can significantly speed up the optimization process.

This talk provides an overview in preparing the energy system model REMix to utilize the parallel interior-point solver PIPS-IPM. The adjusted model is parametrized considering both transition pathways and high spatial as well as temporal resolution. First insights in the resulting problem structure are discussed and performance improvements are presented.

2 - Energy consumption scheduling of electrical devices with various types in a household
Ümmühan Başaran Filik, Oguzkagan Alic

Demand response programs emerge as one of the areas of high concern in smart grid technology and play a key role in the energy efficiency problem which is in fact related to the electricity consumption of users. Given the considerable share of the households in overall energy consumption, managing the household electricity consumption becomes even more important. Thus, this study mainly aims to provide a short-term reduction in the energy consumption of a household by scheduling of electrical devices which have specific electricity consumption properties. The electrical devices in a house are divided into types according to their manner of operation and then an optimization problem that aims to minimize the daily energy consumption and electricity bill is obtained. In accordance with this purpose, a solution algorithm to schedule consumption of each type of device and to meet the user satisfaction is implemented. The results indicate that electricity consumption and bill of a household have been decimated.

3 - Do smart grids increase solar homes price premiums?
Chiara D'Alpaos, Michele Moretto

It is commonly agreed that the greater buildings energy efficiency, the greater property market values. Real estate hedonics literature explores how different housing attributes capitalize into home prices. Recent contributions in the literature provide some capitalization estimates of the sales value of homes with PV systems installed relative to comparable homes without solar panels: solar homes sell to a price premium. Though PV systems are widespread, overall cost-savings by PV-generation systems result in marginal impacts on buildings energy efficiency and real estate market values increase. The aim of the paper is to investigate whether Smart Grids innovation can increase market values due to higher production and consumption flexibility. Smart Grids give de facto producers and consumers, the opportunity to be active in the energy market and strategically decide their optimal production/consumption pattern. In this paper we provide a real option model to determine the value of this flexibility and the related market value increase. We model the homeowner decision to invest in a PV plant and connect to a Smart Grid by comparison to the decision to invest in a solar home not connected to a smart grid. We determine the property potential market value increase due to the opportunity to perform active energy management given by smart grids and we compare this value increase to the PV plant value per se. The greater the flexibility the greater the property market value.

4 - Real options applied to South African electricity capacity expansion
Mantombi Bashe

In South Africa (SA) electricity capacity expansion planning from 2013 to 2050 was based on a least cost base model which results in levelized cost of energy. In the past few years electricity capacity expansion projects were implemented using the Integrated Resource Plan for Electricity 2010-2030. The aim of this study is to investigate the impact of real options on investment costs for capacity expansion projects. This is considered to be an initial attempt to introduce real options in electricity capacity expansion planning in SA. A real options model was used to evaluate options embedded on investment costs for technologies proposed for the South African electricity capacity expansion plan. The model proposed is based on binomial trees and is using American option method. The model was applied to the investment costs of coal, OCGT, CCGT, hydro and wind technologies. The technologies' volatility rates ranged between 18.6% and 3.5%. Even though some volatility rates are on the low side it is a worthwhile exercise to introduce real options in South African electricity capacity expansion planning. This is suggested bearing in mind that the electricity regulator in SA has been approving 50% or below the tariff increase rate applied for by one of the electricity utilities since 2013. This highlights the fact that even the regulated electricity utilities are no longer able to pass all the costs to the consumers.

■ WC-54

Wednesday, 12:30-14:00 - 4D UPV 1.6

Applied OR at SINTEF

Stream: Applied OR
Chair: *Geir Hasle*

1 - The role of research organizations in SESAR 2020
Trond Bakken

This paper reports on the role of research organizations within the Single European Sky ATM Research Programme (SESAR 2020). The SESAR 2020 Programme (2016 - 2021) is intended to demonstrate the viability of the technological and operational solutions developed within the preceding SESAR 1 Programme (2008 - 2016) in larger and more operationally-integrated environments. SESAR 2020 has a funding of 398 M EUR for Industrial Research (IR) and Very Large Demonstrations (VLD) conducted by a Public-Private-Partnership (PPP) consisting of 19 members, where the majority is industry partners. SESAR includes Exploratory Research (ER) contracted via open Horizon 2020 calls (81 M EUR). SESAR covers the lower Technology Readiness Levels (TRL) 1 and 2 (ER) and TRL 3 to 6 (IR). SESAR VLDs are organized in two ways, partly covered by the members of the PPP and partly contracted via open Horizon 2020 calls (37 M EUR). These calls are especially addressing the involvement of the airspace users, e.g. airlines. The only research organizations which are full members of the PPP are: 1) SINTEF from Norway as part of the North European ATM Industry Group - NATMIG Consortium 2) DLR (German Aerospace Centre) and 3) NLR (Netherlands Aerospace Centre) together forming the AT-One Consortium. All involved in developing operational solutions to complex Air Traffic Management systems. The paper will give an overview of the different research topics and the role of research organizations in SESAR.

2 - Multiagent planning in airport and air traffic management
Anders Albert

Air traffic volume is increasing and is expected to continue to increase for the coming years. Two results of this are airspace congestion and need for airport management. Airspace is divided into sectors, each with a finite capacity (number of flights). A sector with congestion is referred to as a hotspot. Hotspots are discovered ahead of time and solved by rerouting and delaying flights. However, it is challenging to solve one hotspot since it can lead to a domino effect (creation of new hotspots due to the interdependencies between airspace sectors). In addition, airlines desire the ability to prioritize between potentially delayed flights. Another result of increased demand is requirement for coordination at airports. It is not trivial, even for moderately sized airports, to coordinate operations, particularly in poor weather situations. Planning for these situations is challenging since it involves multiple stakeholders, often with different objectives, as well as dynamic and complex environments. We will present preliminary results for planning and negotiation algorithms. These algorithms should have several properties. First, they should be stable in the way that small changes in input for an agreed upon plan should only lead to small changes in the plan. Negotiation between stakeholders should converge to plan and avoid looping. Finally, they should be able to handle self-interested stakeholders and be able to react fast to changes in the environment.

3 - Rolling stock maintenance scheduling
Daniel Palhazi Cuervo, Lukas Bach

We discuss an ongoing research project in collaboration with Mantena, the main provider of rolling stock maintenance in Norway. This company has more than 1100 employees and hosts operations in around 13 locations. In order to keep a competitive position, Mantena requires a very detailed planning of its operations. This involves, among other things, the recurring scheduling of each maintenance task that needs to be carried out on each train. Such a scheduling problem should take into account multiple operational constraints (i.e., capacity, staff rostering, and equipment availability at each location), ensure that trains comply with safety regulations, and minimize operating costs. Additionally, the schedule should allow for various levels of granularity, depending on the time horizon considered for planning. Maintenance tasks to be carried out during the following days need to be scheduled in terms of hours/days, while later tasks might be scheduled in terms of days/weeks. In this presentation, we discuss a mathematical model for this problem, along with a heuristic framework to solve it. We also touch upon some of the practical details that need to be considered when tackling a real-life maintenance scheduling problem.

4 - Scheduling professional football leagues
Lukas Bach, Oddvar Kloster, Celso Ribeiro

For professional sport federations, tournament schedules affect a variety of stakeholders (teams, television networks, fans, communities). The quality of such schedules affects the revenue of the teams (and federations themselves), as television networks are willing to pay higher broadcasting rights depending on whether the schedule meets certain requirements (e.g. games that draw larger audiences are scheduled on attractive dates). Fans often also decide whether to buy tickets based on similar reasons. Improved scheduling boosts attendance and generates a positive effect on the local economy. The Norwegian professional football league that we schedule is a double round robin tournament, i.e., a tournament where all teams meet each other once at home and away. To satisfy the stakeholders and thereby create better schedules we use a mixed integer programming model to schedule the top professional Norwegian football league. To solve this model, it is necessary to decompose it into multiple parts. The approach applied is, at the first stage, assigning teams to a home / away pattern. In the second stage, we assign games to the individual rounds. All this subject to a set of home / away wishes from the clubs, game specific requirements from TV and the Norwegian football federation. By solving this problem, we are successfully able to get an optimised schedule. The work presented has been used to develop the schedule currently in use for the 2018 football season in Norway.

■ WC-55

Wednesday, 12:30-14:00 - 4D UPV 2.1

Agile SD: Hands On

Stream: Making an Impact I
Chair: *Kim Warren*

1 - Living business models: fast, effective, reliable
Kim Warren, Giancarlo Bigi

This session is aimed at analysts and consultants, and at teachers/trainers of business modeling. No prior experience is needed. Simulating business challenges and plans has until recently been difficult and time-consuming - but things have changed! We will take you through an "agile" process that makes quantified, working simulations practical for non-experts to build, quickly and reliably. And we need these tools. Spreadsheet-based methods just cannot handle the interdependencies, feedback, thresholds and intangible factors that infect all but the simplest cases. The resulting Living Business Models display with total transparency precisely the factors that management recognises, and exactly the causality that drives the performance outcomes they are interested in. Since everyone sees the same rigorous picture, they get that "joined-up" view that everyone says they want - fully explaining how everything has been changing, and allowing them to explore likely future outcomes under alternative assumptions, decisions and strategies.

■ WC-56

Wednesday, 12:30-14:00 - 4D UPV 2.2

Routing for Dial-a-Ride and Home Health Care Services

Stream: Healthcare Logistics
Chair: *Kris Braekers*
Chair: *Yves Molenbruch*

1 - Decomposition methods for the workforce scheduling and routing problem
Matthieu Gondran, Philippe Lacomme, Tchernev Nikolai, Thierry Garaix, Dario Landa-Silva

The research presented in this paper is an investigation of a decomposition method approach to tackle a Workforce Scheduling and Routing Problem (WSRP). The WSRP tackled here involves the allocation of workers to tasks at different locations with several objectives: first is to maximize the number of performed tasks, second is to maximize the Quality of Service of the workers assignment (working time window and geographical working regions), third is to maximize preference satisfaction between customers and workers and fourth is to minimize the cost (transport and cost of worker to perform a task). WSRP combine constraints from vehicle routing and scheduling problems including, but not limited to, time-windows, pairwise synchronization and pairwise temporal precedence. We introduce a column based approach with a sub-problem resolution that take advantages of a multi-threaded dynamic programming approach to compute route for workers. The approach efficiency is evaluated considering benchmarks instances from real-world home healthcare scenarios [1]. The main contributions of this paper is a better of the understanding of the problem and an improvement of results in some instances.

Ref. [1] Algethami, H., Landa-Silva, D., 2017. Diversity-based adaptive genetic algorithm for a Workforce Scheduling and Routing Problem, in: Evolutionary Computation (CEC), 2017 IEEE Congress On. IEEE, pp. 1771-1778

2 - Dial-a-ride with real-time disruptions
Célia Paquay, Yves Crama, Thierry Pironet

The problem considered in this work stems from a non-profit organization in charge of transporting patients to medical appointment locations. Some patients require to be transported from their home to a given location and the other way around. This organization proposes door-to-door transportation services for these requests. This problem is called a dial-a-ride problem (DARP) in the scientific literature. The DARP investigated in this application consists in determining a set of routes for a fleet of vehicles to satisfy the requests, taking into account several constraints: e.g. time window constraints (the pickups and the deliveries have to be achieved within given time intervals), maximum riding time constraints of patients, and vehicle capacity constraints. The objective function is composed of several aspects: minimizing the route length but also maximizing patient satisfaction (reduced waiting time or route duration). The planning is generated in the evening for the following day. Patients have a fixed appointment time but its duration may vary due to unforeseen circumstances. Thus, even if all requests are known in advance, it may happen that some transportation requests are modified, delayed or cancelled in real time. The aim of this work is to propose recourse actions to adapt the planning in order to manage these real-time disruptions. The planning should be modified quickly, while trying to minimize the changes to avoid confusion for the drivers and patients.

3 - On-demand public transport planning
Evelien van der Hurk

This work considers the problem of a Scandinavian public transport provider that employs a set of minivans and taxis to provide transport to customers with special needs. Customers may make drop-off and pick-up requests for specific times. The service provider guarantees a maximum journey time between scheduled pick-up (drop-off) and the specified deadline for drop-off (pick-up) by the customer. The operator aims to employ the minivans in such a way to maximize the number of serviced trips per hour per vehicle, allowing the combination of customer requests. Schedules are generally made a day in advance. One of the issues is the computational effort involved in calculating the (full) distance matrix for all combinations of requests. While advanced path search algorithms could provide a solution to smartly combine these computations, they require the information of the road network. Especially in large urban areas, keeping such a private map updated may provide to be a nuisance, as was expressed by the public transport provider involved in this study. Online map services, such as Google Maps, do provide (relatively) accurate routing information, but will generally limit the number of allowed requests per user. This research focuses on solving real-life problems with up to 1000 requests in reasonable time, in a situation with only GIS coordinates, no detailed map available, and limited access to an online map service. Results are based on a real-life case study.

4 - Integrating dial-a-ride services and public transport
Yves Molenbruch, Kris Braekers, Patrick Hirsch, Marco Oberscheider

Dial-a-ride (DAR) services typically provide demand-responsive transport to people with reduced mobility. Contrary to general taxi services, users may be combined in the same vehicle, as long as their service level requirements (i.e. time windows, maximum ride time, etc.) are respected. Consequently, DAR providers face a complicated routing problem in their operational activities.

In a traditional mobility policy, DAR services are exploited separate from regular public transport (PT). Modern policy visions efficiently combine both systems. Regular PT is only maintained on a core network of (sub)urban and interurban lines, whereas DAR services provide on-demand transport in rural areas, both to people with and without reduced mobility.

Ambulant users in rural areas submit a single request for their entire trip, although this trip may involve a combination of DAR services and PT. The DAR provider needs to determine their itineraries and potential transfer locations such that costs are minimized, given the PT timetables. For this purpose, an LNS algorithm is introduced. Synchronization between routes is enforced by an exact procedure representing candidate solutions as a simple temporal problem, being a network of time constraints which is consistent for feasible solutions.

Tests on artificial data show that, depending on the demand characteristics and network structure, DAR providers integrating their services into PT can save up to 24% relative to a standalone system.

■ WC-57

Wednesday, 12:30-14:00 - 4D UPV 2.3

Machine Learning or Operations Research

Stream: Making an Impact I
Chair: *Ronald Buitenhek*

1 - Machine learning or operations research: how can consultants provide the best advice to their customers?
Ronald Buitenhek, Tim van Luxemburg

The amount of data in the world is constantly growing at an enormous pace. That offers opportunities for consultants to provide factual insights to their customers. The customer can profit from these insights by taking the right (fact-based) decisions. This is in fact what OR-consultants have been doing for a couple of decades already. Recently however, terms like Analytics, Predictive modelling, Machine learning, and Data Science have become much more popular than Operations Research. Does that mean that OR has become redundant? Can quantitative consultants support decision making without using or even knowing typical OR-models and OR-techniques? Are techniques the most important at all?

We think Data Science and Operations Research should go hand in hand. And we believe business understanding and modelling remain indispensable skills in our work. We illustrate this with some of our typical projects of the last few years. And we invite you to discuss with us. How do you think quantitative consulting should be done?

■ WC-58

Wednesday, 12:30-14:00 - 4D UPV 2.4

Data Analysis and Applications

Stream: Emerging Applications of Data Analysis
Chair: *Vadim Strijov*
Chair: *Mariusz Kaleta*

1 - Optimal clustering of stations for the bike sharing system in Seoul
Kwanghun Chung

Like many cities around the world, bike sharing system has been operated to decrease both traffic and pollution in Seoul since 2015. As the use of shared bicycles increases, managerial issues such as relocation and maintenance of bicycles should be solved to offer better service. In this talk, we develop a mixed-integer programming model for finding optimal clusters of bike stations. For each station, we obtain the net demand from user data for pickups and returns at 210 stations in Seoul. Then, we perform computational experiments to propose better clustering for efficient management of bike sharing systems.

2 - Forecasting international migration based on a hybrid fuzzy and Bayesian method
Duygun Fatih Demirel, Melek Basak

Forecasting international migration is one of the vital elements in demographic analysis since it plays a significant role in shaping the socio-economic structures of countries. The current interest in forecasting migration has led to several migration theories as well as deterministic and stochastic forecasting methods. These methods are based on strict subjective or statistical assumptions which may not always be met. Moreover, the exact values of migrants are seldom known due to data recording and collection errors; thus, there is a significant amount of vagueness and uncertainty in migration data. In this study, to deal with the uncertainties in migration values, a hybrid method integrating fuzzy set theory and Bayesian forecasting is proposed for forecasting age-specific migration. The proposed method models the observed migration values via fuzzy regression and an unconstrained nonlinear optimization model, and forecasts the future fuzzy migration values using Bayesian time series models. The proposed method is applied on emigration and immigration data of Finland, in which annual age-specific migration values for 2011-2025 are forecasted using the fuzzy estimates for 1990-2010. The results are compared with an existing Bayesian migration forecasting method outputs and the numerical findings display that the proposed hybrid method is superior to the existing one in forecasting age-specific migration values within significantly narrower prediction intervals.

3 - Influence maximization with deactivation in social networks
Kübra Tanınmış Ersüs, Necati Aras, I. Kuban Altinel

In this study, we address a competitive version of the Influence Maximization Problem (IMP) which is defined on social networks as selecting an initial set of k nodes to start a spread such that the total number of affected nodes is maximized at the end of the influence spread. Our problem can be considered as a Stackelberg game. The leader of the game tries to maximize its influence spread by selecting a subset of nodes with given cardinality, in the existence of a rational follower whose aim is to minimize the spread by deactivating some of these nodes. The deactivated nodes cannot affect their neighbors, nor they can be affected. After the players make their decisions, the diffusion propagates according to Linear Threshold (LT) diffusion model, where the nodes have uncertain thresholds. The distribution of the spread for a given seed set in the LT model is equivalent to the distribution of the reachable sets via specially generated subgraphs of the original network. Using this identity, we formulate the problem as a stochastic discrete bilevel program. The lower level problem is approximated using a sample average approximation (SAA) scheme. A matheuristic method is proposed to solve the bilevel model. The solution space of the leader is searched via tabu search method with a candidate list strategy. For each solution generated, the optimal response of the follower and the spread are estimated using the SAA procedure.

4 - Network market engineering - connecting the dots
Mariusz Kaleta

The network market design problem addresses designing the economic mechanism that distributes goods or services with a use of some network on the market rules. While classical market mechanism design problem has been studied deeply for more than 60 years, the networked version is an emerging problem. The Network Winner Determination Problem (NWDP) is a part of mechanism design. We study the space of possible NWDPs. Since the space is vast we propose positional notation that facilitates describing the problems and their classifications. We summarize the current state of art in complexity of NWDPs. Even though some settings of NWDP makes it NP-hard in general, there exists some network configurations that allows solving the problem in poly time. Designing the network market mechanism can be supported by dedicated DSS. We draw the picture of general design of required DSS and we emphasize some emerging problems, including bidding language design, simulation and analytical models, structural and parametric approach to mechanism design. The talk presents different aspects of network market design that collects a set of challenges into one holistic approach to market design. Within this design there is a wide variety of emerging problems that should be addressed by OR community in the nearest future.

■ WC-59

Wednesday, 12:30-14:00 - 4D UPV 2.5

Decision Making under Uncertainty in Gas and Electric Energy Systems

Stream: Technical and Financial Aspects of Energy Problems
Chair: *Miguel Carrión*

1 - A bi-objective multi-period optimization model for energy planning
Chandra Irawan, Peter Hofman

This paper proposes a bi-objective multi-period optimisation model for the power generation planning of electric systems. A mathematical model using a Mixed Integer Linear Programming (MILP) model is developed for this bi-objective problem. The model determines the optimal mix of energy supply sources in the presence of two conflicting objectives, namely minimising total cost and minimising total CO2 emissions. In this model, several constraints must be satisfied such as a specified electricity demand and the proportion of electricity generated by renewables energy. Compromise Programming (CP) technique is used where the MILP model is solved by the exact method using CPLEX. The proposed model is applied using data from power plants in Indonesia.

2 - The economics of daily natural gas demand in France and in the UK
Arthur Thomas, Olivier Massol

Because of the rise of intermittent renewable energy sources of electricity, natural gas-based thermal generation is increasingly used as a back-up technology. European regulators are increasingly requiring TSOs to improve the performance of their load forecasting techniques. In some countries (e.g., the UK), a dedicated incentive regulatory mechanism has even been implemented. TSOs have begun to heavily invest in the development of modern forecasting tools. They are reputed to have implemented advanced nonlinear forecasting techniques. Building on the seminal work of Forbes & Zampelli (2014), our approach to load forecasting begins by recognizing that the informational content of day-ahead prices. In case of efficient wholesale markets, it should thus be possible to model the quantity of natural gas demanded in a given day using two variables: the day-ahead price of natural gas (to model the reaction of both industrial users and households) and a spark ratio (i.e., the day-ahead price of electricity divided by the day-ahead price of natural gas) reflecting the economics of gas-based thermal generation. The ambition of this paper is two-fold as it: (i) shows that the estimation of a simple specification can be sufficient to challenge the performance of the TSOs' forecasting models, and (ii) documents the short-run and long-run reaction of the daily consumption of natural gas to both the natural gas and electricity day-ahead prices by measuring the price elasticities.

3 - Development of a cost forecasting model on aviation service delay by low visibility
Hee Kyung Kim, Jae Ung Seok, Chang Won Lee

Demand for aviation services is steadily growing in Korea and other counties, but service delays caused by the fog (low visibility) are causing economic losses as well as customer unsatisfaction. This study develops a forecasting model of the delay cost of aviation service caused by aviation weather(fog). Developed are seasonal ARIMA model and a regression model to forecast the demand for air service and the number of flights. Also, the delay reduction model is developed by MIT Lincoln Lab and EuroControl's estimation criteria for delay cost three major airports in Korea. Study result shows that if the weather forecast service about fog is not improved, the delay cost by fog (low visibility) increase due to the increasing demand for aviation service. This study differentiates others developing the forecasting model of the delay cost in aviation service at airports due to the fog (low visibility) as well as can be used in studies to quantitatively estimate the economic losses of delays caused by various weather factors.

4 - Optimal management of combined-cycle gas units with gas storage under uncertainty
Hernán Gómez-Villarreal, Miguel Carrión, Ruth Dominguez

We propose a problem of a power producer managing a combined-cycle gas turbine (CCGT) in order to maximize its expected profit in a planning horizon of one year. The producer can participate in the spot and over-the-counter markets for purchasing and selling natural gas, as well as for selling electricity. We consider that the combined cycle power plant has available a gas storage facility that can be used for facing the uncertainty of gas price and availability. A stochastic programming model is used to formulate this problem where the electricity and gas prices are characterized as stochastic processes using a set of scenarios. The problem includes the technical constraints modeling both the operation of the combined cycle power plant and the gas storage facility. The performance of the proposed model is tested in a realistic case study.

■ WC-60

Wednesday, 12:30-14:00 - 4D UPV B.5

Meet the editors TOP

Stream: EURO Special Sessions
Chair: *Gustavo Bergantinos*

Wednesday, 14:30-16:00

■ WD-01

Wednesday, 14:30-16:00 - UPV Nexus

The hazards of trading volatility

Stream: Keynotes
Chair: *Rita D'Ecclesia*

1 - The hazards of trading volatility
Carol Alexander

Since trading volatility began more than 20 years ago it has grown in depth and scope to the point of major regulatory concern. Not only is manipulation rife, many investment banks now have considerable exposure to a market crash caused by their large-scale issuance of variance swaps and volatility exchange-traded products. It is possible that volatility could become the new ?credit? in the next global banking crisis. It is therefore imperative to really understand the variance risk premium ? what drives it, and how it behaves in different market circumstances. However, previous estimates of this premium are subject to numerous biases and are based on low frequency data over a relatively short time period.

This talk starts by surveying the potential hazards of trading volatility and the growth in complexity of products which have become the target of manipulative practices, just as they are being pushed out to the ordinary investor. Then we focus on a new and general aggregation property which -for the first time- allows not only variance, but higher moment risk premia to be estimated unbiasedly and efficiently over a long period of time. Finally, we use daily data to examine the determinants of S&P 500 variance, third and fourth moment risk premia, showing that they depend on the market regime. They have also evolved over time as the market for trading volatility continues to expand.

