Betacom

Integrated Planning of Vehicle Routes and Warehouse Operations

Mariusz Kaleta
Warsaw University of Technology
Paweł D. Domański
Betacom SA

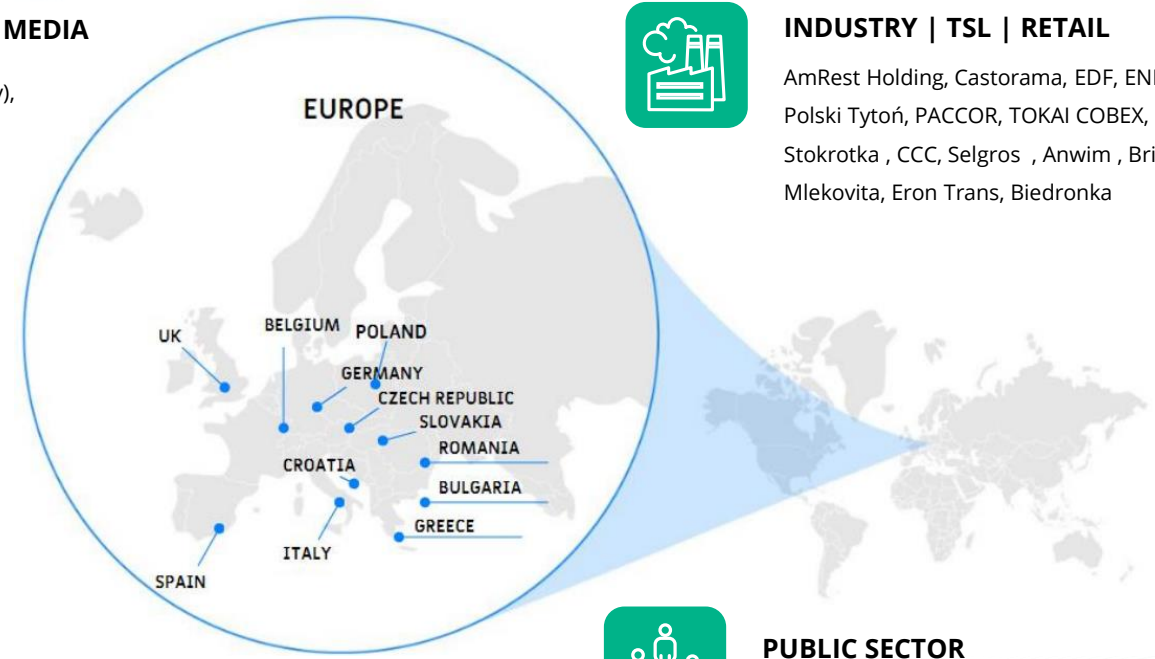
R&D project

- National Center for Research and Development
- **Title:** *Optimization of large-scale intralogistics processes, the fleet structure and distribution process applying multi-criteria distribution planning algorithms*
- **Value:** €2 900 000
- **Time:** 05/2022 - 06/2024

Betacom Project & Customers

TELECOMUNICATION| MEDIA

Exatel, Netia, Orange, P4 (Play), Polkomtel (Plus),T-Mobile, Cyfrowy Polsat, NC+



INDUSTRY | TSL | RETAIL

AmRest Holding, Castorama, EDF, ENEA, Ceramika Paradyż, Polski Tytoń, PACCOR, TOKAI COBEX, DHL, Abrasives, Stokrotka , CCC, Selgros , Anwim , Bricoman, AMIC, Mlekovita, Eron Trans, Biedronka