■ WD-02

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S101

Innovative Applications II

Stream: DEA: Applications
Chair: *Erdem Aksakal*

1 - The DEA method and its application possibilities for measuring efficiency in the public sector
Ewa Cichowicz, Ewa Rollnik-Sadowska

The orientation on the efficiency of managing of public funds is one of the main assumptions of the concept of performance management of public sector entities. The public institutions facing challenges, including growing expectations for high-quality services tailored to the individual needs of its clients, while having limited resources make it increasingly important to improve the efficiency of these institutions. At the same time, the efficiency of a given system can be determined by the performance of individual entities that operate within its framework. On the one hand, it is important to identify and introduce optimization measures, and on the other hand, it is necessary to develop assessment methods adequate to the conditions of functioning of public entities. The aim of the article focuses on presenting the non-parametric method Data Envelopment Analysis (DEA) and justifying why it can be used to assess the efficiency of public sector entities. In addition, two models of performance evaluation were developed based on DEA. In the first case, the model concerned Poviat Labour Offices on the example of one of the local labour markets in Poland. In the second case, an attempt was made to assess the efficiency of the social security system.

2 - A frontier model for public bidding in government procurement
Marcos Estellita Lins, Nilson Trevisan, Angela Cristina Moreira da Silva, José Dulá

This work presents a model based on Data Envelopment Analysis (DEA), as a decision tool to compare and assess bids for government contracts. This tool complies with Brazilian procurement regulations and takes into account certain European Union requirements (Directive 18/2004). Unlike other methodologies, DEA does not require normalized data, since the criteria weights are self-adjusted to reflect the measurements' units. DEA uses a piecewise linear, multi-faceted, frontier which allows for a variety of mixes of weights, each defining a different face of the frontier. The faces are based on observed benchmarks and therefore do not require a functional form. The weights corresponding to each face specify trade-offs that reflect rewards and penalties among the multiple criteria and can be used to establish ranges. We propose a methodology to generate a set of vector weights based on efficient facets of the DEA frontier. Then we apply MOLP to allow the search of the best combination of vectors that comply with the profile of each proposal. All this can be made public as part of the bidding announcement, making DEA particularly well-suited as a tool in government procurement. The bidding model consists of an exploratory phase where three-dimensional graphical representations are used to understand proposals' relative performance from the perspective of the buyer, since government procurement is a particular kind of bipartite negotiation.

3 - Using a MCDEA model for proposing a new efficiency indicator to manufacturing processes
Carlos Ushizima, Fernando Marins, Aneirson Silva, Erica Dias, Marcelo Figueiredo, Raphaela Bueno

This work proposes an innovative approach, based on a Multi-Criteria Data Envelopment Analysis Model, to calculate a new indicator, named by Value-Added Activities in Manufacturing Processes (VAAMP), to evaluate the efficiency of productive processes, which are the studied Decision-Making Units (DMUs), in a multinational auto parts Company. The results of the VAAMP's application were validated by managers of the studied Company, who confirmed the good results in the practice of this VAAMP indicator, when compared to the indicator traditionally adopted by the Company. The specialists also pointed out more VAAMP advantages, including, the establishment of an DMUs' efficiency ranking and the identification of feasible targets to make efficient the DMUs identified as inefficient.

4 - On the problem of benchmarking dependent decision making units and common inputs in DEA: measuring efficiencies of university faculties and careers within those faculties
Sonia Avilés-Sacoto, Wade Cook, David Güemes-Castorena, Joe Zhu

Data Envelopment Analysis (DEA) is a methodology for evaluating the relative efficiencies of a set of decision making units (DMUs) such as maintenance crews, bank branches, hospitals, university departments, etc. It is commonly assumed that the DMUs are independent of one another in that each has its own set of inputs and outputs. In other words if a given bank branch is inefficient relative to other branches, one can describe its efficiency in terms of the amount by which its inputs need to be decreased to take it to the frontier. In case the independence of DMUs assumption holds, decreasing the inputs of one DMU will not affect the inputs of others. However, consider the case where the members of a given subgroup of DMUs have an input in common such as would be the case if a set of highway maintenance crews in a district are under the jurisdiction of a district supervisor. Decreasing the resources of that supervisor in relation to its impact on one maintenance crew, will cause that resource to decrease as well for other members of that same group. We develop a DEA-like methodologies to handle such situations, and apply it to the problem of evaluating a set of departments or careers in a university setting where these careers are grouped under various faculties.

■ WD-03

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S103

Stochastic Inventory Control

Stream: Production and Operations Management
Chair: *Taher Ahmadi*

1 - Capacity planning, resource utilization, and safety stock placement in a supply network

Foad Ghadimi, Tarik Aouam

This work jointly optimizes capacity and safety stocks, while taking into account the dependency between resource utilization and production cycle times (PCTs). Setting capacity at production stages affects mean and variability of PCTs, which in turn impact safety stocks and work-in-process (WIP) inventories. We adopt the guaranteed service framework and model the integrated capacity planning and safety stock placement problem to minimize WIP and safety stock holding costs, subject to satisfying a target service level and a capacity budget constraint. The integrated problem is formulated as a mixed integer nonlinear program (MINLP) and two solution methods are proposed: A sequential approach solves the capacity planning problem followed by the safety stock placement problem, and an integrated approach jointly optimizes the two decisions based on a Lagrangian relaxation algorithm. The integrated approach relaxes the capacity budget constraint, decomposes network nodes based on a dynamic programming algorithm, and employs greedy heuristics to find optimal or near-optimal solutions. Numerical experiments on a small scale network show that the integrated approach leads to more safety stock inventory pooling downstream and higher WIP upstream. Our computational experiments show that the integrated approach leads to significant savings relative to the sequential one and finds optimal or near-optimal solutions for medium to large scale networks in reasonable CPU times.

2 - Controlling excess stock in (s, S) inventory systems with uncertain returns

Ben A. Chaouch

We consider a stochastic inventory system for a single item that addresses the following situation. A seller whose product is subject to uncertain demand faces the additional problem of having to deal with uncertain returns of this product. Demands and returns occur according to two independent compound Poisson processes. The potential for excess inventory resulting from unexpected increases in returns is of concern to the seller. The seller wants to know how many units of the returning items should be kept in inventory for future use when inventory levels rise above current operating levels due to an influx of returns. He monitors the inventory level continuously and utilizes an order-point, order-up-to-level, and keep-level policy to control its behavior, where That is, (a) If, at any time, the inventory level is below an order is placed to raise the inventory level to the order-up-to-level ; (b) if inventory is between and no action is taken; (c) if inventory is greater than the stock in excess of is returned to the supplying source for a refund. The seller seeks to minimize the long-run expected total inventory costs per unit time of running the system. We develop a solution procedure for finding the optimal policy parameters. Several numerical examples are given to illustrate the trade-offs.

3 - Determining warehouse reorder point considering retailers' decision biases under (R,Q) policies

Samantha Seayoung Park, Yong Won Seo

In this talk, a distribution supply chain consisting of one warehouse and multiple retailers under the continuous-review (R,Q) policy is considered. It has been known that the retailers' ordering decisions tend to be irrational due to various decision biases. There have been researches to model the irrational decisions and design the supply chain contracts correspondingly. However, most of existing studies have been focused on the order quantity decisions under the newsvendor environment. In this research, we focus on reorder point decisions of the retailers with continuous-review (R,Q) policies. While demands occur exogenously following Poisson process, retailers issue orders to the warehouse when they expect the demand during fixed lead time may exceed the current inventory level. Under this setting, the retailers' reorder decision biases are modeled by incorporating subjective utility functions such as minimizing ex-post inventories. Upon the real-time stock information and the knowledge about the decision biases of the retailers, the warehouse can determine the optimal reorder timing. Although the optimal decision of the warehouse is known in previous researches, they do not consider the decision bias of the retailers. In this research, we model the ordering behavior of the retailers incorporating decision biases, and investigate the possibilities to optimize the reorder decisions of the warehouse using the knowledge about the retailer's irrationality levels.

4 - Optimal control policies for an ATO system with commitment lead time

Taher Ahmadi, Zumbul Atan, Ton de Kok, Ivo Adan

We study an ATO system consisting of two suppliers and one assembler. Each supplier has a deterministic replenishment lead time and uses a base-stock policy. Customers place their order before their actual need and receive a bonus. The time from placing an order until the time the product is needed called commitment lead time. The ATO manager aims to find a control policy such that a long-run average systemwide cost is minimized. We show that the optimal commitment lead time is either zero or equal to one of the supplier replenishment lead times and its corresponding optimal base-stock levels can be computed by minimizing two nested convex functions, recursively.

■ WD-04

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S104

Optimal Control Applications III

Stream: Optimal Control Applications
Chair: *Raúl de Celis*

1 - Optimization techniques for robotic exploration

Christian Meerpohl, Kathrin Flaßkamp, Christof Büskens

We present an optimization-based approach for robotic exploration. Autonomously operating robotic systems are an essential part for potential space exploration missions. To ensure a mission's success, a variety of conflicting objectives has to be considered, e.g. information gain, safety or energy efficiency. In highly unknown environments, strategies to explore both, the environment as well as the resulting system dynamics when interacting with the environment, are demanded. By using a highly efficient optimization routine we are able to incorporate those objectives in our motion planning scheme. Trajectories are planned towards regions of high interest under the consideration of present obstacles. Solutions can be energy-optimal or time-optimal, but also optimal with respect to the information gain. We use Fisher information theory to recognize model uncertainties during a plan execution and are able to react towards perturbations. When large model errors are detected, optimal control is used to plan trajectories in order to identify certain model or environmental parameters in an optimal way. The optimal control approach further allows us to implement a model predictive controller that is capable of adjusting to changes regarding the model of the system dynamics or within the cost function. Results are shown considering the example of a skid-steering mobile robot in simulation and in practical experiments as well.

2 - Condition-based production and maintenance

Michiel uit het Broek, Ruud Teunter, Bram de Jonge

Many multi-unit systems face significant economic dependencies for performing maintenance, e.g., expensive vessels are needed to perform maintenance at offshore wind farms. Therefore, it is often cost efficient to cluster maintenance for several units. However, when maintenance for units with different degradations levels is clustered, then maintenance is performed too early for the low deteriorated ones or too late for the highly deteriorated ones. In such situations, an interesting question is whether it can be profitable to adjust the production rates in order to synchronize the deterioration processes for the different units.

The current maintenance literature typically assumes that machines always produce at a fixed production rate and that we cannot influence the deterioration rate. However, there are many real-life situations where we can adjust production rate for machines. The deterioration rate of these systems typically depends on the production rate, implying that the deterioration process can be controlled by adjusting the production rate. The applies, for instance, to wind turbine gearboxes and generates that deterioration faster at higher speeds.

We study a multi-unit system with condition monitoring and economic dependencies. We are interested in the structure of the optimal policy, i.e., when to adjust the production rate of a unit in order to postpone or advance its maintenance moment to improve the efficiency of clustering.

3 - A pseudospectral framework for optimal train control

Rob Goverde, Gerben Scheepmaker, Pengling Wang

In the last decade, pseudospectral methods have become popular for solving optimal control problems. They do not need prior knowledge about the optimal control structure and are thus very flexible to complex path constraints, such as are common in optimal train control. Practical optimal train control problems are nonsmooth with discontinuities in the dynamic equations and path constraints corresponding to gradients and speed limits varying along the track. Moreover, optimal train control problems typically include singular solutions. These characteristics make these problems hard and also lead to convergence issues in pseudospectral methods. We propose a theoretical framework that connects pseudospectral methods with Pontryagin's Maximum Principle allowing efficient computations and validation of the solutions. We apply the framework to two basic problems in optimal train control: minimum-time and energy-efficient train control, and consider cases with regional and intercity trains for various scenarios including varying gradients, speed limits, and scheduled running times. The framework confirms the flexibility of the pseudospectral method with regards to state, control and mixed algebraic inequality path constraints, and identifies conditions that lead to inconsistencies between the necessary optimality conditions and the numerical approximations of the states, costates, and controls. This can be used to improve problem formulations and adapt solution algorithms.

4 - Airport arrival management: an optimal descent trajectory and runway assignment integrated model

Raúl de Celis, Adrián Barea, Luis Cadarso

Continuous descent approach (CDA) aims at reducing fuel consumption and noise compared to other conventional descents. Instead of approaching an airport in a stairstep fashion, CDA allows for a smooth descent to landing. The descent profile depends on initial and final positions of aircraft, which depend on the followed route during the flight and the assigned landing runway, which in turn depends on airport congestion and/or availability. This work develops an optimization model for the management of approach and landing operations in airports, managing runway assignment and approach trajectory. The proposed model leads to a mixed integer non-linear model which is difficult to be solved. Therefore, a Benders decomposition is proposed. On one hand, the master model deals with runway assignment, making use of a set of binary variables. On the other hand, the sub-model deals with the trajectory calculation problem, minimizing fuel consumption and complying with noise constraints. The contributions of this work are twofold: first, two decision problems are integated and second, an adaptive mesh is proposed to solve the trajectory optimization problem efficiently. Realistic computational experiments based on real airport operations are presented.

■ WD-05

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S105

Heuristics for Vehicle Routing Problems II

Stream: Vehicle Routing and Logistics Optimization I
Chair: *Jose Escribano*

1 - Optimizing a 2-echelon distribution system with temporary intermediate facilities

Vincent F. Yu, Hsiu-I Ting, Shih-Wei Lin, Winarno Winarno, Aldy Gunawan

We study a distribution network design problem in an urban area where the cost of establishing a consolidation facility is high and the traffic is heavy. The system utilizes temporary intermediate facilities where packages are transferred from trucks dispatched from a central depot to motorcycles that make the deliveries to customers. There is no cost associated with the use of the temporary intermediate facilities and the motorcycles that perform the last-mile distribution are owned by freelance workers instead of the distribution company. We formulate a mathematical programming model and develop a heuristic algorithm based on simulated annealing for this problem. Computational study shows the effectiveness of the proposed algorithm and reveals that the distribution cost can be reduced by more than 10% in most cases.

2 - Large neighborhood search approaches for multi-trip vehicle routing with time windows and driver shifts

Véronique François, Yasemin Arda, Yves Crama

We consider a multi-trip vehicle routing problem with time windows (MTVRPTW) and we assume that the working time of each vehicle may not exceed a maximum duration smaller than the planning horizon. We seek to minimize the total working time, implying that vehicle start times are explicit decision variables. We develop two adaptive large neighborhood search approaches based on different solution representations. The first method treats each vehicle journey as a giant tour that includes trip delimiters. The second one works on separate trips before assigning them to the available vehicles and scheduling them. We configure both methods using an automatic algorithm configuration package and show that the first one is more efficient in the presence of time windows, especially when these are tight. We obtain high quality results on MTVRPTW benchmark instances. We propose a generator to produce instances which characteristics naturally favor the creation of multi-trips. We also show that minimizing the total working time of the vehicles instead of the total distance is suitable in the presence of time windows since accepting a small deterioration in terms of traveled distance has a large positive impact on the working time. This effect increases as the size of time windows decreases.

3 - Optimization of employee transportation services

Bengisu Tosun, Fulya Fidan, Simgenil Arslan, Gulce Haner Guler, Erdinc Oner

This paper presents a model for scheduling the company's blue-collar employee service bus transportation routes. Transportation service bus routes, which are defined as the distances between the employees' addresses and the company, are analyzed considering the total transportation cost. The main objective in solving this problem is minimizing the total transportation cost while minimizing total travel time and number of busses used for employee transportation. The solution method is based on the open vehicle routing problem with time windows (OVRPTW). The OVRPTW is based on finding routes from one depot to a group of geographically scattered points with minimum cost. The routes are modelled, such that each point is visited only once by just one vehicle within the given time interval. All routes should start at the depot and the total demands of all points on one specific route must not exceed the capacity of the vehicle. A mathematical model is developed to solve this problem. The model's applicability and efficiency is studied using the real data for instances of 5, 10 and 15 addresses. The results show that the developed model can be applied for instances with small number of addresses. For the large number of addresses, clustering and heuristic algorithms are applied to solve the problem. Finally, in order to support the enhanced decison making, decison support system is developed.

4 - Cooperative conflict avoidance and path improvement heuristics for humanitarian unmanned aerial vehicles

Jose Escribano, Panagiotis Angeloudis, Washington Ochieng

Battery- powered Unmanned Aerial Vehicles (UAVs) are increasingly used to enhance humanitarian response. An ongoing initiative led by the World Food Programme is exploring their integration in response mechanisms, including last-mile relief distribution systems. The application of this technology requires the development of fast methodologies that determine optimal routes considering UAV endurance as a function of payload and conflict avoidance requirements in terms of minimum safety distances. Building on this, we develop a non-linear trajectory optimisation model that provides the initial near-optimal paths, and an improvement heuristic that alters the initial solution considering kinematic and avoidance constraints. In addition, we use a cooperative avoidance heuristic to resolve conflict with other UAVs in the fleet. The heuristic is integrated into a vehicle routing algorithm that models humanitarian response operations. We analyse the effects on the performance of the humanitarian response operation in terms of safety and mission times.

■ WD-06

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S106

Scheduling and Project Management

Stream: Scheduling, Timetabling and Project Management

Chair: *Tomas Subrt*

1 - Integrated smart history in project management

Banu Ozkeser, Cuneyt Karaarslan

Project performance evaluation is both an important database for the future projects and the milestone of the success in project management. While technical criteria have determined performance primarily in the world literature until today, there has not been a kind of study, integrated organizational performance and risk analysis. In the company that the application done, the carry out of project performance evaluations have not been implemented due to time constraint, especially. The main goal of this study is not only to create a history regarding to the performance data for the project team members but also to bring a new light for the future projects that members take part in.

Owing to include of the historical data and assignment of every team member to a new project has been done according to this history, the system can be defined as smart. Besides, risk monitoring points make the algorithm structure integrated. With this aim, an infrastructure for the project management reports begins to create in the departments which implements this integrated smart system.

2 - A spatio-temporal packing problem in stem cell culture industry

Jongyoon Park, Kyungsik Lee, Jinil Han

In this paper, we consider a spatio-temporal packing problem in the production of stem cell therapy products, which we call the stem cell culture scheduling problem (SCSP). This problem is to maximize the number of stem cell drugs over a given time horizon under spatio-temporal resource constraints due to the long culture period and the limited incubator capacity. More specifically, each stem cell culture process can be viewed as a k-dimensional object that is packed into a given k-dimensional stock(a spatio-temporal space). The basic problem is to pack as many objects as possible into the given stock while satisfying some constraints. For the SCSP, we introduce two integer programming formulations: the process-indexed formulation and the pattern-based formulation. Since the unique characteristics of the stem cell culture process make this problem difficult to solve, some research on polyhedral structure and heuristic method have been conducted. Computational results for some numerical examples also will be reported.

3 - IT project management: service operations' supply chain optimization

Alexey Zalozhnev, Denis Peremezhko, Vasily Ginz

Both Project and Process Approaches can be applied to large-scale IT Project Management. A large-scale IT Project life cycle, as a rule, consists of three Phases: Pre-Investment, Investment (Development and Implementation), and Operations and Maintenance Phases. The third phase also includes the Service Processes.The initial stages of a large-scale IT Project life cycle imply the investment of the significant amount of money. Therefore, it can be viewed as an Investment Project. Thus, Project Management ideas and tools may be taken as applicable for such projects' successful implementation. Software development processes are implemented during the Investment Phase. It is performed in accordance with the life cycle model selected, and standards that regulate the implementation processes. The cost and temporal characteristics of IT system's Implementation, Maintenance, and Service jobs depend on the program code size and software complexity. The Process Approach can be applied to these phases of large-scale IT Project. Service Operations' Supply Chain Optimization, in particular, can be effectively applied. The mathematical model is presented in this paper. It relies on the calculation of the parameters for multiple channel queuing model. This model is implemented in Microsoft Excel.It allows us to make estimates (in the Pre-Investment phase) for the average duration of maintenance and service jobs, and allows us to find the optimal team size for IT Service support.

4 - Modification of crucial earned value parameters for modern project management

Tomas Subrt, Jan Bartoska, Petr Kucera

This paper summarizes and expands author's four-year work in the field of quantitative approaches to project management. Gradually, we started with modification of basic Earned Value Management (EVM) parameters by work effort and Student Syndrome, supposing that every existing activity in any project is determined by the effect of the human agent, also very apparent in the work contours of the resources allocated to the project. Human resources tend to have different shape and top of their work efforts. This influence was formalized by a complex parametric mathematical model of Student Syndrome. Most commonly mentioned EVM lack is a declining credibility of Earned Value (EV) index while approaching the end of the project. The assumption of linearity of Planned Value (PV) can lead to incorrect conclusions about the development of project time and cost indicators. PV should be as close as possible to the real work effort of allocated resources. Our contribution aims to precise these parameter estimates using adequate mathematical models. Also, costs in the phase of project tracking progress vary depending on the internal and external factors. Actual Costs (AC) are usually not sufficiently known and so they are only continuously estimated. Any incorrect estimate of the AC leads to distortion of all EVM characteristics. Our proposal is based on the use of optimistic, neutral and pessimistic scenarios for the development of current costs during project implementation.

■ WD-07

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S107

Scheduling with Resource Constraints III

Stream: Scheduling with Resource Constraints

Chair: *Krzysztof Fleszar*

1 - Mixed integer programming based merge search for open pit block scheduling

Davaatseren Baatar, Dhananjay Thiruvady, Andreas Ernst, Mohan Krishnamoorthy, Angus Kenny, Angus Kenny, Gaurav Singh

Open-pit mine scheduling is a challenging large-scale optimisation problem which tries to create the best possible mine plan in order to maximise the net present value of a resource. We investigate mixed integer programming based methods to tackle this problem, and in particular, propose a novel method - merge search - which combines parts of existing solutions to generate improvements. We find that merge search is able to provide higher quality solutions than those available in the literature and that a parallel branch & bound search improve upon the best known upper bounds known to date. Furthermore, we investigate parallel implementations of merge search and find that convergence to (local) optimal solutions can be achieved in more quickly by increasing the number of nodes.

2 - A MILP model for the unrelated parallel two-machine scheduling problem with a resource constraint
Krzysztof Fleszar, Khalil Hindi

We propose a very efficient mixed-integer linear programming (MILP) model for solving the unrelated parallel two-machine scheduling problem with a renewable resource constraint. The model is based on the observation that when jobs are preassigned to machines, an optimal schedule can be easily obtained if jobs on one machine are ordered by non-increasing resource consumption and on the other by non-decreasing resource consumption. Our MILP model implicitly searches all possible job-machine assignments and for any chosen assignment, schedules jobs in the above-defined orders. Computational experiments show that our MILP model can solve large instances to optimality in very modest computation times, greatly outperforming previously proposed methods.

3 - Resource-constrained project scheduling with alternative activity chains and time considerations for production planning with multiple lots
Viktoria Hauder, Andreas Beham, Sebastian Raggl, Sophie Parragh, Michael Affenzeller

The NP-hard Resource-Constrained Project Scheduling Problem (RCPSP) is a well-known optimization problem. One new extension is called RCPSP with alternative Activity Chains (RCPSP-AC) presented by Tao and Dong (2017), which they describe as a generalized form of the Multi-Mode RCPSP. It consists of two sub problems, the resource-constrained project scheduling and the activity selection problem, which represents the real-world possibility of alternative production ways where one way has to be selected. In this work, the RCPSP-AC is extended by multiple components, motivated by an application in the steel industry. A new activity type called "completion activity" is introduced. Thus, the production completion of multiple lots within the total production time horizon is ensured, which is necessary to satisfy all required precedence relations. Moreover, real-world inherent time restrictions are proposed. A new minimum necessary duration per activity replaces the fixed processing time per activity. Hence, it is possible to decide on the variable processing time per activity and therefore, also on the starting time of every activity. Moreover, new objective functions for this extension are modeled. The throughput time and the tardiness of single production lots or the whole project are minimized. The developed MIP model is implemented in CPLEX and solved to optimality for small instances. For larger, real-world instances, an evolutionary solution approach is proposed.

■ WD-08

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S108

Advances in Combinatorial Aspects of Optimal Control

Stream: Combinatorial Optimization I
Chair: *João Lauro Faco'*

1 - Design and development of discrete optimization approach for agro product clustering: case study of TR72 region in Turkey
Giray Resat

This paper presents the mixed-integer non-linear programming problem to create the basis for both regional and national agriculture strategies, and basin-based development plans for agro products in Turkey. By using the regional resources more active and on-site, this study leads to a guiding document for the evaluation of resources and regional potential, and the transforming product groups into value-added ones. The problem includes objective function to increase the total agricultural production quantities and income, while optimizing the proposed network structure. Production efficiencies, land usage ratios and some geographical data are considered and computational results for different illustrative cases are presented with real data from the TR72 Region of Turkey. Then, the sensitivity analysis of proposed mathematical models with pre-processing constraints is summarized for decisions makers.

2 - Optimal coordinated bidding of a profit maximizing risk-averse EV aggregator under uncertainty
Yelena Vardanyan, Henrik Madsen

This paper proposes a stochastic and dynamic mixed-integer linear program (SD-MILP) for optimal coordinated bidding of a risk-averse profit-maximizing EV aggregator. Markov-based HW model with a standard scenario generation-reduction technique is used to capture the uncertainty in day-ahead, intra-day, and real-time prices. The concept of CVaR on hourly basis (T-CVaR) is applied for controlling the risk of hourly profit of an EV aggregator. The convex combination of the expected profit and T-CVaR is used as the objective of SD-MILP. In order to benefit from the released information over time, the rolling planning is employed to update the scenario trees of intra-day and real-time prices within the day of planning. The main contributions of the paper are: • The development of a SD-MILP for an aggregator who manages big number of stationary storages and EVs to obtain the optimal coordinated bidding in three-settlement markets. • The inclusion of uncertainty in both market prices as well as EV mobility parameters. • The incorporation of the time-dependent version of CVaR (T-CVaR) to focus on the lower tails of the profits on hourly bases.

The developed SD-MILP optimal bidding strategy is applied to derive a bidding discharge/charge curves of an aggregator managing a fleet of 1000 EVs. The coordinated bidding curves are derived and discussed. The economic frontier curve is drawn to illustrate the trade-off between the expected profit and T-CVaR risk measure.

3 - Solving linearly-constrained mixed-integer nonlinear (MINLP) global optimization using GRASP metaheuristic
João Lauro Faco', Ricardo Silva, Mauricio Resende

We consider optimization problems with nonlinear objective-function submitted to m general linear constraints with a large number of n continuous variables and some integer variables. C-GRASP solves continuous optimization problems subject to box constraints by adapting GRASP metaheuristic for discrete optimization. Random search and local improvement phases independently use a discrete and a continuous set avoiding combinatorial difficulties. The constraints with discrete variables are incorporated in the objective function by quadratic penalty terms. We consider the box constraints as implicit and handle the linear equality/inequality constraints explicitly. A Reduced Problem in (n-m) independent variables will be subject only to box constraints. The m basic variables can be computed by solving a system of linear equations. If all basic variables are inside the box, the algorithm stops. Otherwise a change-of-basis procedure is applied, and a new Reduced Problem is solved.

■ WD-09

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S109

Optimization of Machine Learning Models

Stream: European Working Group: Data Science Meets Optimization
Chair: *Dimitri Papadimitriou*

1 - Fractional Euclidean distance matrices for Kriging surrogate model
Natalija Pozniak, Leonidas Sakalauskas

The paper deals with the application of fractional distance matrices to construct the Kriging surrogate model. The objective is to discuss and demonstrate the implementation of the Kriging surrogate modelling technique and verify the computational efficiency of the method. Some examples are tested by computer simulation to illustrate the effectiveness of the proposed model when compared to the Kriging and Shepard extrapolator. The comparison results verify the computational efficiency. Once constructed, the Kriging surrogate model can be used for data extrapolation and optimization. The surrogate model developed has been applied for modeling of surface wastewater treatment filters. The effectiveness of filters filled with construction waste and biocarbon was analysed.

2 - Recurrent parameter estimation algorithm in hidden Markov models with application to multivariate data analysis and signal recognition
Jūratė Vaičiulytė, Leonidas Sakalauskas

Hidden Markov Models (HMMs) have been extensively used in dynamic systems modeling as well as applied to numerous practical areas. Thus, we present a recurrent algorithm for online hidden Markov model parameter estimation and its application to multivariate data clustering and classification. In this work, we focus on continuous HMMs and assume that model parameters have the multivariate normal distribution with unknown mean vector and covariance matrix. We aim to find optimal model parameter estimates. Therefore, the maximum likelihood method was used to estimate the unknown parameters of the model, and formulas for the adapted recurrent Expectation-Maximization (EM) algorithm of HMMs parameter estimation were derived. The complexity of the adapted recurrent EM algorithm is linear in respect of a sample size. Hence, the parameters of the HMM model are updated with each new observation received, without remembering the previous observation set. The adapted recurrent EM algorithm consists of two main parts — model training and recognition. Therefore, we can continuously estimate model parameters and perform online recognition at the same time. In our experiment, the implemented algorithm was used for multivariate data clustering and adapted for isolated word recognition. The results of the experiment are discussed in this work as well.

3 - A novel optimization based algorithm for multi-class data classification problem
Fatih Rahim, Metin Turkay

Multi-class data classification is a supervised machine learning problem that involves assigning data to multiple groups. We present a novel MILP-based algorithm that splits each class's data set into subsets such that the subsets of different classes are linearly separable. At each iteration, we form a subset of samples out of the set of unassigned samples by a MILP model that maximizes the cardinality of the new subset. The generated subset which is linearly separable from the subsets of other classes is removed from the unassigned sample set. The rest of the samples are used for generating new subsets and the algorithm terminates when all the samples are assigned. There is a hyperplane that separates each pair of subsets of different classes such that the hyperplanes form a polyhedral region for each subset and the regions of different classes are disjoint. We build classifiers based on the convex hulls of the subsets and the polyhedral regions for the testing phase. We evaluate our approach on benchmark problems and compare it with the methods from the literature. We conclude that our optimization-based algorithm complemented with the proposed classifiers, provides competitive results in terms of prediction accuracy.

4 - Combined structure and weight learning for neural networks
Dimitri Papadimitriou

Compelling arguments have emerged over time for using multi-layer neural networks (NN) as general pattern for solving supervised machine learning problems. However, designing and training the right NN for a given learning task remains subject to many theoretical gaps and practical concerns. Most algorithms focus on finding the weight values that minimize the empirical loss given a NN structure provided as input to the minimization problem, that is nonlinear, nonconvex and high-dimensional. Common techniques to cope with efficiency (number of layers/depth, units/size, etc.) still rely on handling the NN structure as hyperparameter that is tuned using a validation set or on the dropout method which samples from exponential number of different thinned structures to reduce overfitting at the detriment of increasing training time. Instead, combining structure and weight learning yields a multi-objective minimization problem, where the NN structure itself becomes a variable of the problem (instead of a parameter). The proposed method for solving the combined problem extends the Generalized Benders (variable decomposition) technique to non-convex objective functions. It proceeds by i) iteratively building/tuning the structure of the NN over which the weight learning algorithm performs and ii) adapting this structure according to the learning rate gain and to the epsilon-accuracy of the solution produced.

■ WD-10

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S110

System Dynamics Modeling and Simulation

Stream: System Dynamics Modeling and Simulation
Chair: *Evgenia Ushakova*

1 - Models of regulatory fit
Ann van Ackere, Erik Larsen

We start from the assumption that industry regulation is a behavioural adaptive process, influenced by both external and internal forces. External influences include, among others, technological evolution and policy changes, while internal influences result from, e.g., industry stakeholders, feedback and inertia. We build a system dynamics model capturing these dynamics to gain a better understanding of the interaction between an industry and its regulation. We explore the occurrence and evolution of misfits, i.e., instances where the regulation is not adapted to the state of the industry it regulates. We are particular interested in the underlying behavioural reasons for these misfits, such as inertia, misperception of a rule's consequences and unanticipated responses to rules. Our objective is to gain insight into how to design regulatory frameworks that minimise both the creation and the persistence of such misfits. We use examples from the electricity industry to exemplify the type of misfits that occur, analyse their consequences (typically a dysfunctional market and large costs) and explore how precursory signals of misfits could be detected early so as to potentially prevent their occurrence, or at least limit their persistence, and thus the resulting damage. The insights from this research also apply to other regulated industries characterised by significant time lags.

2 - A system dynamics model of emergency department crowding in Singapore: ways to restore the balance between demand for and supply of emergency medicine
Lukas Schoenenberger, John Ansah, Salman Ahmad, Lin Hui Lee, Yuzeng Shen

Emergency Departments (EDs) worldwide are confronted with rising patient volumes causing significant strains on both Emergency Medicine and entire healthcare systems. As a consequence, many EDs globally are in a situation where the demand for ED care by far outstrips its supply—a phenomenon called Emergency Department (ED) crowding. Besides compromising overall ED performance, ED crowding can impair the quality of care delivered to patients and lead to longer patient waiting times. In Singapore, total ED attendance at public hospitals has grown significantly, that is, roughly 5.57 % per year between 2005 and 2016 and, as a consequence, emergency physicians (EPs) have to cope with patient volumes way above the optimal workload. The purpose of this study is to create a virtual world of a hospital-based ED in Singapore using system dynamics in order to visualize and improve patient flows within the ED. The virtual world integrates both the demand side (patient flows) and the supply side (EPs and nurses) of the ED. This allows identifying bottlenecks, i.e., ED venues where patients accumulate, that put a strain on ED performance. Based on the simulation model, we analyze how ED manpower needs to be adjusted in order to dissolve congestions and smooth ED patient flows. Besides optimal staffing, we test the impact of two additional policies on ED crowding: co-location of general practitioners in the ED and an increase in capacity of the associated hospital.

3 - Structural analysis of conceptual maps and simulation
Mathias Beck, Lukas Schoenenberger

We believe there is a significant leap between qualitative system dynamics, that is problem mapping, and quantitative system dynamics, where model relationships need to be mathematically formalized and parameter values have to be estimated. While the former is quite intuitive, accessible, and doable with limited monetary and temporal resources the latter, in contrast, demands sophisticated analytical and modeling skills and necessitates an extensive budget of resources. As a consequence, policy-makers as well as managerial decision makers, who are often poorly trained in mathematical modeling and have restricted resources, refrain from using quantitative system dynamics and apply, if anything, qualitative system dynamics to their complex strategic problems. However, the sole application of qualitative system dynamics to complex strategic problems bears the risk of generating weakly validated and potentially misleading results. Therefore, in this study, we propose an intermediate phase in the system dynamics modeling process in order to fill the gap between qualitative and quantitative system dynamics. In the intermediate phase, concept models emerging from qualitative system dynamics, are comprehensively analyzed based exclusively on their structure. In particular, model structure is examined for the existence of system archetypes, high leverage points, and causal pathways referring to intended and unintended policy consequences.

4 - Causal structures of financial markets: a dynamic simulation model
Evgenia Ushakova, Chaiporn Vithessonthi, Markus Schwaninger

We aim to present a generic model of the financial market: the MBC (Model of banks and companies), - a dynamic simulation model. It is of interest to both decision-makers in monetary policy and to researchers. The MBC is new in that it is generic and covers all three kinds of agents in a financial market, - Central Bank, commercial banks, and investors. The purpose of the model is twofold: to support decisions of monetary policy, and to enable comparisons of different methods of describing and explaining financial markets. First, the logic and the structure of the model will be presented. The concrete system modeled is highly complex. Conclusively, the abstract model system needs to feature complex structures as well. However, that complexity is limited, because the modeling focused on "essential variables" - according to Ashby, those variables, which have to be kept within "organic" bounds, for the system under study to be viable. Validation tests will be demonstrated, and scenarios explored, which trigger counterintuitive insights and suggest implications for theory and practice.

■ WD-11

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S111

Game Theory Models

Stream: Applications of Dynamical Models

Chair: *Eleonora Fendekova*

1 - Study on the relationships between the agency charges of the public procurement and its corruption
Huirong Jing, Wenxin Jing

This paper uses the normative research method of game theory, and establishes a simulate reality contract model of the purchaser's and the purchasing agent's as well as the bid supplier's expected revenues, and discusses the two kinds of behavior choices of the three parties participating in public procurement auction, that is the independently action and the cooperation with each other. It is found that the contracts of the three parties' expected revenues participating in public procurement auction are non-incentive compatible. Further, the collaborative actions of the three parties in participating public procurement auction are studied. Under the conditions of the cooperation between the purchaser and the purchasing agent as well as the successful supplier, and they share the collusion gains equally, the expected revenues of the three are studied respectively. It is found that their expected revenues are all increased, and the increased revenues of the purchasing agent are higher than that of the purchaser and the winning supplier. In the case of collusion between the purchaser and the purchasing agent as well as all the bid suppliers, the expected revenues of all the collusion participants are studied. It is found that all the collusion participants' revenues have improved. It is found that the revenues of all the collusion participants are improved. And the procurement price of collusion is no upper limit.

2 - A game theory approach to determine the optimal penalty of online copyright infringement
I-Hsuan Hong

This research investigates the issues of punitive damages stated in the copyright law. The punitive damages are typically determined by the subjective judgement of legislators. In this study, the mechanism to determine the punitive damages is designed to optimize the total social welfare with consideration of human behaviors on the basis of the Stackelberg game, where the government is the leader, and media publishers and online video platforms are followers. We compare our model with the model with the other objective function of the maximization of legal users.

3 - Endogenous timing in a quantity duopoly with differentiated products
Eduardo Zuñiga, Leonardo Basso, Pedro Jara

We consider a linear quantity setting duopoly in which firms have different marginal costs and sell a differentiated product. In that context, we determine endogenously which of the players will emerge as a leader and which one will be a follower. In order to do so, we extend the game using the models of Hamilton and Slutsky (1990) [Game with Observable Delay and Action Commitment Game]. In the case of the Game with Observable Delay, we provide conditions over the costs and the degree of differentiation that ensures the leadership of the low cost firm. In the case of the Action Commitment Game, we find that there are three possible equilibria in pure strategies: simultaneous play and the two sequential configurations (with each firm being a leader and the other one being a follower). We perform a risk analysis based on the Tracing Procedure of Harsanyi and Selten (1998) to conclude that the risk dominant equilibrium is with the low cost firm being a leader. This work generalizes the model in Van Damme and Hurkens (1999) by adding product differentiation. The next step in the future work is to consider symmetrical firms, add a previous stage where they can invest in some variable that diminishes their marginal cost and analize how will they behave if they know that this investment could give them the best role in the market (due to the endogenous timing of movements).

4 - Utilizing of microeconomic and optimization models in protection and formation of competitive environment in Slovakia
Eleonora Fendekova, Michal Fendek

Cartel as a market structure de facto represents a specific form of oligopoly where an agreement is made between legally independent economic subjects in order to restrict the mechanism of economic competition. Cartels which based on the agreed market strategies may follow common price strategy, set their production quotes or divide the market, are forbidden in the EU countries as well as in many countries outside the EU. Existence of the cartels is in sharp contrast with generally accepted principles and practices of economic competition protection. In developed economies of the EU and the world the governmental institutions are established to control and guarantee the conditions of competition. In Slovakia these tasks are performed by the Antimonopoly Office of the Slovak Republic. In this article we will present the mathematical formalization of the model of equilibrium price and supply of the cartel agreement participants and point out the social inefficiency of such decision-making scheme. In paper we study the properties of a cartel optimization problem and economically interpretable implications of Kuhn-Tucker optimality conditions of this model. We will study the properties of the cartel profit optimization problem considering various marginal costs of homogeneous production of the cartel participants and point out the interpretation possibilities of solving this optimization problem.

■ WD-12

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S112

Hyper-heuristics

Stream: Hyperheuristics
Chair: *Víctor Parada*

1 - Evolutionary algorithms and supply chain network design: a comparative analysis on the effectiveness of heuristics, meta-heuristic and hyper-heuristics

Sahar Validi

Designing a supply chain network is a complicated task and the overall performance of the supply chain is extremely affected by the structure of its logistics network. The complexity of designing a logistics network increases when the number of players involved and the layers within the network are increased. Designing and optimising such a complex network is a very challenging task that requires taking into account different criteria and conflicting objectives to satisfy all stakeholders. Facility Location with its wide range of integrated models combined with Multi-Criteria Decision Analysis techniques are two of the well-established subject areas in Operational Research that their applications in network design and optimisation are increasingly growing. Multi-layer integrated facility location problems are typically computationally NP-hard. Solving such complex combinatorial optimisation models often requires multi-phase solution approaches. Review of literature reveals that varieties of methods have been tested for this purpose yet the search for an efficient and generic solution method continues. This paper reports on an ongoing research on the effectiveness of evolutionary-algorithm based heuristics, meta-heuristics and hyper-heuristics in solving multi-echelon integrated facility location problems.

2 - A hyperheuristic framework to optimise the implementation of dual local search

Mona Hamid, Jamal Ouenniche

In this research, we propose a refined generic and parametrised dual local search (GPDLS) algorithm with application in routing. The novelty of this dual search framework lies in exploring the space of infeasible solutions in search for the optimal or near optimal feasible solution. Furthermore, a hyperheuristic framework is proposed to optimise the implementation of the GPDLS, referred to as HH-GPDLS. The proposed HH-GPDLS aims to automate the choice of parameters, components or criteria of the GPDLS. Empirical results suggest that the proposed HH-GPDLS delivers an outstanding performance.

3 - Automatically generated hybrid algorithms

Víctor Parada, Carlos Contreras-Bolton, Carlos Rey

A way to yield a cooperation between heuristic and exact methods in the automatic generation of algorithms is to combine terminals of both types. The automatic generation of algorithms is a technique that automatically assembles the components that potentially make up an algorithm for a given combinatorial optimization problem. Thus, exact and heuristic terminals are combined to generate an algorithm for a particular type of problem instances. Specifically, following a constructive process based on genetic programming that combines heuristic components with the exact terminal, new algorithms for the binary knapsack problem are produced. A numerical experiment is conducted to study the relevance of the exact terminal related to the heuristic terminals, to find the optimal solution for a large number of problem instances.

■ WD-13

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S201

Risk Measurement and Management

Stream: Financial Modeling, Risk Management and Managerial Accounting
Chair: *Michalis Doumpos*

1 - Psychographic segmentation of Italian bank customers

Caterina Liberati, Galina Andreeva

Traditionally, customer's 'character' was used as one of the main criteria in credit granting process (Three 'C's of Credit). Credit scoring (risk models targeted at screening individuals) replaced it with hard information, such as credit history and demographics. Recent studies reignited the interest in character/ personality by showing its relevance in modelling consumer indebtedness, and more general financial behaviour. Unfortunately, most literature in this field is mainly based on self-reported financial measures. We overcome this limitation by analysing a unique dataset of Italian bank customers that contains hard information about credit and investment performance, in addition to soft measures of personality, financial knowledge and preferences for different levels of customer support. The purpose of this work is twofold: first, we aim at detecting if there are different psychographic segments of banking customers based on personality traits and other soft information. We experiment with clustering and different kernels in Kernel Principal Components Analysis. The comparison indicates the presence of different clustered structures in the data but some partitions may be difficult to interpret from a managerial perspective. Second, we analyse the investment and credit performance of the different customer typologies. We comment on the model fit and predictive accuracy of models for different segments.

2 - The impact of collection actions on recovery rates using retail loan level panel data

Angela Freitas de Moraes, Galina Andreeva, Jonathan Crook

Loss given default (LGD) models predict losses as a proportion of the outstanding loan, in the event a debtor goes into default. The LGD model is one of the components on the Expected Credit Loss (ECL) calculation for the Basel II Accord for banks that have adopted the advanced Internal-Rating-Based (IRB). The existing studies focused on LGD mainly investigated different modelling algorithms in order to achieve the most accurate estimation of Recovery Rate (RR) =1 -LGD. There is practically no literature that explores the impact of the lender's collection actions on RR/LGD. For this reason, this work investigates the role of different collection actions, at loan-level, for a retail credit product, and estimates LGD models using Panel Data which is built by combining borrowers' personal information, loan finance details and payments from the collection process. The analysis considers accounts opened in 2011 from a loan retail portfolio and tracks the customer payment behaviour on a daily basis in order to measure the impact of each collection action on the amount repaid. The data was provider by a finance company from Brazil. The findings suggest that there is a strong relationship between the collection actions and recovery rates. This means that it would be advantageous for financial institutions to take into consideration information about collection actions in models aimed at estimating LGD in line with the regulatory requirements.

3 - Risk management for sovereign debt
Stavros A. Zenios, Andrea Consiglio

Debt sustainability analysis hinges upon two conditions: declining debt stock and bounded gross financing needs (both measured as a ratio to the country's GDP). However, both debt stock and gross financing are stochastic processes due to the volatility of (1) GDP growth, (2) fiscal variables, (3) market rates at which a sovereign can finance its debt. We develop portfolio models for sovereign debt financing that jointly optimizing debt stock and gross financing flows for countries in distress. The models minimize or bound tail risk in both metrics of interest. There are trade-offs between the two metrics, and we discuss how the trade-offs can be quantified and each one restricted to remain below a threshold of sustainability. In case of either metric denoting unsustainable debt, the model identifies the hot spots and optimizes debt restructuring strategies. Illustrative results will be presented and discussed.

In this talk we extend the authors' previous paper on debt restructuring using risk CVaR optimization and the use of sovereign contingent convertible debt.

Consiglio, A. and S.A. Zenios, Risk management optimization for sovereign debt restructuring, Journal of Globalization and Development, 6(2):181-213, special issue on sovereign debt restructuring, J. Stiglitz et al. (editors), 2016.

4 - Developing predictive models for US bank failures: an empirical analysis using machine learning approaches
Michalis Doumpos, Georgios Manthoulis, Constantin Zopounidis, Emilios Galariotis, George Baourakis

The banking system is the backbone of every economy. However, banks are highly leveraged and face major risks at the local, country, and global level. Thus, the development of accurate and transparent tools for micro-prudential purposes has become an unavoidable and urgent duty. For this reason, it is important to have reliable techniques to detect early signals when a bank is near to default. Such tools would allow financial authorities to take preventive actions to mitigate contagion effects. This study examines the development of bank default prediction models using a sample of US banks for the period 2005-2014. We consider a rich set of variables through different scenarios. The first scenario incorporates basic CAMEL financial ratios. In the second, we also consider diversification ratios for different areas such as risk, income, expenses, loan portfolio quality, off-balance sheet assets etc. Finally, we use dummy variables to account for regional macroeconomic factors. The prediction horizon varies from 1 to 3 years prior to failure. Analytical models are developed with several machine learning methods, namely logistic regression, support vector machines, naïve Bayes, extreme gradient boosting, random forests, and neural networks. Extensive out-of-sample results are reported based on bootstrap tests.

■ WD-14

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S202

ETHOR IV Ethics and OR last part - Award Ceremony

Stream: OR and Ethics
Chair: *Pierre Kunsch*
Chair: *Cathal Brugha*
Chair: *Dorien DeTombe*
Chair: *Ulrike Reisach*
Chair: *Gerhard-Wilhelm Weber*

1 - Democracy unveiled by OR
Cindy-Ricarda Roberts

The aim of the research is to discuss possible applications of operational research in political science with respect to democracy. Political science is a multidisciplinary field and comprises various aspects of other disciplines, such as: economics, law, sociology, geography, philosophy, and psychology. It seems fair to say that operational research is an interesting, yet not thoroughly investigated, solution to this discipline. This research offers a simple example of how to use and incorporate operational research into problem structuring within political science, namely by analysing the concept of democracy. In the presented case study, DEMATEL method, which is used to capture the causal relationships between factors or criteria, is examined as a solution for assessing interdependencies and linkages between principles of democracy. The research presents an analysis of relationships between key elements of democracy such as (among others): rule of law, balance of power, free and fair elections, human rights, common good, or public opinion. The evaluation is based on an interview with a selected expert in the field of political philosophy. The conclusions drawn from this research illustrate how operational research could be incorporated into the field of political science in order to make problem structuring more transparent, reasonable, and efficient.

■ WD-15

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S203

Scheduling Theory III

Stream: Scheduling Theory
Chair: *Paz Perez Gonzalez*

1 - Scheduling with additional resources in the setups
Juan Camilo Yepes Borrero, Federico Perea, Fulgencia Villa

In this talk, we address the unrelated parallel machine scheduling problem with sequence dependent setup times and additional resources required for the setups. Due to the complexity of this problem, we propose a heuristic to solve it. A computational experience on randomly generated instances validates the efficiency of the algorithm proposed.

2 - Unrelated parallel machines problem with setups, resources and makespan minimization
Luis Fanjul Peyró, Ruben Ruiz, Federico Perea

The Unrelated Parallel Machine Problem with setups and resources (named UPMRS) with the objective makespan minimization is considered. Setups, processing times and resources depend on the job and the machine. The goal is to obtain a single general model that can solve UPM with or without setups, with or without resources used for the processing and/or setup times, being these resources specific or shared for processing and setup times. Although the Unrelated Parallel Machine problem with Resources in processing times (UPMR) has been recently studied, in order to reduce the gap between academic research and the needs of industry, our proposed model generalizes the problem. Two new models are presented, one based on time control (TC) and other based on a spatial approach (SA). Both take as a base the Unrelated Parallel Machine problem with Setups (UPMS) model and then we add resource and link constraints to complete the model. The SA model is based on a version of the strip-packing problem adapted for scheduling. Experiments prove that the UPMRS model solves medium size instances with a low gap in a few minutes. Furthermore, the UPMRS model significantly improves the results of the best UPMR model and obtains similar results to UPMS. This shows that the proposed complete model can compete or improve results of more specific models and maintains its performance for more complex problems.

3 - A computational evaluation of approaches for flowshop scheduling with variability of the processing times
Jose M Framinan, Paz Perez Gonzalez, Victor Fernandez-Viagas

In this communication, we analyse the different alternatives for scheduling jobs in a permutation flowshop where the processing times are subject to variability. More specifically, we discuss the usage of base schedules based on deterministic scheduling, stochastic scheduling, and robust scheduling, and compare their performance with the usage of different rescheduling strategies. Using an exhaustive computational experience on different test-beds, the merits and pitfalls of the different approaches are analysed, and the most efficient configurations for each approach are identified.

4 - Scheduling unpaced assembly lines with limited buffers: a mathematical model and some solving methods
Carlos Andres, Julien Maheut

The problem of scheduling jobs in unpaced assembly systems with restricted buffer space between stations to hold the work-in-process has received scant attention in the scheduling literature. It consists of a system with several stations at the main line where a set of n jobs must be processed in a given sequence. Each station has a supply from an auxiliar machine and there is a limited buffer between each pair of machines/stations. Under Lean Manufacturing paradigm, it is interesting to minimize the time that all jobs wait in the buffers and total machine blocking time. A mathematical model of the unpaced assembly line with auxiliary supply machines and finite storage conditions will be presented together with some heuristics. The aim of the research is to show the effect of buffer size over the total blocking time plus inventory time.

■ WD-16

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S115

Graphs and Networks II

Stream: Graphs and Networks
Chair: *Alessandra Cornaro*

1 - Online search problems with traveling and search costs on undirected graphs
Davood Shiri, Sibel Salman

We study online search problems of the following type. An undirected graph together with non-negative edge costs are given. Each node of the graph is associated with a given non-negative search cost. A static hider is at one of the nodes of the graph which is not known to a searcher. The hider is not found unless the searcher arrives at the same node in which the hider is positioned and incurs the search cost of the node. Starting from one of the nodes, the searcher wants to devise an online strategy to locate the hider with minimum total cost. We consider two cases. In the first one the starting node of the searcher is given and in the second one it can be chosen arbitrarily. We address these two problems from the competitive ratio perspective. We propose a lower bound on the competitive ratio of deterministic strategies and show its tightness by introducing an optimal deterministic strategy, for the first case. We also estimate the tight lower bound on the competitive ratio of randomized strategies and provide a randomized strategy with a competitive ratio very close to optimal, for the first case. For the second case, we prove that no deterministic or randomized strategy can achieve a bounded competitive ratio.

2 - On maximum cycle packings in minimum 3-connected graphs
Christin Otto

Let G=(V,E) be an undirected graph. The maximum cycle packing problem is to find a collection C=C_1, ... , C_s of edge-disjoint cycles C_i in G such that the cardinality s of the collection is maximum. In general, this problem is NP-hard. For a special class of minimum 3-connected graphs an algorithm is presented for computing C. The procedure is based on splits and decomposition into wheels. Since the components can be represented by a decomposition tree (similar to SPQR-trees) the approach can be considered as a generalization of decomposing graphs into blocks and blocks into 3-connected components.

3 - Critical node problem based on connectivity index and properties of components
Binwu Zhang, Xiucui Guan
In this paper we deal with the critical node problem (CNP), in which we search for a given number K of nodes in a graph G, whose removal minimizes the connectivity of the residual graph in some sense. Many researchers proposed several methods to minimize some connectivity measure of the residual graph, including minimizing the (weighted or unweighted) number of connections between pairs of nodes (known as connectivity index), maximizing the number of components, minimizing the number of nodes in the maximum connect component. However, these measurements cannot overall describe the fragmentation of the residual graph. We propose a new CNP (Called Comb_CNP) by combining the above three measurements plus the degrees of the residual graph. It is a generalization of the CNP based on connectivity index, which is shown NP-completeness for general graphs. We study the case where G is a tree. In the Comb_CNP on a tree, we need to delete at most K nodes V_d such that the number of components is upper-bounded by P, the number of nodes in the maximum component is upper-bounded by M, and the objective is to minimize the sum of connectivity indexes and degrees in the residual graph. A dynamic programming algorithm is proposed to find the optimal value, as well as, an optimal solution of Comb_CNP, and the time complexity of the algorithm is O(nK2P2M2). A computational study is presented which shows that the algorithm is really effective.

4 - Assessing robustness in complex networks through the Kirchhoff index
Alessandra Cornaro, Monica Bianchi, Gian Paolo Clemente, Anna Torriero
Measuring robustness in complex networks has gained increasing attention in the literature and several approaches to capture the robustness properties of a network have been undertaken. Robustness is usually defined as the ability of a network to maintain its total throughput under node and link removal. We focus on spectral graph theory where robustness is measured by means of a graph invariant called Kirchhoff index, expressed in terms of eigenvalues of the Laplacian matrix associated to a graph. The Kirchhoff index (also known as effective graph resistance) can be alternatively defined as the accumulated effective resistance between all pairs of vertices. This index can be highly informative as a robustness measure, showing the ability of a network to continue performing well when it is subject to failure and/or attack. In fact, the pairwise effective resistance measures the vulnerability of a connection between a pair of vertices. Since the direct calculation of the Kirchhoff Index is computationally intensive, we provide new and tighter bounds of this graph invariant when edges are added or removed. These limitations take advantage of real analysis techniques, based on majorization theory and optimization of functions which preserve the majorization order, the so-called Schur-convex functions. Applications to both simulated and real data show the effectiveness of our bounds, also in providing meaningful insights with respect to the results obtained in the literature.

■ WD-17

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S205

Reliability and Robust Optimization

Stream: Stochastic and Robust Optimization
Chair: *Eric Bourreau*

1 - Robust single machine scheduling with uncertain interval processing times for minimising weighted completion time
Ao Zhou, Amir Salehipour, Feng-Jang Hwang

Single-machine scheduling is a classical combinatorial optimisation problem that has been widely addressed in literature. Considering the minimisation of the total weighted completion time with deterministic job processing times, the WSPT dispatching priority rule can simply yield the optimal solution. This study copes with the case of uncertain job processing times bound by the preassigned intervals, of which the processing time of each job could take any value between its corresponding lower and upper bounds. The objective is to minimise the maximum regret for any scenario generated within an instance. Given a set of jobs, an instance refers to the generation of the intervals of processing times and weights for jobs, whilst a scenario stands for the realisation of the job processing times generated within the intervals. Four heuristic algorithms utilising the lower and upper bounds are proposed in this paper. We develop the first heuristic with a pessimistic sense by considering only the upper bound, whilst the second one takes the optimistic approach using only the lower bound. The interval length is taken into account in the third heuristic, and the fourth one considers the position of the midpoint in relation to the mean of the midpoint of other jobs. We generated the instances by utilising an instance generation method available in the literature. The performance comparisons of the proposed algorithms in terms of the effectiveness and efficiency are then provided.

2 - A novel replacement policy for a mechanical system with imperfect maintenance and gradual degradation
Aynura Poladova, Salih Tekin, Tahir Khaniyev

In this study, a mechanical system with imperfect maintenance and gradual degradation is considered. It is assumed that at initial time the system has z>0 available resource, and the capacity is decreasing consistently and gradually (c_n) during service time. The resource of the system will reach z-c_0 level in the end of the first service period. Also, at the end of the first period a certain maintenance policy is applied and general resource of the system is increasing by a random amount (_1). Afterwards, the process starts gradually decreasing from z-c_0+_1 level and show similar change. The subsequent periods will proceed similarly and eventually when the total available resource reaches zero, the process will restart from an initial state z and the change of system continuous as a similar manner. An available capacity of the mechanical system at time t is expressed by a stochastic process with dependent components (X(t)). The main goal of this study is to determine when the system will be replaced by new and similar system by using the stochastic process. For this aim, the process X(t) and certain boundary functionals of the process are constructed mathematically. Then, asymptotic expressions for the expected value and variance of these boundary functionals have been obtained by using methods of renewal theory. These boundary functionals are important for determining novel replacement policy for the system.

3 - Robust Rolling Stock Rescheduling
Joris Wagenaar

Railway operators are, unfortunately, influenced by all kinds of disruptions every day. During a disruption the current timetable, rolling stock circulation, and crew schedule have become infeasible, so effective rescheduling is necessary. In this paper the focus will be on rescheduling the rolling stock. Current rolling stock rescheduling models assume the duration of a disruption given. However, in practice only an estimation of the duration is known, the exact duration is still uncertain at the start of the disruption. Our focus will be on developing robust rolling stock schedules that, given a probability distribution for the duration of a disruption, uphold as much of the passenger service as possible. First, a model is developed that is able to reschedule the rolling stock for only two possible disruption lengths; the most optimistic and the most pessimistic ones. Thereafter, this model is extended such that it can take all possible disruption lengths into account.

4 - Robust optimisation on GPU. A use case with shortest path problem
Eric Bourreau, Michael Poss

Recently Robust Optimisation start a new era with the possibility to manage in a polynomial way some combinatorial problems with a budget of deviation (Gamma) in data [Bertsimas 2003]. In the same decade GPU computation jump from Graphical Domain to any computational area such as Grid Computing (multi scenario simulation), Deep Learning or Crypto Mining. In this presentation we will merge these two aspects by computing Robust Optimisation of a problem P with the help of massively parallel GPU power. Our testbed will be a shortest path problem (with possible deviations on the time/distance matrix) with famous Dijkstra algorithm. Despite the gap in programming paradigm between CPU and GPU, we will show how it is possible to have x50 speedup with very few modifications in algorithms.

■ WD-18

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S206

Soft Computing in Transportation Problems

Stream: Transportation
Chair: *Sandra Zajac*

1 - Decision making policies for integrated vehicle scheduling and container storage allocation in a straddle carrier system: risk neutral and risk averse analysis
Jiabin Luo, Yue Wu

Container terminals serve as a link between sea side and land side for transporting and storing of containers to/from ships. Due to the increasing number of containers handled by terminals, the arising uncertainties, such as traffic conditions, inaccurate container information and vehicle availability, can significantly influence terminals' efficiency. This work proposes the integration of vehicle scheduling and container storage allocation with the consideration of a variety of risk scenarios during unloading process in a straddle carrier-based terminal, in which quay cranes (QCs) and straddle carries (SCs) are used to handle containers. The ship's berth time is used to measure the efficiency of terminal operations and can be calculated by the time when all containers are unloaded from ships. Risk scenario in this work is represented by a number of uncertain factors, which affect the handling time of SCs for containers. The uncertain handling time of SCs is defined as fuzzy parameters with triangular membership functions. This problem is first modelled as a fuzzy optimisation model and then defuzzified into a crisp mixed integer programming model. Two types of decision making policies are investigated: (1) risk neutral policy, minimising the berth time with the consideration of all risk scenarios; and (2) risk averse policy, using a Conditional Value-at-Risk (CVaR) approach to measure the worst-case scenario. The corresponding decisions are compared and discussed.

2 - Optimization of operational offshore wind farm maintenance scheduling under uncertainty
Toby Kingsman, Burak Boyaci

The rapid growth expected in the offshore wind sector presents a growing opportunity to find savings from conducting operations and maintenance activities more efficiently. The predicted increase in the size and quantity of offshore wind farms means that mathematical tools for scheduling maintenance activities will be necessary to exploit economies of scale fully. In order to complete an activity, a predetermined combination of skilled personnel, equipment and vessel support is required to be present at its location for the duration of the task. A fleet of heterogeneous fleet of vessels is responsible for both transporting the resources around the wind farm and conducting personnel transfers. Vessel movements must also account for limitations imposed by offshore weather conditions and the periodic need to return resources to port. In this research, we have developed a mathematical model capable of determining the best routes for vessel movements and the ideal times to undertake crew transfers. Our mixed-integer programming formulation can compute high quality schedules that minimize the twin costs of performing maintenance and lost production. We extend our optimization model to include a set of scenarios that represent the stochastic evolution of weather and sea conditions in future shifts. Solving the resulting model with a rolling horizon approach allows us to produce a detailed solution for the current shift, which contains actions informed by future weather patterns.

3 - A modified nonlinear Muskingum flood routing model with lateral flow contribution

Ersin Bahar, Gurhan Gurarslan, M. Tamer Ayvaz

Flood routing problem is one of the important problems in water resources engineering. There are two widely used flood routing approaches in the literature: hydraulic and hydrological methods. Accuracy of hydrological methods are may be poor compare to hydraulic methods but the application of hydrological methods are easier than hydraulic methods. The Muskingum flood routing model is one of the widely used hydrological methods. It was developed by The US Army Corps of Engineers to solve the flood problems which occur in the Muskingum River basin in Ohio, USA.

In this study, a modification is made for the use of inflow values in the nonlinear Muskingum flood routing model with lateral flow contribution. The calibration of parameters is made by using an optimization algorithm named as Water Cycle Algorithm which is used in this kind of problem for the first time. The performance of the modified nonlinear Muskingum flood routing model with lateral flow contribution is tested on two flood routing applications. Obtained results indicate that this model could be suitable for improving the flood routing procedures.

4 - Determining unpredictable routes for reasons of security

Sandra Zajac

In cash-in-transit operations, money needs to be collected from a set of customers, e.g. banks, financial institutions or automated teller machines. Driving the same routes day after day allows predicting the vehicle routes. As a result, the risk of assault rises. Increasing the unpredictability of the actually driven routes decreases the uncertainty of arriving back to the depot without an incident. This can be achieved by switching between dissimilar routes. Besides this application area, many fields exist where rising the unpredictability of routes is beneficial, e.g. when determining the tours of security men as well as of ticket inspectors. On the one hand, the total distance of the longest routing plan is minimized for economic reasons. On the other hand, the minimum dissimilarity between a pair of alternative routing plans should be high for reasons of security. Since short routing plans tend to be similar to each other, an objective conflict arises. In the talk, various dissimilarity metrics are discussed and a heuristic solution approach is suggested to approximate the Pareto set of this bi-objective problem. The influence of instance characteristics on the strength of the trade-off is examined. Another important aspect for future research is time dissimilarity. It is discussed how time dissimilarity can be measured, how the heuristic approach can be modified accordingly and what kind of interdependencies exist between the selected dissimilarity metrics.

■ WD-19

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S207

Supply Chain Design and Operations

Stream: Supply Chain Management I
Chair: *Nesim Erkip*
Chair: *Burcu Keskin*

1 - Value of supplier flexibility and initial shelf life information in an EOQ environment

Z. Pelin Bayindir, İsmail Serdar Bakal, Ceren Sar

We consider an infinite horizon, continuous review inventory model with deterministic stationary demand where the shelf life of the items is uncertain. The initial life times of the incoming items from the supplier is a discrete random variable. When the age of the items reaches the initial shelf-life, a quality control test for which the outcome is random is applied. According to the result of this test, it is possible to use the items to satisfy demand for an additional time period. In this environment, our objective is to investigate the supplier flexibility which is modeled by including a return policy and the initial shelf life information received before ordering decisions. Several scenarios are constructed and compared using Renewal Theory.

2 - Data driven robust order batching decisions for warehouse operations management: a branch and price approach

Vedat Bayram, Gohram Baloch, Fatma Gzara, Samir Elhedhli

The foremost and the biggest challenge related to optimization of warehouse operations is that the warehouses are as diverse as the products stored in them. A general comprehensive approach and a global optimization model that could be applied to any kind of a warehouse are lacking. Order picking operations, the process of retrieving products from storage areas, is regarded as the most labor intensive, time consuming and as a result the most expensive operation in warehouses specifically with manual systems. Therefore, in order to manage a warehouse efficiently, the order picking operations must be robustly designed and optimally controlled. One common approach to increase the efficiency of the picking operations is batching orders. We propose a data driven, exact, and general solution methodology for solving order batching problem (OBP). We first detect the most problematic processes in the warehouse through descriptive analytics methodologies. Then we present a prediction model that was devised by analyzing the historical data set collected for the warehouse management operations. This prediction model allows us to predict the picking time of any configured batch within a prediction interval. This leads us to develop prescriptive analytics methodologies, i.e., define a robust order batching problem (ROBP). We present an enhanced branch and price algorithm to solve the ROBP exactly.

3 - A cooperative shipment consolidation game

Secil Savasaneril, Banu Yuksel Ozkaya

We study the cooperation problem for shippers who ship items from the same origin to the same destination and who can possibly share space on capacitated trucks. Each shipper is characterized with shipment requests that occur randomly over time. Each request consumes truck space and brings a revenue to the shipper upon dispatch of the truck. As requests arrive, if there is a truck waiting to be dispatched with a queue of requests, the shipper may join the queue with its request and start waiting until the truck dispatches. By making the dispatch decisions jointly, shippers may save from waiting and dispatch related costs while maximizing revenue. We define the shipment consolidation problem as a cooperative game where the characteristic function is obtained through Markov Decision Process. The characteristic function cannot be expressed in closed form and thus identifying an allocation which is in the core is computationally burdensome, especially if the number of shippers is large. We discuss the properties of the game, propose an allocation scheme borrowing results from its deterministic counterpart and present results on the performance of the allocation scheme.

4 - Designing an omnichannel distribution system with inventory rationing policies

Burcu Keskin, Jia Guo

Rapid changes in e-commerce and increased customer expectations force traditional retailers to rethink their channel strategy, operational efficiency, and revenue/cost streams. Within this paradigm, omnichannels, serving customers via regular stores and web-based stores, offer new opportunities. Many retailers have been integrating their network of brick-and-mortar stores with their online channel by fulfilling web-based orders from nearby stores instead of distribution centers (ship-from-store) and by offering their customers the option to buy online and pick up in store (BOPS). These omni-channel fulfillment strategies can improve profitability by moving store inventory faster, pooling inventory, and avoiding markdowns. Avoiding markdowns is typically preferred in the retail industry as higher margins drive higher profits. In this context, we study a centralized distribution system in a single-period newsvendor setting. The distribution system consists a retail store, a web-based store, and a distribution center. The web-based demand, received by the web-based store, is mainly satisfied through shipments from the distribution center. However, the retail store may use its in-store inventory to satisfy the web-based demand via two omni-channel strategies: Ship-from-Store (SfS) and Buy-Online-Pickup-in-Store (BOPS). We investigate the impact of demand and cost structures affect the retailer's decisions on SfS and BOPS strategies as well as on inventory rationing.

■ WD-21

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S303

Convexity on Riemannian Manifolds, Feasibility and Equilibrium

Stream: Nonlinear Programming: Theory
Chair: *Sandor Zoltan Nemeth*

1 - Linear complementarity problems on extended second order cones

Lianghai Xiao, Sandor Zoltan Nemeth

We study the linear complementarity problems on extended second order cones (ESOCLCP). We convert the ESOCLCP into a mixed complementarity problem on the nonnegative orthant. We state necessary and sufficient conditions for a point to be a solution of the converted problem. We also present solution strategies for this problem, such as the Newton method and Levenberg-Marquardt algorithm. Finally, we present some numerical examples.

2 - Stable and scalable incremental nonconvex optimization approach for phase retrieval from minimal measurements

Ji Li

We aim to find a signal $bmxinmathbbRn/mathbbCn$ by solving a system of quadratic equations of the form $y_i=lvertlanglebma_i,bmxranglervert2$, $i=1,2,ldots,m$. It has been proved that the number $m = 2n-1$ of generic random measurement vectors $bma_iinmathbbRn$ is sufficient and necessary for uniquely determining the n-dimensional real vector bmx up to a global sign. We retrospect to the convex relaxation semidefinite programming (SDP) and put forth a novel procedure for indirectly minimizing the convex objective by successive and incremental nonconvex optimization, termed as texttIncrePR, to overcome the dimensional disaster of original SDP solvers. The algorithm distinguishes itself from prior nonconvex solvers by the needless requirement of good enough initialization. For the certain real Gaussian measurement models, our proposed method is shown capable of finding the true solution for all random quadratic equation systems from the minimal number $m=2n-1$ measurements and the perfect signal recovery holds for any arbitrary dimensional signals. Numerical results show that texttIncrePR corroborates markedly improved quality of the initialization and improved perfect signal recovery for noiseless case and stability in the presence of noise for the minimal measurement limit. It also outperforms the original convex SDP counterpart in the computational efficiency and recovery accuracy.

3 - On the spherical convexity of quadratic functions

Sandor Zoltan Nemeth, Orizon P Ferreira

We study the spherical convexity of quadratic functions on spherically convex sets. In particular, conditions characterizing the spherical convexity of quadratic functions on spherical convex sets associated to the positive orthant and Lorentz cone are given.

4 - Digraphs for modeling systems' representation of mathematical knowledge

Patricia Balderas

One of the main goal in education is narrow the teaching according to students' knowledge and skills, so many topics could emerge and be so important as well, and many research questions could be posed and studied. In this context I present and discuss a methodology to analyze, under a systemic approach, the visual reasoning processes given with the use of mathematical representations when learning Differential Calculus at a high school level has place. The interest is knowing how those who learn, acquire, and use some of the systems of mathematical representation and how they organize them to produce acceptable responses in the school environment. The representation systems used by the participants were modeled by digraphs, which turned out to be complete, entirely disconnected and transitive, and strong, weak, and idiosyncratic systems of representation were point out. Also, based on the conclusions, some teaching recommendations were created for making decisions in the classroom for students to acquire solid systems of representation by which acceptable answers may be given to solve Differential Calculus problems.

■ WD-22

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S304

Methods and Theory of Multiobjective Optimization

Stream: Multiobjective Optimization
Chair: *Theodor Stewart*

1 - When to burn it? Bi-objective scheduling on a restricted batching machine

Edgar Possani, Marta Cabo Nodar, Jose Luis Gonzalez-Velarde, Yasmin Rios-solis

In this work we consider a batching machine that can process several jobs at the same time. Our problem is motivated by the burn-in operations in semi-conductor manufacturing, in which a batch of integrated circuits are placed in an oven and exposed to a high temperature to test their thermal standing ability. Hence, the processing time of a batch is given by the maximum processing time of all jobs within the batch, and a limited number of jobs may be processed as the same time in a single batch. In this research we solve the bi-objective problem of minimizing the maximum lateness and number of batches. This function is relevant as we are interested in meeting due dates and minimizing the cost of handling each batch. Our aim is to find the Pareto optimal solutions by using an epsilon constrained method on a new mathematical model that is enhanced with families of valid inequalities that avoid symmetric solutions. Additionally, we present a biased random-key genetic algorithm to approximate the optimal Pareto points of larger instances in reasonable time. Experimental results show the efficiency of our methodologies.

2 - Formation of homogenous sections of students based on multiple characteristics

Shubhabrata Das

In many academic program, the admitted students are divided into smaller sections to achieve more effective teaching and learning. Especially in higher education, it is desirable that these sections are similar to each other. The similarity in the academic quality of the students may be judged on the basis of the admission rank. In addition, there should be homogeneity in terms of gender, category (reservation) prior academic discipline, and prior work experience. Since it is extremely difficult to get to the optimal partition that needs to take into account multiple criterion, we focus on devising heuristic that lead to very good acceptable solutions. As a case-study, we look at the challenge in forming such similar sections in a typical MBA program in India. Two indices - a weighted and another un-weighted - are formulated combining multiple attributes that captures disparity across the sections, once formed. We investigate the effectiveness of different randomized heuristic algorithms to minimize the indices, capturing the overall degree of heterogeneity. Analysis from a few real data sets as well as extended simulation show that within group randomization is typically more effective than randomization carried out for the aggregate population. This leads to the more involved question of suitably deciding on such groups. Finally we also attempt to study how the effectiveness of these algorithms depend on the input set characteristics.

3 - Numerical experimentation with multiobjective optimization using multiple reference points
Theodor Stewart

We consider multiobjective optimization with "many" objectives (more than 2 or 3), but in which the comparison of potential solutions requires careful and possibly time-consuming evaluation by decision makers or experts, possibly including subjective judgements. In practice, only a relatively small number ("7 +/- 2") of solutions can be examined in this way. After a (possibly only partial) selection is made from these, a few more alternatives may need to be generated in an interactive manner, taking into account the preferences revealed from earlier sets of comparisons.

Within the context of reference point methods, we discuss experiments to evaluate in particular (a) design of a set of reference points to represent an initially wide spread of potential preferences; and (b) progressive refinement of this design in the light of preferences expressed (after which the process repeats).

■ WD-23

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S305

Lot Sizing V - Extensions

Stream: Lot Sizing, Lot Scheduling and Production Planning
Chair: *Nadjib Brahimi*

1 - Dynamic lot-sizing in a reverse logistics environment
Aaron Luntala Nsakanda, Moustapha Diaby

We deal with the dynamic lot-sizing problem (DLSP) in a setting where returned items are acquired at costs and fully remanufactured to meet a deterministic but time-varying demand of a single product over a finite planning horizon. We propose a model that considers time-varying separate set-up and inventory holding costs for the manufactured and remanufactured items, time-varying separate variable manufacturing and remanufacturing processing costs, and time-varying acquisition and inventory holding costs for the returned items. We discuss a solution procedure based on lagrangian relaxation in which an extension of the Wagner-Whitin algorithm is embedded and report on our computational results. Because of the generality of the cost structure we consider, our proposed procedure can be readily used as a "stand-alone," or as the foundation for solution procedures aimed at more realistic models involving multiple-items and capacity limits.

2 - A lot-sizing problem in deliberated and controlled co-production systems
Z. Caner Taşkın, Bahadir Pamuk, Semra Agrali

We consider a lot sizing problem in co-production systems, in which it is possible to produce multiple items simultaneously in a single production run. Each product has a deterministic demand to be satisfied without backlogging. The decision is to choose which items to co-produce and the amount of production throughout a predetermined planning horizon. We show that the problem is strongly NP-Hard, and investigate polynomially solvable special cases. We develop mixed-integer linear programming formulations of the problem, introduce valid inequalities and efficient separation algorithms for these valid inequalities. We test efficacy of our approach on a suite of randomly generated problem instances.

3 - Valid inequalities for the proportional lot-sizing and scheduling problem with fictitious micro-periods
Waldemar Kaczmarczyk

Small bucket lot-sizing and scheduling problems allow for at most one machine set-up operation during each time period. To ensure a high-quality solution despite this restrictive assumption, periods are often split into several short fictitious microperiods with non-zero demand only at the end of the last microperiod of each real period.

Short microperiods ensure also shorter lead times, which are usually non-zero multiples of period length. This is important especially for multilevel product, i.e., dependent and multi-stage flow lines.

We propose for this case several extended formulations of mixed-integer linear programming (MIP) models. The presented results of our numerical experiments confirm the benefits of such extensions.

4 - Solving a lot sizing problem with lead time sensitive demands
Nadjib Brahimi, Adam Ferreira, Ramzi Hammami

In this work we are interested in inventory levels optimization within supply-chains under stochastic demand. Our objective is to extend existing models with further assumptions on customer demands such as sensitivity to lead-times. This work will especially focus on how waiting-time sensitive demand affects inventory level decisions and how to find the optimal waiting-time minimizing total holding cost in a supply chain. To the best of our knowledge, the trade-off between reducing inventory level and keeping a high demand at the same time was not considered in the literature of the single-stage configuration within the guaranteed service framework. We modeled the problem as a univariate non-linear integer problem, and optimized it analytically. We made the assumption that demand reacts linearly to lead-times quotations and showed how this endogenous demand affects the supply chain's behavior. Our model was successfully applied to extension with capacitated and uncertain replenishments. In either cases we were able to analytically find the optimal service time to be quoted to the customer. It could be interesting to build models where demand sensitivity to service time has a more complex interaction, like non-linear loss function, non-constant coefficient of variation or a non-null demand when the service time meets its upper bound. One good contribution would be to propose a specific algorithm to deal with endogenous demand in multi-stage supply chains.

■ WD-24

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S306

Miscellaneous Topics related to Global Optimization

Stream: Global Optimization
Chair: *Marco Castellani*

1 - Adaptive space-filling designs for large-scale metamodel-assisted expensive black-box optimization
Rommel Regis

Metamodel-based or metamodel-assisted algorithms for expensive black-box optimization are typically initialized by space-filling designs such as Latin hypercube designs (LHDs). This paper develops LHDs where a fraction of the points are generated sequentially and the expensive black-box functions are evaluated as these points are generated. The selection of the next LHD point is guided by simplex gradients or by more complex metamodels. The idea is to make progress in the optimization process during the initialization phase of a metamodel-based optimization algorithm, providing some advantage on problems with a large number of decision variables. Numerical experiments are performed on 100-dimensional instances of well-known test problems on a 72-dimensional groundwater bioremediation application.

2 - Support to decision making in a semi-continuous canning process
Carlos Gómez Palacín, José Luis Pitarch Pérez, Mendez Carlos, Cesar de Prada, Miguel Antonio López

This work focuses on a semi-continuous production line in a canned-tuna factory, where carts full of cans arrive to a series of autoclaves to be sterilized in batches. There are different can types which may be sterilized following different continuous-time temperature profiles. All sealed cans must start sterilization before a maximum time to ensure required bacteria lethality values.

Apart from lethality and energy consumption, the sterilization conditions determine quality features like the tuna color or the nutrients kept. There are also shared resources to consider like the available number of carts, personnel or buffer space. Hence, problems of optimal cart grouping, group-to-autoclave assignment and sequencing arise. The goal is grouping carts which share similar features (sterilization profiles) to reduce the waiting time of the cans until sterilization, dead times in load/unload operations as well as the energy consumption.

The authors propose a quasi real-time scheduling tool to support operators in these daily tasks, avoiding the formation of bottlenecks, keeping lethality and product quality. Tackling this complex problem in a centralized way via MILP makes the amount of possible combinations exploit, and so the resolution time does. Therefore a two steps decomposition approach is proposed in which the optimal cart groups as well as sterilization profiles are chosen first; and then their assignation/sequencing to autoclaves is performed afterwards.

3 - Obtaining deep local minima of smooth functions by using local optimization with global multidimensional search
Juan José Mesas, Albert Ferrer, Luis Sainz

Locating and identifying global minimizers of functions is, in general, a hard and time-consuming task. In addition, existing global optimization methods are difficult to apply to high-dimensional optimization problems even when the derivatives of the functions defining these problems are available. To overcome these limitations, and taking into account that some methods for global optimization, such as the Extended Cutting Angle Method (ECAM), are fast enough when applied to low-dimensional optimization problems, a suitable procedure for obtaining deep local minima of smooth functions is proposed, which exploits the differentiability properties of these functions. It combines the use of local optimization techniques to determine a cone of descent directions (not a single descent direction), and the use of a global optimization algorithm to find a global minimum within the intersection of the cone and the feasible region of the programming problem (i.e., a global multidimensional search is carried out instead of a line search). In functions with many shallow local minima, this procedure allows deep enough local minimizers to be obtained, which could even be global minimizers. Some obtained results from numerical experiments with smooth functions are presented and discussed.

4 - Ekeland's principle for equilibrium problems
Marco Castellani

The triangle inequality property is a basic assumption for the Ekeland's variational principle for equilibrium problems to hold. This property has been used to study the existence of solutions of equilibrium problems and arbitrary systems of equilibrium problems which do not involve any convexity concept, neither for the domain nor for the bifunction. The main aim of this talk is to extend the the Ekeland's variational principle to a larger class of bifunctions. We replace the triangle inequality property by a condition, that is shown to be equivalent to a certain monotonicity of the bifunction. Moreover we prove the existence of solutions in compact and noncompact settings. The proofs of existence don't rely on the Ekeland's variational principle but they are performed using only elementary results. This fact allows us to remove the metric structure on the topological space and additional technical conditions.

■ WD-25
Wednesday, 14:30-16:00 - SOUTH BUILDING UV S307

Scheduling Applications in Urban and Rail Logistics

Stream: Combinatorial Optimization II
Chair: *Dominik Kress*
Chair: *Erwin Pesch*

1 - Assignment of collection centers and routing of recycling vehicles in a city
Lorena Pradenas, Sergio Aliaga

This study solves the allocation of collection points for recycling, for a group of users, according to their location and the installation costs of these centers and the subsequent routing of vehicles to centers of greater capacity. First, it seeks to minimize both the distance traveled by each user and the costs associated with the installation of smaller collection centers. Subsequently, the route planning problem is solved from the larger capacity collection centers to withdraw from the smaller centers, in order to minimize the cost in the route, considering the traveling salesman problem. This approach is used by other authors in the specialized literature (Sheriff et al., 2015 and Bilgen & Çelebi, 2013). We proposed a mathematical programming model and solve with real and generated instances

2 - Single track railway scheduling problem
Grzegorz Pawlak, Jacek Blazewicz, Gaurav Singh

Single Track Railway Scheduling Problem (STRSP) with criterion of trains throughput rate maximization for the particular railway network is considered. Trains are traveling form the source station to the destination station traveling through the transiting stations generally on the single track. The stations are characterized by the capacity of the potentially waiting trains. The model contains the practical constrains such as time windows, the safety time between the trains and the traveling time limits for the particular train. The motivation for consideration of such an optimization problem was taken from the actual real system of Australian Railways servicing the mining industry. A mathematical model for STRSP was formulated and algorithms were proposed for a few particular cases where the unit traveling time between stations was assumed. Computational experiments and simulations models were conducted and results are presented.

3 - A dynamic programming approach for scheduling cooperative gantry cranes
Dominik Kress, Jan Dornseifer, Florian Jaehn

We consider a twin crane scheduling problem at a single storage block of a seaport in the presence of two types of storage jobs. On the one hand, containers originating at the seaside have to be stored in the block. On the other hand, containers that are already stored in the storage area at the beginning of the planning horizon have to be delivered to the landside handover point within given time windows. The objective is to minimize the makespan of seaside container processing while guaranteeing on-time processing of landside containers and while considering non-crossing constraints among cranes. We allow preemption of seaside container processing, i.e. we allow the gantry cranes to cooperate. This has previously been shown to be an effective method of reducing the makespan when compared to classical non-cooperative approaches. We present a dynamic programming (DP) algorithm and a related beam search heuristic for the crane scheduling problem under consideration. The DP method makes use of bounding techniques and applies dominance properties of optimal solutions. The algorithms are evaluated in extensive computational tests.

■ WD-26

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S308

Freight Transportation

Stream: Public Transportation I
Chair: *Pengling Wang*

1 - Integrating terminal processes in the demand-flow problem for European railway networks
Tobias Pollehn, Moritz Ruf

In wagonload freight, railcars are transported through a hub-and-spoke network switching from one train to another. The arising disassembling, sorting and assembling processes are carried out in the hubs of the network, also known as classification yards. On the tactical planning level, train services are determined (train-scheduling problem) and on this base, the demand is routed through the network (demand-flow problem). In Europe, train scheduling decisions are taken a long time before reliable demand forecasting data is available. Thus, transport orders have to be assigned to fixed train services. The optimisation potential arises in routing the transport orders such that utilisation of train length is maximised and the number of used train services is minimised. One of the challenges is to meet the capacity restrictions for each classification yard. Therefore, we propose a model which determines the flow of transport units through the network and the selection of train services. The novelty of the model is the explicit consideration of the processes in classification yards with respect to scheduling and resource allocation. Compared to existing formulations, this leads to more realistic routing decisions as railcar interchanges are modelled precisely. Computational results reveal significant cost-saving potential and highlight that not considering the processes in classification yards can lead to an overestimation of the capacity of bottleneck classification yards.

2 - Reliability analysis of a rail truck intermodal network
Kiran Ali

This research presents a method to conduct reliability analysis on a rail truck intermodal network. Origin-destination pairs and intermodal terminals are represented by nodes and roads and rail tracks are represented by arcs. Terminals and the transportation mode between them are capacitated. Both nodes and arcs are considered vulnerable and susceptible to attack. An attack can either cause a complete failure of the respective node or arc or it can result in partial reduction of service or capacity. This research first implements a reliability analysis on the current intermodal network. It proposes an indicator to measure the reliability of a network and suggests changes in the infrastructure which results in a more resilient network if implemented. This indicator is developed by computing probability function and mean of network performance.

3 - Branch and price approach for a vehicle routing problem in public service
Cansu Yurtseven, Merve Avcı, Deniz Türsel Eliiyi

The population of developing countries has an economically unbalanced distribution. As the low-income people have limited resources to meet their needs, the municipal authorities try to meet these requirements via collecting donations from donors and distributing these to the indigent. The donations such as dry food packages, clothing, furniture and such are collected by the donations centers, and the donations are made through phone calls, or by directly bringing them to the donation center. In this study, we handle the daily problem of a single donation center owned by the municipality, having several vehicles for picking up the donated items from the donors and distribution to the indigent residents. A fair donation-indigent matching considering utility, and an efficient distribution operation for the pick-up and delivery of the donations are of concern. Therefore, we integrate the problems of assignment and vehicle routing with time windows, and solve this hard real-life public logistics problem using the branch-and-price method. The computational results are reported.

4 - Running time prediction for optimal freight train merging
Pengling Wang, Rob Goverde

We study the problem of freight trains merging from sidetracks into railway corridors, where both passenger and freight trains run. In the Dutch railway network, some corridors are quite busy. Those high-frequency passenger train corridors leave little buffer for merging freight trains. Therefore, it is necessary to develop a methodology to facilitate smooth merging of freight trains into a stream of passenger trains with short headways. The research focuses on optimizing the freight train movement, while the passenger trains can be observed but not controlled. The objective is to avoid red/yellow signals that passenger and freight trains may meet and reduce train delays. We present an algorithmic framework for guiding and optimizing the freight train movement. Within this framework, a learning method is adopted for running time prediction of passenger trains based on real-time observed train states, and a linear programming formulation at a microscopic level of operational and infrastructural detail is developed in order to find feasible merging times. In addition, a dynamic adaptive process is designed for the train movement based on real-time observed train states. Computational results are reported on real-world instances with a moving freight train merging between two running passenger trains. This research provides solutions for real-time guidance of train drivers, helping them achieve smooth merging of freight trains.

■ WD-27

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S309

Quality Management

Stream: Production, Service and Supply Chain Management
Chair: *Ashkan Keykavoussi*
Chair: *Ahmad Ebrahimi*

1 - Optimal supplier quality development under uncertainty
Guven Demirel, John Quigley, Lesley Walls, Bart MacCarthy, Mahdi Parsa

We investigate the supplier quality development decision of a prime manufacturer facing supplier part quality risk. We consider the uncertainty in both the process improvement effectiveness and the non-conformance rate, which is represented as a Poisson-Gamma model. We calculate the optimal investment decisions and the value of information under a range of conditions, which helps to understand when further information on non-conformance rate and effectiveness is beneficial. We analyze the impact on the optimal investment policy of the uncertainty distribution parameters, the investment budget, and the unit cost of non-conformances. We show that the optimal level of investment has a non-monotonic dependence on the effectiveness distribution parameters. Both exact expressions and approximations are provided for the value of information. We further investigate the equilibrium policies of the supplier and the prime manufacturer when they are engaged in a Stackelberg game, leading to conditions under which either one, both, or neither party makes an investment into quality improvement.

2 - Queueing system with vacations, disasters and repairs under diferrent control policies
George Mytalas

We consider a M/G/1 queueing system with batch arrivals subject to disasters and server breakdowns. The server is turned off as soon as the system empties. When a disaster occurs the system is cleared of all customers and the server initiates a repair period. During the repair period arriving batches of customers accumulate in the queue without receiving service. Besides, the server has an exponential lifetime in addition to the catastrophe process. By applying the supplementary variables method and renewal arguments, we obtain the steady-state solutions for both queueing measures and reliability quantities of interest.

3 - Warranty parameters for extended two-dimensional warranties incorporating consumer preferences
Amitava Mitra

Certain products, such as automobiles, typically have warranty policies that incorporate two attributes, namely time since purchase of the product and usage based on accumulated mileage. If both of these parameters are less than the stipulated values in the warranty policy, in case of product failure, the manufacturer replaces or repairs the product free of charge. In many consumer durable goods, while an initial warranty is offered during purchase of the product, options exist to renew the warranty in the event of no product failure during the initial warranty. Here we consider such extended warranties. The decision variables in the formulated model are the warranty time and usage in the initial policy, the warranty time and usage in the extended policy, the product price, and the premium to be charged by the manufacturer for extending the warranty. We assume, however, that not all customers will choose to renew the warranty even if the product did not fail during the initial warranty. Customer propensity to renew warranty could be influenced by the unit product price and the customer's threshold price level, above which the customer is motivated to extend the warranty.

4 - The implementation of lean manufacturing utilizing fuzzy value stream mapping (case study: SAIPA automobile manufacturing group)
Ahmad Ebrahimi, Ashkan Keykavoussi

Following the emergence of economic crises and considering the global competitive conditions in business environments in recent decades, the optimal use of existing resources as well as the timely recognition and response to customer requirements have become inevitable issues for manufacturing organizations. In this regard, organizations have turned to continuous elimination of non-value added activities in order to preserve and even increase their share of the global market. Therefore, in the last few decades, the development and implementation of techniques and tools based on the principles of lean thinking have had a significant share in eliminating waste, enhancing quality and cutting the finished products cost in manufacturing organizations all over the world. Value Stream Mapping (VSM) is considered as one of the most basic and most practical tools for the lean manufacturing implementation. However, many advantages are considered in the literature in using VSM, it also has some limitations such as the uncertainty incorporated in the manufacturing processes and less care about it in utilizing it in VSM. This paper seeks to investigate and analyze the uncertainty related to the time in the VSM using a fuzzy approach, considering the importance of time as the main indicator in the applying the VSM tool. Finally, the methodology was implemented in one of the largest automobile companies in Iran and its results were studied and analyzed in this regard.

■ WD-28

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S310

Machine learning

Stream: Machine Learning
Chair: *Michal Walczak*

1 - Oprimized neural networks applications for aircraft engine modeling
Ruxandra Botez

The availability of accurate aircraft models is one of the key elements in ensuring aircraft improvements. These models are used to improve flight controls and design new aerodynamic systems for the design of deformable aircraft wings. A novel methodology is here presented for the identification of engine model parameters of the Cessna Citation X business aircraft for the cruise phase from the flight tests. These tests were performed on the designed flight simulator manufactured by CAE Inc. which has flight dynamics D level. Level D is the highest level of accuracy given by the FAA Civil Aviation Authority in the United States. This methodology is based on optimized neural networks, and uses the "Extended Great Deluge" algorithm to design the identification model. Several flight tests for different altitudes and Mach numbers were performed to serve as databases for learning neural networks. The validation of the model was obtained using the simulator data. Despite the non-linearity and complexity of the system, engine parameters were predicted very well for a particular flight envelope. This estimated model could be used for engine performance analyses, and could thus provide aircraft control during this cruise phase. Engine model identification could also be extended for its application to other phases of climb and descent in order to obtain its complete model for the whole Cessna Citation X aircraft flight envelope (climb, cruise, descent).

2 - Convolutional deep neural network model to classify citizen complaints in Bogotaì'
Xavier Gonzalez

The Citizen Complaints District System is a digital tool that allows Bogotá citizens to submit complaints, claims, information requests, questions, suggestions, congratulations, and other requests. The submission channels vary (e.g. phone, internet, written). The nature of complaints is also diverse (e.g. mistreatment in a public office, transit ticket appealing, public school slot requests, etc.). The only mandatory field in each complaint record is a free text that the citizen fills in with the explanation of the issue. The Mayor's office must allocate at least three people working full time whose responsibility is to read the text and direct it to one or some of the public offices involved. Giving this scenario, the need of an automatic system that classifies the complaints into multiple categories that represent the offices involved arises. This study shows a multi-class classification model by using a deep learning convolutional neural network. The model is fed with a corpus labeled with the Entity the complaint was directed to in the past. The corpus is split in training and testing. Multiple configurations of networks were evaluated. The one that returns the best results includes one embedding layer, one convolutional 1D layer, and two dense layers. The results obtained show 82% of accuracy. Although more exploration is needed, it is proved that an implementation of this approach can reduce significantly the workload.

3 - Improved operational excellence through big data analytics
Andreas Felsberger, Boualem Rabta, Gerald Reiner

In this period of accelerating digital transformation and advanced big data analytics, utilizing quality performance data for designing and developing improved operational services will lead to innovative management approaches and superior decision making in operations management. To assess big data analytics value, this paper proposes a model based on a triangle of knowledge, data and model-driven decision support components. The semiconductor industry constitutes as the main object of interest. The implementation of additional sensors and intelligent databases for quality assurance processes within the stated industry motivate our investigation for the selected unit of analysis.

The goal of this work is the further development of a global operational excellence (OPEX) framework by adding big data insights. Our study connects the competitive value of big data analytics and performance measures to enhance OPEX. For this purpose the application of rapid modeling (queuing networks modeling) is promising. The core components of the proposed OPEX system are based on a queuing networks modeling approach that can help to examine the behavior of digitalized process improvements by analyzing what-if questions and vast amounts of data. Moreover, these methods enable the development of scenarios and simulations that facilitate instant managerial support when disruptions within a system occur.

4 - Chemical process design aided by grey-box modelling
Michal Walczak, Raoul Heese, Tobias Seidel, Michael Bortz

Chemical process design is a computationally challenging multi-criteria optimization task. In practice, a design relies on simulations that model the underlying physical and chemical phenomena. The difficulty of performing the simulations for industrial applications often stems from the vast numerical effort in solving many thousands of nonlinear equations. For a given set of design parameters, such a simulation outcome may therefore not always be numerically convergent and can even become physically unfeasible. Moreover, inaccuracies of the underlying model itself can lead to wrong conclusions.

We propose a grey-box approach to address these two major issues. A grey-box model combines domain-specific knowledge and statistical relationships learnt from measured or simulated data. This combination of white and black-box approaches enables to save expensive numerical calculations or to improve the agreement between a simplified model and available data. We demonstrate the usability of grey-box modelling to approximate feasible range of design parameters in an industrially relevant chemical process simulation.

■ WD-29

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S311

Cutting and Packing IV

Stream: Cutting and Packing
Chair: *J. M. Valerio de Carvalho*

1 - Modeling and solving the open-end bin packing problem with incompatibility constraints

Mohamed Maiza

The Open-End Bin Packing Problem (OEBPP) aims to pack a set of items with varying sizes in a minimum number of identical bins such that any bin can be filled beyond its capacity as long as the removal of the last packed item returns the bin not fully filled. In this work, we propose a new extension of the problem, called OEBPPC, obtained throw additional incompatibility constraints. Such constraints are usually characterized by an undirected conflict graph whose vertices correspond to the items while edges correspond to couples of items that cannot be packed together in the same bin. Firstly, we provide an original problem formulation as an Integer Linear Program. Then, in order to solve this problem variant, we propose an heuristic approach based on the adaptation of the first-fit decreasing algorithm. An extensive experimental evaluation shows the efficiency of our proposed approach in both running time and solution quality.

2 - One-dimensional cutting stock instances for which few patterns are needed

Arnaud Vandaele

The Cutting Stock Problem (CSP) is one of the most famous combinatorial optimization problem. An instance of the 1-dimensional CSP consists of d items with different number of copies to cut from larger master rolls. The goal is then to produce the required demands with the minimum possible number of master rolls. Each possible combination of items on a master roll is called a pattern. In general, there exists an upper bound, exponential in d, for the number of different patterns needed in an optimal solution of a 1-d CSP instance. In this work, we study specific instances for which at most d patterns are needed at the optimum. For example, we study the special case where it is assumed that any k items fit into a pattern but no k+1 do. This particular case is easy to solve, but we show in this talk that there is an optimal solution using at most d different patterns.

3 - When bin packing meets scheduling: a case of just-in-time batch scheduling with bin packing constraints

Sergey Polyakovskiy, Rym M'Hallah

This research introduces and approximately solves a multi-component problem where small rectangular items are produced from large rectangular bins via guillotine cuts. An item is characterised by its width, height, due date, and earliness and tardiness penalties per unit time. Each item induces a cost that is proportional to its earliness and tardiness. Items cut from the same bin form a batch, whose processing and completion times depend on its assigned items. The items of a batch have the completion time of their bin. The objective is to find a cutting plan that minimizes the weighted sum of earliness and tardiness penalties. For this problem, we first propose a complete constraint programming model, which is solved approximately via the general-purpose solver IBM CP Optimizer following an impact-based search strategy. Our second approach adopts the logic-based Benders decomposition technique, where the master problem performs constraint-programming search assigning items to bins subject to solutions of low-level two-dimensional orthogonal packing problems. The computational investigation shows that the solutions of the complete model outperform those of the decomposition-based approach on small-sized instances while the opposite prevails for larger instances.

4 - A strong integer linear optimization model to the compartmentalized knapsack problem

J. M. Valerio de Carvalho, John Quiroga-Orozco, Robinson Hoto

The Compartmentalized Knapsack Problem (CKP) is a relatively new type of problem with a wide application in industrial processes, arising, for instance, in the case of cutting steel coils in two phases in the metallurgical industry.

In the literature, there are two mathematical formulations for the CKP: a classical formulation, which is a nonlinear integer programming model, and a recent (linear) integer programming formulation, obtained by discretizing the compartments that can be built for each class of items. It is an important contribution, because it makes the problem amenable to solution by mixed-integer linear programming tools. Combinatorial enumeration algorithms and several pseudo-polynomial decomposition heuristics were also developed for the CKP.

This paper presents a new model for the exact solution of the CKP, denoted as the Strong Integer Linear model, derived from the (linear) integer programming formulation by strengthening data, reducing symmetry and lifting, and a new pseudo-polynomial heuristic, the Heuristic of the p_k Strong Capacities. Computational experiments are presented with a large set of instances that show the advantage of the new approaches. The strong model solves the CKP exactly more than seven times faster, and the new heuristic is more effective, presenting a good balance in the terms of efficiency.

■ WD-30

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S312

Vehicle Routing: Recent Theory and Applications

Stream: Transportation and Logistics
Chair: *Riccardo Rossi*

1 - Electric vehicle routing problem with time windows and ambient temperature effect

Bülent Çatay, Sina Rastani, Tugce Yuksel

Range anxiety poses crucial limitations for logistics operations performed with electric vehicles (EVs) despite the advancements in the battery technology. Accurate route planning by considering external conditions is of critical importance for operational efficiency since different factors may increase the energy consumption significantly. In this study, we extend the Electric Vehicle Routing Problem with Time Windows (EVRPTW) by taking into account the ambient temperature. In EVRPTW, the energy on the battery is consumed proportional to the distance traveled by the EV. In our case, the energy discharged during the trip is affected by the ambient temperature as well since it may increase the consumption due to cabin heating or cooling. In addition, the battery efficiency drops in low temperatures. We formulate this problem as a mixed integer linear program and propose a set of new valid equalities. We perform an extensive experimental study to investigate how ambient temperature influences the routing decisions and to analyze the contribution of the valid inequalities on solving the problem. Our aim is to present managerial insights to both researchers and practitioners. We solve small instances using a commercial solver. The results reveal that valid equalities can provide significant speed up and neglecting temperature effect on the EV performance may yield route plans that cannot be implemented in the real business environment.

2 - Branch-and-price for probabilistic vehicle routing
Mathias Klapp, Felipe Lagoo, Alejandro Toriello

The Vehicle Routing Problem with Probabilistic Customers (VRP-PC) is a fundamental building block within the broad family of a priori and dynamic routing models and has two decision stages. In the 1rst stage, the dispatcher determines a set of vehicle routes serving all potential customer locations before the actual requests for service realize. In the second stage, vehicles are dispatched after observing the subset of customers requiring service; a customer not requiring service is skipped from its planned route at execution. The objective is to minimize the expected vehicle travel cost assuming known customer realization probabilities. We propose a column generation framework to solve the VRP-PC to a given optimality tolerance. Compared to Branch and Cut approaches for the VRP-PC, our framework can handle sequence dependent constraints such as time windows. Specifically, we present two novel algorithms, one that under-approximates a solution's expected cost, and another that uses its exact expected cost. Each algorithm is equipped with a route pricing mechanism that iteratively improves the approximation precision of a route's reduced cost; this produces fast route insertions at the start of the algorithm and reaches termination conditions at the end of the execution. We provide a priori and a posteriori performance guarantees for these algorithms and test their performance on VRP-PC instances with time windows.

3 - An integrated fleet management model introducing alternative fuel trucks into existing diesel fleets
Ilke Bakir, Alan Erera

We address the challenge of smoothly introducing alternative fuel trucks (AFTs) into an existing fleet while making necessary structural changes and maintaining feasible operations during the transition. In this study, we develop an integrated fleet management model, which incorporates the decisions for (i) opening new maintenance/fueling facilities, and (ii) assigning trucks to travel routes for ensuring demand satisfaction, into a fleet replacement framework. We demonstrate that the integrated model finds non-obvious solutions by making use of information that is often overlooked by conventional fleet replacement strategies. For finding optimal or good heuristic solutions to the integrated fleet management model efficiently, we propose a Benders' decomposition framework and a Variable Neighborhood Search (VNS) algorithm. Finally, in order to demonstrate the performance of these solution methods on realistic problem instances, we conduct a comprehensive computational study.

4 - Crash prediction at road intersections based on extreme value theory
Riccardo Rossi, Massimiliano Gastaldi, Federico Orsini

Extreme Value Theory (EVT) is an emerging method to evaluate road safety at intersections, making use of surrogate safety measure instead of crash data. This work contributes to study the application of EVT, estimating the risk of being involved in an entering-circulating collision in single-lane roundabouts and T-bone accidents at unsignalized intersections. Detailed trajectory data of the vehicles were derived from a driving simulator experiment, and both time-to-collision (TTC) and post-encroachment time (PET) were used as surrogate safety measures. Three EVT approaches were applied, tested and compared: (1) the Generalized Extreme Value distribution used in the block maxima (BM) approach, (2) the Generalized Pareto Distribution used in the peak-over-threshold approach (POT), with negated-TTC (nTTC), and (3) shifted-reciprocal-TTC (srTTC). A number of covariates (flow rate, roundabout geometry, tester characteristics) were tested and included in the models. According to our findings, TTC performs better as a surrogate safety measure in roundabout collisions, while PET in T-bone collisions at unsignalized intersections; both BM and POT-with-shifted-reciprocal-TTC appear promising and deserve further attention in order to develop effective ready to practice crash prediction models useful in the process of intersection design and operational analysis.

■ WD-31
Wednesday, 14:30-16:00 - SOUTH BUILDING UV S313

Strategy and Soft OR

Stream: Soft OR, Problem Structuring Methods and Behavioural OR
Chair: *Colin Eden*

1 - Cognitive mapping with preference analysis in selecting cases for multinational and multi-discipline research projects
Jukka Tikkanen

Multinational and -discipline research projects follow often a case study strategy. In such studies selection of cases is a prerequisite to extract solid and comparable results. Anyhow, it is evidenced that researchers have a tendency to consider the relevance of cases exclusively from the view of sampling or searching strategies, i.e. focusing on the representativeness of the case set, or on looking for success stories as cases. Such a biased case selection may considerably hinder validity of the studies and feed conflicts among researchers of the consortium.

This paper demonstrates a collaborative methodology for identifying a "common ground" for case selection. It applies integrated use of cognitive mapping, simple multi-attribute rating technique and stochastic analysis of missing priority values. Methodology is demonstrated with an EU seventh framework project on the societal change towards sustainability. A set of community based initiatives, from six countries, were selected to study their role in transition. The sampling methodology consisted a combination of snowball technique and a random sampling for dominantly quantitative research tasks, and purposive sampling with transparent multi- attribute selection process for in-depth qualitative studies. The demonstrated methodology is adaptable for collaborative start-up procedure for multi-discipline, large group case research and for project evaluation.

2 - A conceptual framework for incorporating Maturana's onto-epistemology into Checkland's soft systems methodology
Alberto Paucar-Caceres, Bruno Jerardino-Wiesenborn

This paper addresses Checkland's Soft Systems Methodology (SSM) limitations and proposes a theoretical framework that incorporates key concepts from Maturana's Theory of Autopoiesis (ToA) and Biology of Cognition (BoC). The proposed framework aims to help to expand and complement Checkland's SSM application process. We outline and examine paradigmatic compatibility between Checkland's ontological position (reality is problematic and unknowable) and interpretivist epistemology (multiple perceptions will enrich the ever-changing and 'unknowable' reality). We argue that Maturana's phenomenological onto-epistemology (we are immersed in the praxis of living in an ontological multi-universe) resonates with SSM tenets making feasible to combine and graft some of Maturana's ideas (structural determinism/structural coupling and organisational closure) into some of the phases of the Checkland's well-known SSM seven-step process. Checkland and Maturana's work aim to understand and to improve problematic situations in organisations and in our everyday life; the proposed combined framework when adopted can have substantial implications to overcome SSM limitations. An enriched and improved SSM process could have significant consequences in the Operational Research and Systems community practice. The framework proposed can have major social repercussions since it will incorporate the well-known influential ToA and BoC ideas into Operational Research practice.

3 - Causal mapping workshops and strategic development
Parmjit Kaur, Ashley Carreras

This paper investigates the medium and long term impacts of a series of Causal Mapping workshops that focused on the strategic development of one large PLC. and a series of SME's. We will report not only on the financial well being of the organisations but also upon the use of the materials generated in the workshops and how they influenced the development of the organisations. The results will influence the recommendations we make to organisations, both on the use of the use and availability of the maps generated, and on the advice we give in determining the suitability of the technique to be used in the specific organisational context.

4 - Developing robust strategy: modelling stakeholder interactions - a case example
Colin Eden

The implementation of strategy is often of significant interest to external as well as internal stakeholders. Stakeholders with power can respond and create unexpected and undesirable dynamics. Exploring the interactions between multiple stakeholders can be a crucial task in developing robust strategies. Ideally stakeholder responses/dynamics would lead to a reinforcement of the success of a strategy. This presentation considers ways of helping a group consider stakeholder interaction in such a way that more robust strategy can be developed - strategies that a self-reinforcing through the dynamics of stakeholder responses to the strategy and to one another. The presentation shows steps in a soft-OR modelling process designed to assist a management team - the process is illustrated through a real case involving airport security.

■ WD-32

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S314

Dynamic Models in Game Theory II

Stream: Dynamic Models in Game Theory
Chair: *Jiajia He*

1 - A game-theoretic approach to solving the dynamic traveling salesman problem
Svetlana Tarashnina, Yaroslavna Pankratova

We study a dynamic traveling salesman problem (DTSP) allowing all considered objects (the salesman and customers) to move on a plane with constant velocities. We apply a game theoretical approach to solving the DTSP.

In fact, we propose to use some methods of pursuit game theory for this purpose. This means that each agent is considered as a player that has his own aim and his profit is described by a payoff function. The players may use admissible strategies and interact with each other. Here we offer to find a solution of the DTSP as a Nash equilibrium in a non-zero sum game of pursuit. In other words, we define strategies of all players that provide the minimal length of the salesman route.

In the considered dynamic traveling salesman problem we propose a new approach to finding a solution of this task. Applying methods and solution concepts of pursuit game theory we describe motion of the salesman and customers in a form of differential equations and assign them goals to meet the salesman as soon as possible. We find Nash equilibria and consider different examples which illustrate all possible cases of behavior.

2 - Population dynamics in electricity markets: going against the flow
Athanasios Papakonstantinou, Jethro Browell, Pierre Pinson

The dominance of fluctuating and intermittent stochastic renewable energy sources (RES) has introduced uncertainty in power systems which in turn, has challenged how electricity market operate.

In this context, there has been significant research in developing strategies for RES producers, which however typically focus on the decision process of a single producer, assuming unrealistic access to aspects of information about the power system. Still, even if there are several producers with access to advanced models that can predict similar market outcomes and with accurate information of their own generation, it is not guaranteed that their strategies will be optimal if all the competition deploys similar approaches. For example, a RES producer expecting high price in the balancing market may be inclined to underbid its quantity in the day-ahead market and overbid in the balancing market. If the majority of the producers behave in similar fashion then it is likely that the market delivers the opposite outcome than the one they predict.

This work analyses the behaviour of an entire population of RES producers in an electricity market using as basis a minority game: the "El Farol Bar problem". We generalise the typically binary strategies of a minority game to model the complexity of RES forecasting, prove the convergence of the system towards and equilibrium and illustrate the impact of the quality of information on the developed strategies and producers' revenues.

■ WD-33

Wednesday, 14:30-16:00 - SOUTH BUILDING UV S315

New Applications and Perspectives III

Stream: Data Mining and Statistics
Chair: *Emilio Carrizosa*

1 - Applying cluster analysis and collaborative filtering to develop hybrid recommendation for personalized picture book
Ling-Jing Kao, Chih-Chou Chiu, April Ying-Chieh Chiu

Personalization has made a dramatic effect on how companies do business. The success of Amazon, Netflix and Spotify relies on providing personalized recommendation for each customers. However, most studies in personalized content focuses on the application in digital service. There is very little discussion about how to utilize data mining techniques and recommendation algorithms to facilitate the design of customized product given customer transaction data. This research collaborates with a well-known Taiwanese picture book publisher to develop a recommendation algorithm for personalized picture book. The objective of this research is to develop an approach that can generate a list of book features, such as figure (e.g., a bear), role (e.g., a princess), scene (e.g., real vs unreal) and story (e.g., adventure), for a customer to choose from. By selecting from the list of recommended book features, a customer can personalize the content of picture book for herself easier. In this study, we propose to first analyze customer transaction data with cluster analysis to obtain individual preference and cluster preference in book features. Then given these information, collaborative filtering and hybrid recommendation are used to generate a list of picture book features for each individual customer. The empirical result show that the proposed approach can successfully recommend features of picture books that customers prefer.

2 - Homogenous or heterogeneous? Demand effect of user similarity network in online video website
Jun Yang, Hongjun Huang, Ling Zhao

With the rapid development of social web and television technologies, increasing numbers of people tended to share the experience with others. Online social media communities such as message boards, YouTube, Hulu, aiqiyi build a platform to enable television-viewer to interact and make comments instantly. On the basis of homogeneity theory, this paper analyzed the effect of viewer's similarity network on the demand of video view. Based on data from aiqiy.com, we build the reviewer network considering their interests similarity. To create the similar reviewer network, we extract the preference from reviewers' following interests clubs and subscribing clubs on their homepages. By counting the number of same clubs between two reviewers, we defined the degree of reviewer similarity. Firstly, we examine the effect of comments by calculating the cosine similarity of text. The results show that the diversity and richness of comments has positive demand effect. Secondly, we explore the effect of different characters of the network. The results reveal that the density and connection intensity of the network have negative demand effect. The homogeneity of network is negative with video views. The cluster coefficient and average node degree have positive economic impact.

3 - Personalized detection - integrating epidemic modeling and user behavior to improve malware detection

Amir Yavneh, Roy Lothan, Dan Yamin

Individual behavior plays a key role in malware transmission. Previous studies showed that users' characteristics, such as web-surfing habits and type of app downloading, may increase their risk of becoming infected with malware. However, despite its role in transmission, user behavior is rarely modeled to improve malware detection. We developed a network-driven framework for early detection of malware, where user nodes are connected if they became infected by being exposed to the same malicious website. The model considers the user's history of infections, and his similarity to other users as portrayed by the network. Additionally, we incorporated epidemic modeling to account for transmission dynamics of malware throughout the network over time. Using web-browsing data collected from 1.7 million users worldwide, we demonstrate how our model can serve as a powerful tool to infer the user's risk of becoming infected as it varies over time. Our methodological approach presents a novel personalized framework for malware detection, which is instrumental given the exponential rise in the magnitude and sophistication of malware nowadays.

4 - Characterization for the determination of production times using fuzzy clustering and relative risks

Maria Pastuizaca, Francisco Moreira

The production time of an automotive vehicle depends on several factors of different nature, such as the specifications of the manufacturer or manufacturing requirements provided by the customer; generating a large number of variables, making it necessary to determine the use of methodologies and tools of data analysis such as multivariate analysis and machine learning, both supervised and unsupervised. In the present work we propose the use of association measures such as relative risk and methodologies such as fuzzy classification in order to determine the main characteristics that influence the creation of vehicle profiles and estimate the total production time based on them.

■ WD-48

Wednesday, 14:30-16:00 - 4D UPV B.3

OR in Hydro Energy Management

Stream: OR in Water and Hydro Energy Management
Chair: *Jorge Daniel Páez Mendieta*

1 - Heuristic for dispatching of seasonal hydro storage power plants

Florian Zimmermann

In Switzerland, generation capacity is dominated by nuclear power plants with an installed capacity of 3.3 GW and hydro power plants with a total capacity of 16.1 GW by a maximal demand of over 9.2 GW (by 2016). The majority of the installed hydro capacity are seasonal storages with 8.7 GW (by 2017) together with a maximum storage capacity of 8'800 GWh (by 2017, this value also includes the pump storage). This figures indicate that hydro power plants need to be modelled in the energy system models appropriately particularly for Switzerland. However, by applying complex models considering multiple market areas, computing time plays a crucial role. In order to reduce computing time, heuristics are often used instead of optimization methods. There are already existing heuristics for hydro pumped storage. To the best knowledge of the authors, there are no appropriate heuristic for hydro seasonal storage power plants.

For this purpose a multi stage heuristic for dispatching seasonal hydro storage power plants is developed. First, a preliminary dispatch of the seasonal hydro power plants is determined based on the residual load, the historical production volume and the storage level. In the second step, adjustments are made taking into account the price forecast for the wholesale markets. The heuristic always considers technical limits such as turbine capacity and water storage levels.

2 - Decompostion techniques in hydro storage valuation and scheduling

Vadim Omelčenko

We consider a practical problem of hydro storage valuation where nonconvexities and price and inflow uncertainties are taken into account. We present hardware solutions on how to incorporate more sophisticated price models into valuing and how to preserve convexities. A popular method for handling this problem is stochastic dual dynamic programming. However, in practical problems, nonconvexities arise, e.g., due to ancillary services, and we provide our way of handling this issue. Additionally, we provide comparisons of price models for hydro storage valuation and present a way of incorporating probability constraints (for stable innovations) without losing convexity.

3 - Comparison of algorithms for valuation of hydroelectric pumped storages

Maik Günther, Christoph Rapp

Hydroelectric Pumped Storages (HPS) are able to balance variations in wind and solar gen-eration. They play an important role in electricity systems, especially in the future with a high-er share of volatile renewable generation and less thermal power plants in the market. HPS generate a large proportion of their revenues at the spot market. For investment decisions in HPS a various number of algorithms is available to calculate these revenues. Beside exact algorithms like Linear Programming or Dynamic Programming also a lot of heuristics can be applied. This leads to the question which of these solution techniques should be favored, based on the evaluation criteria: quality of the solution, computation time, implementation ef-fort and the effort to make adjustments. To answer this question, different algorithms are compared at three existing HPS in Germany. For hourly electricity prices real data from 2005 till 2016 and for comparison an hourly price forward curve for the same period are used. Nevertheless, to see the effect of changes in generation capacities in long-term, hourly prices of Germany from a fundamental electricity model are also applied from 2023 till 2050. In ad-dition, the effect of solution techniques on interest rates for an investment in the three existing HPS is analyzed. The results reveal that there are significant differences in revenues and in interest rates, based on the solution technique and the source of hourly prices.

4 - Optimal design of a hybrid power system in Fernando de Noronha Island

Jorge Daniel Páez Mendieta, Caroline Paulino, Paulo Correia, Ieda Geriberto Hidalgo

The Brazilian Isolated Systems (IS) are located mainly in the states of the North and Center-West region, and distributed throughout the interior of these states. These systems usually have a large number of small diesel generating units and a great difficulty of supply logistics. Given the continental dimensions of Brazil and the existence of remote locations, especially in the northern region of the country, the existence of IS's are essential. Among the SIs, the Fernando de Noronha archipelago draws attention to its location. According to ELETROBRAS, in order to satisfy the expected electric demand for the island, 5,199 m3 of diesel oil per year is needed, which shows a high dependence on this resource for supplying electric energy on the island. The expected energy load for the SI of the island of Fernando de Noronha is 1.98 MW average, corresponding to a maximum demand of 2.9 MW. This article is an economic analysis of the cost of generating electricity from solar, wind and thermal energy on the island of Fernando de

Noronha. It looks for a solution to reduce the dependence of diesel oil, main resource of electric power generation, and to use renewable sources to not harm the environment of the archipelago. In this sense, a mathematical model of optimization with annual horizon and hourly discretization was used so that the result of the economic analysis would be closer to reality.

■ WD-49

Wednesday, 14:30-16:00 - 4D UPV B.4

Emerging Applications in Portfolio Selection and Management Science

Stream: Emerging Applications in Portfolio Selection and Management Science
Chair: *Enrique Alba*

1 - A Fama and French four factor model

Juan E. Trinidad-Segovia, Maria de las Nieves López-García, Miguel A. Sanchez-granero, Igor Pouchkarev

We introduce a Fama and French four factor model by substituting the momentum for a Hurst exponent based factor. Hurst exponent is a classical measure of market memory. We will show the relevance of this new factor through an application in a sample of 1.500 companies of different markets.

2 - Using heuristics to maximize costumer attractiveness in retail stores

Sara Hatami, Mage Marmol, Leandro Martins, Angel A. Juan, Vicente Fernández

Nowadays, product recommendation is one of the strategies which is used from brick and mortar stores to omni-channel retail in order to increase sales and revenues. Recommending the subset of most relevant products which contains a high level of correlation between themselves and are most likely to purchase, leads to increasing customer attractiveness and probability into sales of the recommended products. This article is studied how determines the subset of most relevant products to expose on showing tables at brick and mortar stores in a planning horizon so that the overall attractiveness of the customers to these products is maximized. In order to have attractive tables, a number of assumptions and strategies such as price and product category diversification, acceptable profit margin and analyzes the behavior of each visitor are considered. Solving this proposed problem equips the brick and mortar stores to be capable to provide an exciting experience for the customers when visiting the store, and consequently to generate several benefits to the stores, such as increasing the number of sales and the profit. To solve this problem, we proposed Biased-Randomized (BR) heuristic. A set of instances to the problem was generated based on real-life assumptions and different selection methodologies were developed, tested and compared. The results were analyzed using a comprehensive statistical evaluation.

3 - New challenges for OR in smart cities

Enrique Alba

OR is a domain where modeling and solving problems led to many successful applications. The field of smart cities is a promising land for OR, but for this we need a new generation of OR techniques: - Problems in smart cities are not static. What kind of techniques can deal with a problem that changes as the solver is trying to get the optimum? - Time consuming applications are normal in smart cities, since the quality of a solution might need to be simulated (forget on derivatives and equations). Is parallelism a way to go? How can we split our solvers to be parallel in the modern ecosystem of cloud, GPUs and multiprocessors? - Solving OR problems does no longer remain in the realm of desktop computers. How problem models and algorithms run on smartphones and Raspberry Pi? How can we match a very low number of iterations to react in real time and on the street? - How OR collaborates with machine learning, neuronal networks, bio-inspired techniques? - What is the scalability of our present solvers? Are we actually studying it in all our papers? - How we can deal with multi-objective optimization and decision making? New metrics to measure performance? Can we bear with fifty objectives? - How can the new OR techniques deal with uncertainty in data? Probability distributions instead of numbers? - In smart cities, every solver is hoped to run on its own for a long time. How do we incorporate proprioception in it? How concept drift can be embedded into OR?

4 - Managing knowledge in public R&D: cases of regional specialization strategies adopted by national laboratories in India

Santanu Roy

We investigate aspects of knowledge management strategies adopted by three laboratories functioning under a public-funded R&D laboratory system, the CSIR, India. We highlight one specific dimension impacting technological innovation from these laboratories, the recognition of the strategic imperative of regional specialization of technological innovation. We begin by tapping the quality R&D performance of three CSIR laboratories, namely, the Central Leather Research Institute (CLRI), Chennai, the Indian Institute of Integrative Medicine (IIIM), Jammu, and the Central Mechanical Engineering Research Institute (CMERI), Durgapur, in terms of the following measures: number of Indian patents filed and granted, number of foreign patents filed and granted, and the number of published papers figuring among the top 50 CSIR publications in specific research areas of biological sciences, chemical sciences, engineering sciences, physical sciences, and information sciences, over an extended period of eleven years (2003-04 to 2013-14). We follow this up by presenting laboratory-specific cases studies on regional specificity of R&D and innovation from these laboratories. We specifically investigate the role played by CLRI in nurturing and supporting the leatherwear cluster in Chennai, how IIIM has contributed to the development of a regional knowledge-base in J&K and how CMERI has contributed to the development of Durgapur-Asansol industrial belt and other small scale industrial clusters.

■ WD-51

Wednesday, 14:30-16:00 - 4D UPV 1.2

Planning and Scheduling for Health Care

Stream: OR for Health and Care II
Chair: *Rosita Guido*

1 - Stochastic kidney exchange problem

Bart Smeulders, Yves Crama, Frits Spieksma

Traditionally, the Kidney Exchange Problem (KEP) is treated as a deterministic problem. However, the transplant compatibility graph is subject to uncertainty. While initial tests, which are used to build the compatibility graph, may suggest a donor is compatible with a donor, more detailed tests can uncover incompatibilities. Donors or patients may also withdraw from the exchange due to illness, transplants outside of the exchange, etc. In this talk, we look at the KEP as a two-stage stochastic problem. In the first stage, potential transplants are selected for detailed compatibility tests. In the second stage, a KEP is solved using only transplants which passed these tests. The goal is to choose potential transplants in the first stage, so that the expected number of transplants in the second stage is maximized. To solve this problem, we make use of Monte Carlo simulation to generate scenarios, and optimize the number of transplants over these. A straightforward IP formulation of this problem quickly becomes intractable, but by making use of the strong linear relaxations of KEP-formulations and Benders decomposition we are able to increase the size of the KEP and the number of scenarios that we can handle.

2 - Heuristic solutions for kidney exchange program
Utkarsh Verma, Narayan Rangaraj

Kidney exchange programs were developed to find compatible matches for recipients with incompatible donors. These incompatible pairs register themselves in PKE (Paired Kidney Exchange) registry and get a compatible kidney through either a swap or a cycle of exchanges within registry. Execution of long cycles are logistically challenging - thus a bound on The cycle length was implemented. Researchers have come up with different MILP models to find the optimal number of exchanges for these registries considering the bounds on cycle length. Finding bounded length cycles over a network is a NP hard problem and for large number of nodes these models can take exponential amount of time to solve for optimality. Thus we propose a heuristic solution which will allow us to solve the problem of kidney exchange in reasonable time. It is a data driven approach which uses the compatibility of blood groups and the idea of prioritizing crucial pairs to increases the number of transplants. All proposed transplants do not execute in practice due to various reasons, cross match positivity being one of them which shows that a recipient has become sensitized to a blood group profile. These sensitized recipients need to be incentivized as they are having higher chances of cross match positivity. Our algorithm prioritizes these sensitized recipients to increase the probability of successful execution of the proposed transplants.

3 - Analyzing economies of scale and scope in hospitals by use of case mix planning
Jens Brunner, Sebastian McRae

This study analyzes the effect of economies of scale and scope in hospitals on the optimal case mix of a hospital or hospital associations. For this purpose, the impact of efficiencies in resource consumption and potential effects of spreading fixed costs among more patients are evaluated with respect to the ideal volume and composition of patients. The problem is formulated as a non-linear mixed integer program. An iterative solution procedure using linear approximations to derive lower and upper bounds is proposed since the original problem is too difficult to be solved with standard solution approaches. These bounds converge against the optimal solution value. The procedure is applied to data of German hospitals. Results indicate that resource efficiencies have a considerable impact if similar services can be consolidated, e.g., among different departments. However, if the decision scope regarding the volumes of different patient groups is limited, resource efficiencies can be neglected.

4 - Patient admission, surgery planning and bed assignments problems: a solution approach
Rosita Guido, Vittorio Solina, Giovanni Mirabelli, Domenico Conforti

Elective patient admission and surgery planning with bed assignment is a very challenging problem, recently introduced in the literature. Its main aim is to find a good matching between demand and resource, namely bed, equipment, and operating rooms. It is an extension of the patient bed assignment problems, which is NP-hard.

Our contribution to the existing literature is a matheuristic solution approach, which can improve the ability of hospitals to provide the best possible care to patients. Computational experiments on benchmark instances show that the proposed approach provides high-quality schedules in reasonable times and the results reported in the literature are improved.

■ WD-52

Wednesday, 14:30-16:00 - 4D UPV 1.3

Pricing and Revenue Management III

Stream: Analytics and Pricing
Chair: *Andre Schnabel*

1 - Pricing and coordination decision in closed-loop supply chain considering joint advertising
Juhong Gao

With the consideration of ordinary and green consumers'different willingness to pay for new and remanufactured products, the market was segmented into two scenarios by the utility theory. Further considering the impact of cooperative advertisement on new product demand, demand functions under different scenarios were obtained. The optimal pricing strategy and advertising strategy in decentralized decision under different dominant modes and centralized decision-making under each market scenario were compared, and the impacts of advertising effect on CLSC were analyzed, and an improved two part tariff contract was proposed to coordinating of the CLSC with the effect of cooperative advertisement.

2 - Optimal order quantity and dynamic pricing for multiple, vertically-differentiated products
Prasenjit Mandal

We consider a retailer's optimal order quantity and dynamic pricing problem for multiple substitutable products with m-period lifetime. Also, the products are vertically-differentiated. As part of the problem, the retailer seeks to determine the optimal order quantity of the highest-quality item at the beginning of each epoch. Subsequently, given the inventory of multiple products, the retailer would like to dynamically vary the price for each product during of an epoch to maximize his expected profit. We assume that customers are heterogeneous in their willingness to pay for product quality. Moreover, an arriving customer chooses a product that provides her the maximum utility from the available alternatives. To study this problem, we develop a dynamic programming formulation and analyze characteristics of the optimal decisions. We identify novel structural properties of the optimal revenue function. We find a simple algorithm to find the optimal inventory of the highest-quality item at the beginning of each epoch. Also, we show that the optimal value function is anti-multimodular which guarantees that our algorithm finds a globally optimal order quantity. The optimal order quantity and the existing inventory of any other product are economic substitutes and the order quantity is more sensitive to the inventory of a higher-quality product compared to a lower-quality.

3 - Dynamic pricing of new products in competitive markets: a mean-field game approach
Régis Chenavaz, Corina Paraschiv, Gabriel Turinici

Dynamic pricing of new products has been extensively studied in monopolistic and oligopolistic markets. But, the optimal control and differential game tools used to investigate the pricing behavior on markets with a finite number of firms are not well-suited to model competitive markets with an infinity of firms. Using a mean-field games approach, this paper examines dynamic pricing policies in competitive markets, where no firm exerts market power. The theoretical setting is based on a diffusion model à la Bass. We prove both the existence and the uniqueness of a mean-field game equilibrium, and we investigate mean tendencies and firms dispersion in the market. Numerical simulations show that the competitive market splits into two separate groups of firms depending on their production experience. The two groups differ in price and profit. Thus, high prices and profits do not have to signal anticompetitive practices of managers, stimulating the debate on market regulation.

4 - Simulation-based service portfolio optimization
Andre Schnabel, Carolin Kellenbrink

Service contractors in the field of regenerating complex industrial goods, like aircraft engine re-manufacturers, face the complex decision problem of accepting or rejecting unsteadily arriving regeneration orders from different customer types. Specifically, there are customers entering long term contracts with comparatively low revenues and customers placing spontaneously arriving orders with comparatively high revenues. In this context, service providers require a strategy to avoid the displacement of more profitable jobs and the associated revenue loss.

One instrument for inducing a tangible policy for order acceptance is an allocation of the finite resource capacities to these different classes of customers, denoted as the service portfolio of the contractor. This resembles the usage of booking limits in traditional revenue management problems. A distinctive feature of our problem is the non-uniformity of the number of resource units occupied by a single order. This motivates the design of novel solution procedures for this specific allocation problem.

We consider both mathematical programming with scenario generation (simulation for optimization) and repeated simulations with heuristic configuration improvement (optimization for simulation). In the latter case, a commercial black box local search based solver called LocalSolver and the application of the meta-heuristic procedure of particle swarm optimization were evaluated on a newly developed problem library.

■ WD-53

Wednesday, 14:30-16:00 - 4D UPV 1.4

Electricity Supply

Stream: Stochastic Assessment of Renewable Energy
Chair: *John Boland*

1 - Analysis and clustering of residential electricity consumers using smart meter data
Olga Varganova, Behzad Samii

Electricity consumption data captured by smart meters provides a valuable resource for identifying energy producing and consuming behavior of prosumers. The ensuing demand response schemes help maintaining a flatter demand curve throughout the day which in turn contributes to the lifetime extension of the physical assets and decreases the usage of costly gas-fired peaker plants.

In this study, we provide an in-depth analysis of real smart electricity meter data of 102 residential households in Belgium. We use hierarchical and k-mean clustering to identify different energy behavioral segments in order to distinguish consumers' fit for peak reduction purposes. While our analysis focuses on clustering based on mean and standard deviation of electricity consumption, we extend our approach to account for intra-day and seasonal variations of residential consumers as well as variations across days of the week, for a period of one year.

Our research shows that the majority (88%) of consumers have a highly predictable demand behavior while a minority (6%) show highly disruptive and unpredictable pattern. Our research partner, a major Distribution System Operator (DSO), can then use this clustering information to design zero-sum targeted demand response schemes that penalize disruptive consumption segments while rewarding the segments with predictable demand behavior.

2 - A shared balancing responsibility model for the integration of ancillary services from demand side management and distributed generation
Cristina Núñez-del-Toro, Cristina Corchero, Pol Paradell, Gerard del Rosario

Transmission system operators (TSOs) are responsible for procuring balancing services from balancing service providers (BSPs) in order to ensure operational security. BSPs include generators but also demand response which involves customers changing their operating patterns to aid system balancing. The larger the number of BSPs in a given market, the higher the chance to increase competition among them and, thus, to reduce costs for society. The inadequate interconnection of Iberian market with the rest of Europe is recognized for all network development scenarios and therefore the transition of such market to a larger regional market is still limited. Furthermore, complex (and costly) associated ancillary services joint to highly-variable renewable energy production, causes reserves increases in order to balance supply and demand. In addition, the increasing number consumers and distributed energy resources, offering flexible ancillary services on the market, may lead to grid congestion issues. In order to manage these potential problems, particularly TSO-DSO interconnection balancing and DSO congestion management, we present a real-time "Shared Balancing Responsibility Model". Based on an Optimal Power Flow (OPF) problem, the model assess current imbalances in order to re-schedule the target active power at the interconnection point. The model also considers flexibility dispatching, providing, along with market results, the market clearing prices.

3 - Real-time energy dispatching in smart microgrids
Selçuk Gören, Ahmet Önen, Yeliz Yoldaş, Salem Al-Agtash, Brian Azzopardi, Nis Martensen, Jose L. Martinez-Ramos, Tsolakis Apostolos, Dimitrios Tzovaras, Lenos Hadjidemetriou, Mounir Khiat, Tim Camilleri, Nicholas Borg

Centralized electrical grids have demonstrated a proven failure in successful integration of distributed and renewable energy sources. A series of phenomena such as widening energy demand-supply gap, tendency towards more electrical vehicles, increased energy losses due to aging equipment in transmission and distribution networks, and increased need for electrification of secluded areas such as islands, have created the necessity for alternatives that can improve the energy management in modern networks. Microgrids are considered as a possible solution that can tackle, if not all, of the aforementioned issues.

In this study, we consider a pilot smart microgrid that consists of photovoltaic and wind generators, standby diesel generators, and backup energy storage units (batteries, fly wheels, and power capacitors). We propose a dynamic energy management system that optimally generates dispatch control signals in real time to 1) minimize load shedding, 2) maximize the utilization of renewable generators, 3) maximize active/reactive voltage and current consistency when islanded, and 4) avoid too short charge/discharge cycles of batteries. Our simulations demonstrate the robust performance of the proposed system.

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4 - Long-term wind power forecasting using singular spectrum analysis
Soraida Aguilar, Paula Maçaira, Reinaldo Souza, Fernando Luiz Cyrino Oliveira

The share of wind power generation in Brazil has been steadily growing in recent years, and this increase in the wind resource is accompanied by the inclusion of policies that regulate the expansion of the country's energy matrix and the growth of the electricity demand. To assess the wind power output this work analyzes the seasonality and the long-term deviations via the application of singular spectrum analysis (SSA) to generate a wind power forecasting model. The results obtained by this proposed model are compared to other time series of wind power production from wind speeds derived from wind speed measurements and two global climate reanalysis models: NCAR and ECMWF.

■ WD-54

Wednesday, 14:30-16:00 - 4D UPV 1.6

Personnel Scheduling Applications

Stream: Applied OR
Chair: *Geir Hasle*

1 - Airline cabin crew rostering based on a column generation algorithm
Nan Xu, Mingyu Zhao, Fan Yang, Zhiyao Zhang

Here we focus on the cabin crew rostering problem, which is challenging due to the extremely large size and the complex working rules involved. In our approach, the objective of rostering consists of two major components. The first is to minimize the unassigned pairings and the second is to ensure the fairness to crew members. There are two measures of fairness to crew members, the number of overnight duties and the total fly-hour over a given period. Pairings should be assigned to each crew member so that their actual overnight duties and fly hours are as close to the expected average as possible. Deviations from the expected average are penalized in the objective function and the penalization is quadratic. Our model is based on column generation. The problem is decomposed into a master problem and subproblems. The master problem is modeled as a set partition problem and the subproblem is modeled as resource constrained shortest path problems. The major contribution of our model is: 1) We propose a method to deal with non-additive shortest path problem; 2) Operation to allow relaxing some soft rules is allowed in our algorithm, which can improve the coverage rate; 3) Multi-thread techniques are used to improve the efficiency of the algorithm when generating Line-of-Work for crew members. The algorithm we propose in this paper has been put into production in a major airline in China and numerical experiments show that it has a good performance.

2 - Modelling real-world strict seniority bidding problems in airline crew rostering

Andriy Svynaryov, Magnus Björk, Paweł Pietrzak

Jeppesen provides a range of crew and fleet planning products, mainly for airlines. Such problems are challenging for various reasons, including problem size, legal requirements of schedules, and company policies. The rostering optimizer builds schedules (rosters) for individual pilots and cabin crew using small chunks of work provided by a previous separate optimization program. It must take into account such aspects as costs, industry rules and regulations, quality and robustness, and also individual crew preferences (bids). Airline industry has two main approaches for handling crew bids. One is weighted fair share, where all crew could equally likely get their bids granted. The other is strict seniority bidding, where bids are granted in crew seniority order. The scope of the presentation is modelling a real-world strict seniority rostering problem. The first challenge is how to model complex business rules that determine roster legality, which are imposed by government regulations, the airline, union agreements etc. The second challenge is cost function definition. In particular, the optimizer should assign the best possible roster even for a junior crew member while keeping senior crew member bids satisfied and still respecting other cost components and business constraints. Jeppesen's rostering optimizers are used commercially by a large number of major airlines, solving problems with several thousands of crew members and five to ten times more trips.

3 - Analysis of firefighter absences and hiring schedule optimization at a Canadian fire department

Tamon Stephen

We study staffing issues at the Surrey (British Columbia, Canada) Fire Department with a view to understanding and optimizing the annual hiring cycle for full-time firefighters. This project includes discussion of a previous model used by the Fire Department which predicts absences based on seasonally adjusted historical data and then optimizes the hiring cycle based on a simulation. We extend the analysis of the data to include the age cohort as a variable and compare short-term and long-term absences. We use time series to predict future absences and use these predictions along with additional constraints to optimize the hiring schedule.

This is joint work with Bolong He and the Surrey Fire Department.

4 - Making schedule recommendations for managing personal processes by using a constraint programming model

Sercan Oruc, P. Erhan Eren, Altan Koçyiğit, Sencer Yeralan

Personal process management is the management of "flow of activities" (processes) in people's personal lives; such as registering for a college, applying for a visa, and preparing a birthday party. These flows of activities could be as complex as planning a marriage organization or procedures for buying a house, or could be as simple as baking a cake or following an exercise program. There are two main properties of personal processes. First, they are ad hoc, i.e. the process may change significantly depending on the context such as time of the day or location. Secondly, contrary to the processes for businesses, personal processes are highly dependent on the individual. Two different people conducting the same process may have many distinct requirements compared to each other.

In this study, we present a context aware mobile scheduling software application that serves as a decision support system in managing personal processes. We develop a constraint programming model which takes a set of processes and related activities, the context information, and user's objective preferences as input, and gives a suggested schedule of activities as the output. We also discuss the empirical results of using such a system in managing personal processes.

■ WD-55

Wednesday, 14:30-16:00 - 4D UPV 2.1

Ethical Dilemmas in Everyday Practice

Stream: Making an Impact I
Chair: *Ruth Kaufman*

1 - Ethical dilemmas in everyday practice

Ruth Kaufman

Ethical practice is important if practitioners are to retain the trust of their clients as well as their own self-respect. There are a number of codes of practice available for anybody who wants guidance on this. But even for the most ethical practitioner, real life can sometimes throw up ethical dilemmas, or tempt us into imperfect behaviour: perhaps fulfilling our contract obligations may require turning a blind eye to unethical conduct from the client; or the client does not want to engage with the caveats around our analysis; or we want to convince the client to employ us even where the work area is new to us, to name just a few situations where a purist approach may result in no OR work happening at all. This session will start with a short introduction to the ethical dilemmas that can arise in everyday OR, and then open out into discussion inviting participants to share their own experiences and approaches. It is intended to give an opportunity to people engaged in practical OR to reflect on their own practice and to share learning and ideas with others, so that they may be better equipped to make good choices in future.

■ WD-56

Wednesday, 14:30-16:00 - 4D UPV 2.2

Scheduling Problems in Hospitals

Stream: Healthcare Logistics
Chair: *Inês Marques*

1 - Multi-appointment scheduling in a diagnostic facility

Joren Marynissen, Erik Demeulemeester

As proven in recent review articles (Marynissen and Demeulemeester, 2018; Leeftink et al., 2018), the (centralized) scheduling problem of patients who require multiple (and interrelated) appointments has gained recent attention in the healthcare literature. In this research, we try to extend this literature by studying a real-life diagnostic facility in which patients need to be scheduled on multiple diagnostic resources. The goal of this problem is to sequentially schedule all patients such that a weighted objective function is optimized. This objective function focuses on the in-hospital waiting time of patients, the number of days on which patients need to visit the hospital and provider idle time. Using a discrete-event simulation model, we measure the effect of different scheduling methodologies on the performance of the system. These scheduling methods include (meta)heuristics as well as optimal methods.

2 - The introduction of pediatric operating room sessions: quality vs efficiency
Carla Van Riet, Erik Demeulemeester

The need for specialized anesthesia equipment for pediatric patients and the preference for audio-visual separation of pediatric and adult patients can be addressed by separating pediatric surgeries in one or more fully equipped operating rooms (ORs). Although the benefits of this separation are clear with regards to equipment (e.g., less investment and/or less movement), its impact on patient scheduling has barely been studied.

The aim of this study is to assess the feasibility of allocating OR sessions to pediatric patients with regards to keeping the access times of both adult and pediatric patients within acceptable limits and with regards to the change in several operational performance measures. Introducing these separate pediatric sessions obviously decreases the scheduling flexibility. The question is whether this decrease is acceptable compared to the benefits the separation offers. We assess several scenarios using a data-driven simulation model.

The results show that the percentage of patients that are served within their due time is only slightly affected when looking at adult and pediatric patients together, but this percentage for the pediatric patients separately drops from 86% to 73%. This decrease for some disciplines can be as large as 69 percentage points. This talk discusses the results and the implications for hospital managers.

3 - Reallocate operating room time among surgical services
Luisa Lubomirska, Inês Marques

Health Care providers are facing a continuous increase in the complexity of their organizations mainly due to the increasing demand and to the development of new and expensive technologies. The operating room (OR) is a major challenge in the hospital and is crucial for the financial health of the hospital. In the last decades, surgery demand has been increasing, forcing operating rooms to be more efficiently managed. This work is developed under a partnership with a Portuguese public hospital and aims to improve the efficiency of the OR. Given the hospital restrictions in terms of space and human resources, this work tries to reallocate the operating room time among the surgical services, proposing a new master surgical schedule - a cyclic timetable with the number of hours, the days and rooms in which each specialty should operate. This reallocation has as main objective the balance between supply and demand, as well as the maximization of the OR efficiency. These two objectives contribute to a major social impact, which is the reduction of patients on the waiting list. The inclusion of stakeholders' preferences is considered to be important for the future implementation of the study in the hospital. Therefore, another objective has been added: the maximization of the satisfaction of the stakeholders including surgeons, anesthesiologists, nurses and hospital managers.

4 - Blood supply chain planning: the Portuguese case
Ana Margarida Araújo, Inês Marques, Ana Barbosa-Povoa

The blood supply chain comprises diverse activities as the processes of collecting, testing, processing and distributing blood and blood products, from donor to patient. Blood products are transfused to patients as part of routine medical treatments or surgical operations and in emergency situations. The availability of the right blood products at the right time in the right quantity is critical for the health provision since shortages can be fatal to patients. The management of these products is particularly challenging. Matching supply and demand in an efficient manner is not straightforward: the supply of donor blood is irregular while the demand for blood products is highly stochastic, and there is a wide range of blood types and products. Moreover, blood products are perishable which hinders the stock accumulation and pressures the stock management. An efficient blood supply chain planning should meet demand while at the same time reducing wastage and minimizing costs. The aim of this work is to characterize the Portuguese blood supply chain and to improve the main identified sources of inefficiencies by proposing a model to handle tactical and operational decisions. The overall goal is to deliver the correct quantity of the correct blood product to the patient at the moment and where it is required at minimum cost.

Wednesday, 17:30-18:30

■ WE-01

Wednesday, 17:30-18:30 - Opera House

Theory can sometimes be useful

Stream: Plenaries
Chair: *Greet Vanden Berghe*

1 - **Theory can sometimes be useful**
Gerhard Woeginger

We sometimes get stuck while trying to model computational problems in a certain framework, or while trying to design fast algorithmic solutions for certain subproblems. The talk discusses some concrete situations, and convincingly explains (with the help of computational complexity theory) the various reasons for our failures.

Wednesday, 18:45-20:00

■ WF-01

Wednesday, 18:45-20:00 - Opera House

Closing Session

Stream: Opening and Closing
Chair: *Ramon Alvarez-Valdes*
Chair: *Ruben Ruiz*

1 - **Closing session**
Ramon Alvarez-Valdes, Ruben Ruiz

Closing session

STREAMS

Agent-Based Simulation in Business and Economics

Stephan Leitner
Alpen-Adria-Universität Klagenfurt
stephan.leitner@aau.at

Friederike Wall
Alpen-Adria-Universitaet Klagenfurt
friederike.wall@uni-klu.ac.at

Track(s): 23

Analytic Hierarchy Process / Analytic Network Process

Alessio Ishizaka
University of Portsmouth
alessio.ishizaka@port.ac.uk

Josef Jablonsky
University of Economics Prague
jablon@vse.cz

Y. Ilker Topcu
Istanbul Technical University
ilker.topcu@itu.edu.tr

Track(s): 7

Analytics and Pricing

Luce Brotcorne
INRIA
Luce.Brotcorne@inria.fr

Arnoud den Boer
University of Amsterdam
boer@uva.nl

Track(s): 52

Analytics, Data Science and Data Mining

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl

Track(s): 22

Applications of Dynamical Models

João Almeida
LIAAD - INESC TEC and Instituto Politécnico de Bragança
jpa@ipb.pt

Alberto Pinto
University of Porto
aapinto1@gmail.com

Track(s): 11

Applications Related to Continuous Optimization

Attila Gilanyi
University of Debrecen
gilanyi@inf.unideb.hu

Track(s): 13

Applied OR

Geir Hasle
SINTEF Digital
geir.hasle@sintef.no

Track(s): 54

Behavioural OR

L. Alberto Franco
Loughborough University
L.A.Franco@lboro.ac.uk

Raimo P. Hämäläinen
Aalto University, School of Science
raimo.hamalainen@aalto.fi

Track(s): 31

Biomass-Based Supply Chains

Magnus Fröhling
TU Bergakademie Freiberg
magnus.froehling@bwl.tu-freiberg.de

Taraneh Sowlati
University of British Columbia
taraneh.sowlati@ubc.ca

Track(s): 50

Business Analytics

Dries Benoit
Ghent University
dries.benoit@ugent.be

Kristof Coussement
IESEG School of Management
k.coussement@ieseg.fr

Wouter Verbeke
Vrije Universiteit Brussel
wouter.verbeke@vub.ac.be

Richard Weber
University of Chile
rweber@dii.uchile.cl

Track(s): 11

Combinatorial Optimization I

Silvano Martello
University of Bologna
silvano.martello@unibo.it

Paolo Toth
University of Bologna
paolo.toth@unibo.it

Track(s): 8

Combinatorial Optimization II

Silvano Martello
University of Bologna
silvano.martello@unibo.it

Paolo Toth
University of Bologna
paolo.toth@unibo.it

Track(s): 25

Computational Biology, Bioinformatics and Medicine

Marta Szachniuk
Poznan University of Technology
Marta.Szachniuk@cs.put.poznan.pl

Metin Turkay
Koc University
mturkay@ku.edu.tr

Track(s): 57

Convex Optimization

Attila Gilanyi
University of Debrecen
gilanyi@inf.unideb.hu

Track(s): 18

Convex, Semi-Infinite and Semidefinite Optimization

Olga Kostyukova
Institute of Mathematics, National Academy of Sciences of Belarus
kostyukova@im.bas-net.by

Tatiana Tchemisova
University of Aveiro
tatiana@ua.pt

Track(s): 21

Cutting and Packing

Julia Bennell
University of Southampton
j.a.bennell@soton.ac.uk

Track(s): 29

Data Mining and Statistics

Pakize Taylan
Dicle University
ptaylan@dicle.edu.tr

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl

Track(s): 33

DC Programming and DCA

Hoai An Le Thi
University of Lorraine
hoai-an.le-thi@univ-lorraine.fr

Tao Pham Dinh
INSA Rouen
pham@insa-rouen.fr

Track(s): 34

DEA: Applications

Jesús T. Pastor
Universidad Miguel Hernández
jtpastor@umh.es

Jyrki Wallenius
Aalto University School of Business
jyrki.wallenius@aalto.fi

Track(s): 2

DEA: Theory

Jesús T. Pastor
Universidad Miguel Hernández
jtpastor@umh.es

Jyrki Wallenius
Aalto University School of Business
jyrki.wallenius@aalto.fi

Track(s): 11

Decision Analysis and Decision Support Systems

Juuso Liesiö
Aalto University
juuso.liesio@aalto.fi

Eeva Vilkkumaa
Aalto University, School of Business
eeva.vilkkumaa@aalto.fi

Track(s): 20

Decision Making Modeling and Risk Assessment in the Financial Sector

Cristinca Fulga
Bucharest University of Economic Studies
fulga@csie.ase.ro

Track(s): 18

Demand and Supply Management in Retail and Consumer Goods

Pedro Amorim
Faculty of Engineering of University of Porto
amorim.pedro@fe.up.pt

Tamer Boyaci
ESMT Berlin
tamer.boyaci@esmt.org

Rob Broekmeulen
TU Eindhoven
r.a.c.m.broekmeulen@tue.nl

Alexander Hübner
Technical University Munich
alexander.huebner@ku.de

Heinrich Kuhn
Catholic University of Eichstaett-Ingolstadt
heinrich.kuhn@ku-eichstaett.de

Winfried Steiner
Clausthal University of Technology, Institute of Management and Economics
winfried.steiner@tu-clausthal.de

Track(s): 6

Discrete and Global Optimization

Jan van Vuuren
Stellenbosch University
vuuren@sun.ac.za

Track(s): 16

Discrete Optimization, MIP and MINLP

Luís Gouveia
Universidade de Lisboa - Faculdade de Ciências
legouveia@fc.ul.pt

Track(s): 34

Dynamic and Stochastic Scheduling

Wim Vancroonenburg
KU Leuven
wim.vancroonenburg@cs.kuleuven.be

Track(s): 4

Dynamic Models in Game Theory

Stefan Wrzaczek
Wittgenstein Centre
stefan.wrzaczek@tuwien.ac.at
Track(s): 32

Dynamical Models in Sustainable Development

Pierre Kunsch
Vrije Universiteit Brussel
pkunsch@vub.ac.be
Track(s): 24

Dynamical Systems and Mathematical Modelling in OR

Katsunori Ano
Shibaura Institute of Technology
kano2@mac.com

Selma Belen
Ankara
kristina.aub@gmail.com

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl
Track(s): 34

Emerging Applications in Portfolio Selection and Management Science

Norbert Trautmann
University of Bern
norbert.trautmann@pqm.unibe.ch
Track(s): 49

Emerging Applications of Data Analysis

Vadim Strijov
Russian Academy of Sciences, FRC Computer Science and Control
strijov@phystech.edu
Track(s): 58

Energy Economics, Environmental Management and Multicriteria Decision Making

Ana Barbosa-Povoa
Instituto Superior Tecnico
apovoa@tecnico.ulisboa.pt

Jacqueline Bloemhof
Wageningen University
jacqueline.bloemhof@wur.nl

Maximilian Schiffer
RWTH Aachen University
maximilian.schiffer@om.rwth-aachen.de

Grit Walther
RWTH Aachen University
walther@om.rwth-aachen.de
Track(s): 54

Engineering Optimization

Wolfgang Achtziger
Friedrich-Alexander University Erlangen-Nürnberg
achtziger@math.fau.de
Track(s): 48

Environmental Sustainability in Supply Chains

Werner Jammernegg
WU Vienna University of Economics and Business
werner.jammernegg@wu.ac.at

Tina Wakolbinger
WU (Vienna University of Economics and Business)
tina.wakolbinger@wu.ac.at
Track(s): 51

EURO Special Sessions

Sarah Fores
EURO
sarahfores@gmail.com
Track(s): 60

European Working Group: Data Science Meets Optimization

Patrick De Causmaecker
Katholieke Universiteit Leuven
Patrick.DeCausmaecker@kuleuven.be

Ender Özcan
University of Nottingham
ender.ozcan@nottingham.ac.uk

Andrew J. Parkes
University of Nottingham
ajp@cs.nott.ac.uk

Dolores Romero Morales
Copenhagen Business School
drm.eco@cbs.dk
Track(s): 9

Financial Mathematics and OR

Katsunori Ano
Shibaura Institute of Technology
kano2@mac.com

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl
Track(s): 24

Financial Modeling, Risk Management and Managerial Accounting

Rita D'Ecclesia
Sapienza University of Rome
rita.decclesia@uniroma1.it
Track(s): 13

Fintech: Economic and Financial Challenges in Cryptocurrencies

Alessandra Cretarola
University of Perugia
alessandra.cretarola@unipg.it

Gianna Figà-Talamanca
Università di Perugia
gianna.figatalamanca@unipg.it
Track(s): 25

Fuzzy Optimization

Jose-Luis Verdegay
Universidad de Granada
verdegay@ugr.es
Track(s): 12

Game Theory and Mathematical Economics

Track(s): 34

Game Theory and Operations Management

Greys Sosic
University of Southern California
sosic@marshall.usc.edu

Track(s): 30

Game Theory, Solutions and Structures

Encarnación Algaba
Seville University
ealgaba@us.es

Track(s): 29

Global Optimization

Attila Gilanyi
University of Debrecen
gilanyi@inf.unideb.hu

Track(s): 24

Graphs and Networks

Bernard Ries
Université de Fribourg
bernard.ries@unifr.ch

Track(s): 16

Green Logistics

Tolga Bektas
Southampton Business School
T.Bektas@soton.ac.uk

Harilaos Psaraftis
Technical University of Denmark
hnpsar@dtu.dk

Jakob Puchinger
CentraleSupélec, IRT-SystemX
jakob.puchinger@irt-systemx.fr

Track(s): 16

Healthcare Logistics

Kris Braekers
Hasselt University
kris.braekers@uhasselt.be

Walter Gutjahr
University of Vienna
walter.gutjahr@univie.ac.at

Patrick Hirsch
University of Natural Resources and Life Sciences, Vienna
patrick.hirsch@boku.ac.at

Track(s): 56

Humanitarian Operations

Maria Besiou
Kuehne Logistics University
maria.besiou@the-klu.org

Luk Van Wassenhove
INSEAD
luk.van-wassenhove@insead.edu

Nico Vandaele
Katholieke Universiteit Leuven
nico.vandaele@kuleuven.be

Tina Wakolbinger
WU (Vienna University of Economics and Business)
tina.wakolbinger@wu.ac.at

Track(s): 48

Hyperheuristics

Patrick De Causmaecker
Katholieke Universiteit Leuven
Patrick.DeCausmaecker@kuleuven.be

Mustafa Mısır
Nanjing University of Aeronautics and Astronautics
mustafamisir@yahoo.com

Ender Özcan
University of Nottingham
ender.ozcan@nottingham.ac.uk

Rong Qu
University of Nottingham
rxq@cs.nott.ac.uk

Track(s): 12

IBM Research Applications

Martin Mevissen
IBM Research - Ireland
martmevi@ie.ibm.com

Track(s): 49

IFORS Tutorial Lecture

Michael Trick
Carnegie Mellon University
trick@cmu.edu

Track(s): 1

Insurance and Pension Risk Management

Susanna Levantesi
Sapienza University of Rome
susanna.levantesi@uniroma1.it

Track(s): 34

International Aspects of OR

Ulrike Reisach
Neu-Ulm University of Applied Sciences
ulrike.reisach@hs-neu-ulm.de

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl

Track(s): 53

Keynotes

Greet Vanden Berghe
KU Leuven
greet.vandenberghe@cs.kuleuven.be

Track(s): 1

Location Analysis and Optimization

Olivier Péton
IMT Atlantique
olivier.peton@imt-atlantique.fr

Track(s): 3

Long-term Planning in Energy, Environment and Climate

Nadia Maïzi
MINES ParisTech
nadia.maizi@mines-paristech.fr

Track(s): 50

Lot Sizing, Lot Scheduling and Production Planning

Nabil Absi
Ecole des Mines de Saint-Etienne - LIMOS
absi@emse.fr

Bernardo Almada-Lobo
INESC-TEC, Faculty of Engineering of Porto University
almada.lobo@fe.up.pt

Christian Almeder
European University Viadrina
Almeder@europa-uni.de

Track(s): 23

Machine Learning

Tony Wauters
KU Leuven
tony.wauters@cs.kuleuven.be

Track(s): 28

Making an Impact I

Ruth Kaufman
n/a
ruth.kaufman@btinternet.com

Track(s): 55 57

Making an Impact II

Track(s): 55

Maritime Transportation

Henrik Andersson
Norwegian University of Science and Technology
Henrik.Andersson@ntnu.no

Marielle Christiansen
Norwegian University of Science and Technology
marielle.christiansen@iot.ntnu.no

Kjetil Fagerholt
Norwegian University of Science and Technology
kjetil.fagerholt@iot.ntnu.no

Track(s): 12

Matheuristics

Tony Wauters
KU Leuven
tony.wauters@cs.kuleuven.be

Track(s): 9

Memory-based Heuristics

Rafael Marti
Universitat de València
Rafael.Marti@uv.es

Track(s): 28

Metaheuristics

Carlos M. Fonseca
University of Coimbra
cmfonsec@dei.uc.pt

Track(s): 30

Mixed-Integer Linear and Nonlinear Programming

Juan José Salazar González
Universidad de La Laguna (Tenerife)
jjsalaza@ull.es

Track(s): 5

Moments in History of OR

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl

Track(s): 49

Multiobjective Optimization

Michael Emmerich
LIACS
emmerix@gmail.com

Manuel López-Ibáñez
University of Manchester
manuel.lopez-ibanez@manchester.ac.uk

Kaisa Miettinen
University of Jyväskyla
kaisa.miettinen@jyu.fi

Track(s): 22

Multiple Classifier Systems and Applications

Koen W. De Bock
Audencia Business School
kdebock@audencia.com

Sureyya Ozogur-Akyuz
Bahcesehir University
sureyya.akyuz@eng.bau.edu.tr

Track(s): 28

Multiple Criteria Decision Aiding

Salvatore Corrente
University of Catania
salvatore.corrente@unict.it

Michalis Doumpos
Technical University of Crete
mdoumpos@dpem.tuc.gr

José Rui Figueira
CEG-IST, Instituto Superior Técnico, Universidade de Lisboa
figueira@tecnico.ulisboa.pt

Milosz Kadzinski
Poznan University of Technology
milosz.kadzinski@cs.put.poznan.pl

Constantin Zopounidis
Technical University of Crete
kostas@dpem.tuc.gr

Track(s): 10

Network Optimization and Social Networks

Christina Büsing
RWTH Aachen University
buesing@math2.rwth-aachen.de

Markus Leitner
University of Vienna
markus.leitner@univie.ac.at

Track(s): 16

New Challenges in Investment Strategies, Risk and Financial Modelling

Roy Cerqueti
University of Macerata
roy.cerqueti@unimc.it

Giulia Rotundo
Sapienza University of Rome
giulia.rotundo@uniroma1.it

Track(s): 4

Nonlinear Programming: Methods

Chong Li
Zhejiang University
cli@zju.edu.cn

Marco A. López-Cerdá
Alicante University
marco.antonio@ua.es

Xiaoqi Yang
The Hong Kong Polytechnic University
mayangxq@polyu.edu.hk

Track(s): 14

Nonlinear Programming: Theory

Chong Li
Zhejiang University
cli@zju.edu.cn

Marco A. López-Cerdá
Alicante University
marco.antonio@ua.es

Xiaoqi Yang
The Hong Kong Polytechnic University
mayangxq@polyu.edu.hk

Track(s): 21

Numerical and Simulation Methods in Finance

Hacer Öz
Applied Mathematics
haceroz.oz@gmail.com

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl

Fikriye Yilmaz
Gazi University
yfikriye@gmail.com

Track(s): 34

Opening and Closing

Ramon Alvarez-Valdes
University of Valencia
ramon.alvarez@uv.es

Ruben Ruiz
Universitat Politècnica de València
rruiz@eio.upv.es

Track(s): 1

Operational Research in Financial and Management Accounting

Matthias Amen
Bielefeld University
Matthias.Amen@uni-bielefeld.de

Track(s): 17

Operations/Marketing Interface

Kathryn E. Stecke
The University of Texas at Dallas
KStecke@utdallas.edu

Xuying Zhao
University of Notre Dame
xzhao1@nd.edu

Track(s): 53

Optimal Control

Stefan Wrzaczek
Wittgenstein Centre
stefan.wrzaczek@tuwien.ac.at

Track(s): 24

Optimal Control Applications

Gernot Tragler
Vienna University of Technology
gernot.tragler@tuwien.ac.at

Stefan Wrzaczek
Wittgenstein Centre
stefan.wrzaczek@tuwien.ac.at

Track(s): 4

Optimization in Renewable Energy Systems

Serap Ulusam Seckiner
University of Gaziantep
seckiner@gantep.edu.tr

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl

Track(s): 56

OR Advances in Agribusiness

Jorge E. Hernández
University of Liverpool
J.E.Hernandez@Liverpool.ac.uk

Track(s): 59

OR and Ethics

Cathal Brugha
University College Dublin
Cathal.Brugha@ucd.ie

Dorien DeTombe
Founder and Chair Euro Working Group
detombe@nosmo.nl

Erik Kropat
Universität der Bundeswehr München
erik.kropat@gmx.de

Pierre Kunsch
Vrije Universiteit Brussel
pkunsch@vub.ac.be

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl

Track(s): 14

OR Education

Maria Antónia Carravilla
Universidade do Porto | Faculdade de Engenharia
mac@fe.up.pt

Track(s): 58

OR for Developing Countries

Pedamallu Chandra Sekhar
Dana-Farber Cancer Institute
pcs.murali@gmail.com

Herman Mawengkang
The University of Sumatera Utara
mawengkang@usu.ac.id

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl

Track(s): 50

OR for Health and Care I

Joana Matos Dias
Inesc Coimbra
joana@fe.uc.pt

Humberto Rocha
University of Coimbra
hrocha@mat.uc.pt

Ana Viana
Inesc Tec/isep
aviana@inescporto.pt

Track(s): 52

OR for Health and Care II

Joana Matos Dias
Inesc Coimbra
joana@fe.uc.pt

Humberto Rocha
University of Coimbra
hrocha@mat.uc.pt

Ana Viana
Inesc Tec/isep
aviana@inescporto.pt

Track(s): 51

OR for Sustainable Development

Sadia Samar Ali
King Abdul-Aziz University
sadiasamarali@gmail.com

Vida Maliene
School of the Built Environment, Liverpool John Moores University
v.maliene@ljmu.ac.uk

Tatjana Vilutiene
Vilnius Gediminas Technical University
tatjana.vilutiene@vgtu.lt

Track(s): 51

OR in Agriculture, Forestry and Fisheries

Victor M. Albornoz
Universidad Tecnica Federico Santa Maria
victor.albornoz@usm.cl

Concepcion Maroto
Universitat Politecnica de Valencia
cmaroto@eio.upv.es

LluisM Pla
University of Lleida
lmpla@matematica.udl.es

Track(s): 49

OR in Neuroscience

Dorit Hochbaum
UC Berkeley
hochbaum@ieor.berkeley.edu

Track(s): 56

OR in Quality Management

Ipek Deveci Kocakoç
Dokuz Eylul University Faculty of Economics and Administrative Sciences
ipek.deveci@deu.edu.tr

Track(s): 53

OR in Sports

Dries Goossens
Ghent University
Dries.Goossens@ugent.be

Konstantin Pavlikov
University of Southern Denmark
kop@sam.sdu.dk

Frits Spieksma
Eindhoven University of Technology
f.c.r.spieksma@tue.nl

Track(s): 54

OR in the Physical Internet

José Fernando Oliveira
INESC TEC and Faculty of Engineering, University of Porto
jfo@fe.up.pt

António Ramos
ISEP
agr@isep.ipp.pt

Elsa Silva
Inesc Tec
emsilva@inescporto.pt

Track(s): 8

OR in Water and Hydro Energy Management

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl

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Plenaries

Greet Vanden Berghe
KU Leuven
greet.vandenberghe@cs.kuleuven.be

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Production and Operations Management

Nevin Mutlu
Eindhoven University of Technology
n.r.mutlu@tue.nl

Track(s): 3

Production, Service and Supply Chain Management

Michal Tzur
Tel Aviv University
tzur@eng.tau.ac.il

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Project Management and Scheduling

Joanna Józefowska
Poznan University of Technology
Joanna.Jozefowska@cs.put.poznan.pl

Jan Weglarz
Poznan University of Technology
jan.weglarz@cs.put.poznan.pl

Track(s): 21

Public Transportation I

Marie Schmidt
Erasmus University Rotterdam
schmidt2@rsm.nl

Anita Schöbel
University Goettingen
schoebel@math.uni-goettingen.de

Track(s): 26

Public Transportation II

Marie Schmidt
Erasmus University Rotterdam
schmidt2@rsm.nl

Anita Schöbel
University Goettingen
schoebel@math.uni-goettingen.de

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Routing, Logistics, Location and Transportation

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Scheduling Practice

Tony Wauters
KU Leuven
tony.wauters@cs.kuleuven.be

Track(s): 2

Scheduling Theory

Denis Trystram
ID-Institut IMAG
Denis.Trystram@imag.fr

Track(s): 15

Scheduling with Resource Constraints

Norbert Trautmann
University of Bern
norbert.trautmann@pqm.unibe.ch

Track(s): 7

Scheduling, Timetabling and Project Management

Tony Wauters
KU Leuven
tony.wauters@cs.kuleuven.be

Track(s): 6

Service Operations Management

Zeynep Aksin
Koc University
zaksin@ku.edu.tr

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Soft OR, Problem Structuring Methods

Leroy White
bristol
sh340@bath.ac.uk

Mike Yearworth
University of Exeter
m.yearworth@exeter.ac.uk

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Soft OR, Problem Structuring Methods and Behavioural OR

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Software for Optimization

Timo Berthold
Fair Isaac Germany GmbH
timoberthold@fico.com

Robert Fourer
AMPL Optimization Inc.
4er@ampl.com

Track(s): 57

Stochastic and Robust Optimization

Milos Kopa
Charles University in Prague, Faculty of Mathematics and Physics
kopa@karlin.mff.cuni.cz

Chungmok Lee
Hankuk University of Foreign Studies
chungmok@hufs.ac.kr

Francesca Maggioni
University of Bergamo
francesca.maggioni@unibg.it

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Stochastic Assessment of Renewable Energy

John Boland
University of South Australia
john.boland@unisa.edu.au

Track(s): 53

Stochastic Modeling and Simulation in Engineering, Management and Science

Katsunori Ano
Shibaura Institute of Technology
kano2@mac.com

Bhakti Stephan Onggo
Trinity College Dublin
stephan.onggo@tcd.ie

Zeev (Vladimir) Volkovich
Ort Braude Academic College
zeev@actcom.co.il

Gerhard-Wilhelm Weber
Poznan University of Technology
gerhard-wilhelm.weber@put.poznan.pl

Track(s): 6

Stochastic Models and Queueing

Raik Stolletz
University of Mannheim
stolletz@bwl.uni-mannheim.de

Track(s): 6

Supply Chain Management I

Nesim Erkip
Bilkent University
nesim@bilkent.edu.tr

Track(s): 19

Supply Chain Management II

Michal Tzur
Tel Aviv University
tzur@eng.tau.ac.il

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Sustainable Supply Chains

Gal Raz
College of Law and Business
graz@clb.ac.il

Track(s): 34

System Dynamics Modeling and Simulation

Markus Schwaninger
Universität St.Gallen
markus.schwaninger@unisg.ch

Evgenia Ushakova
University of St. Gallen
evgenia.ushakova@unisg.ch

Track(s): 10

Technical and Financial Aspects of Energy Problems

Luis Baringo
Universidad de Castilla-La Mancha
Luis.Baringo@uclm.es

Raimund Kovacevic
Institut für Stochastik und Wirtschaftsmathematik, ORCOS
raimund.kovacevic@tuwien.ac.at

Track(s): 59

Timetabling

Sanja Petrovic
Nottingham University Business School
Sanja.Petrovic@nottingham.ac.uk

Greet Vanden Berghe
KU Leuven
greet.vandenberghe@cs.kuleuven.be

Track(s): 23

Transportation

Riccardo Rossi
University of Padova
riccardo.rossi@unipd.it

Track(s): 18

Transportation and Logistics

Mike Hewitt
Loyola University Chicago
mhewitt3@luc.edu

Track(s): 30

Variational Inequalities

Patrizia Daniele
University of Catania
daniele@dmi.unict.it

Laura Rosa Maria Scrimali
Università di Catania
scrimali@dmi.unict.it

Track(s): 33

Vector- and Set-Valued Optimization

Lidia Huerga
Universidad Nacional de Educación a Distancia, UNED
lhuerga@ind.uned.es

Vicente Novo
Universidad Nacional de Educacion a Distancia
vnovo@ind.uned.es

Track(s): 19

Vehicle Routing and Logistics Optimization I

Roberto Roberti
Vrije Universiteit Amsterdam
r.roberti@vu.nl

Michael Schneider
RWTH Aachen
schneider@dpo.rwth-aachen.de

Track(s): 5

Vehicle Routing and Logistics Optimization II

Roberto Roberti
Vrije Universiteit Amsterdam
r.roberti@vu.nl

Michael Schneider
RWTH Aachen
schneider@dpo.rwth-aachen.de

Track(s): 15

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Author Index

Maggi, Mario TB-04, TC-04
mario.maggi@unipv.it
Department of Economics and Management, University of Pavia, Pavia, Italy

Maggioni, Francesca TD-17, WC-30
francesca.maggioni@unibg.it
Department of Management, Economics and Quantitative Methods, University of Bergamo, Bergamo, Italy, Italy

Mahéo, Arthur MC-26
arthur.maheo@anu.edu.au
ANU, Australia

Mahdavi, Mojtaba MC-13
m.mahdavi@auckland.ac.nz
Business School, The University of Auckland, Auckland, New Zealand

Maheut, Julien WB-23
juma2@upv.es
Departamento de Organizacion de Empresas, Universitat Politecnica de Valencia, Valencia, Spain

Maheut, Julien WD-15, TB-53
juma2@upvnet.upv.es
Departamento de organización de empresas, Universidad Politecnica de Valencia, Valencia, Spain

Mahler, Cláudio Fernando MD-54
mahler@coc.ufrj.br
Getres/coppe, Ufrj, Rio de Janeiro, Brazil

Mahmud, Salaheddin TA-33
salah.mahmud@umanitoba.ca
Department of Community Health Sciences, University of Manitoba, Winnipeg, Manitoba, Canada

Maia, Fábio TD-08
8090379@estgf.ipp.pt
CIICESI, Instituto Politécnico do Porto, Felgueiras, Portugal

Maillart, Lisa WB-03, WC-03
maillart@pitt.edu
University of Pittsburgh, United States

Maina, Samuel Chege MB-49
samuelm@ke.ibm.com
Inclusive Financial Services, IBM Research Africa, Nairobi, Kenya

Maiza, Mohamed WD-29
maiza_mohamed@yahoo.fr
Laboratoire de Mathématiques Appliquées, Ecole Militaire Polytechnique, Algiers, Algeria

Majewska, Justyna TA-24
justyna.majewska@ue.katowice.pl
Department of Demography and Economic Statistics, University of Economics in Katowice, Katowice, Katowice, Poland

Makajic-Nikolic, Dragana MC-13
gis@fon.rs
Laboratory for Operational Research, Faculty of Organization Sciences, Serbia

Makiishi, Naoya WC-16
c5617165@aoyama.jp
Management Technology Course, Graduate School Of Science And Engineering, Aoyama Gakuin University, Japan

Makui, Ahmad TA-12
amakui@iust.ac.ir
Industrial Engineering, Iran University of Science and Technology, Tehran, Iran, Islamic Republic Of

Malaguti, Enrico WC-08
enrico.malaguti@unibo.it
DEI, University of Bologna, Bologna, Italy

Maldonado, Sebastian TA-11, TD-11, WC-21
smaldonado@uandes.cl
School of Engineering and Applied Sciences, Universidad de los Andes, Santiago, Chile

Malicki, Sebastian TD-23
sebastian.malicki@tum.de
TUM School of Management, Technical University of Munich, München, Germany

Malladi, Krishna Teja MA-50
kmalladi@alumni.ubc.ca
Industrial Engineering Research Group, Dept. of Wood Science, University of British Columbia, Vancouver, British Columbia, Canada

Mallor, Fermin WB-56
mallor@unavarra.es
Statistics and O.R., Public University of Navarre, Pamplona, Spain

Malloy, Timothy MD-54
malloy@law.ucla.edu
School of Law, UCLA, Los Angeles, CA, United States

Malpass, Jonathan MD-31
jonathan.malpass@bt.com
Research & Innovation, BT, Ipswich, Suffolk, United Kingdom

Mancinelli, Marco TC-13
marco.mancinelli@uniroma1.it
Ph.D School in Economics and Finance, Sapienza University of Roma, Roma, Italy, Italy

Mancini, Simona MC-15, MB-30
simona.mancini@unica.it
Dipartimento di Matematica e Informatica, Universita' di Cagliari, Torino, Italy

Mancuso, Alessandro MC-20
alessandro.mancuso@aalto.fi
Systems Analysis Laboratory, Aalto University School of Science, Finland

Mandal, Prasenjit WD-52
prasenjit.mandal10@iimb.ernet.in
Decision Sciences and Information Systems, Indian Institute of Management Bangalore, Bangalore, Karnataka, India

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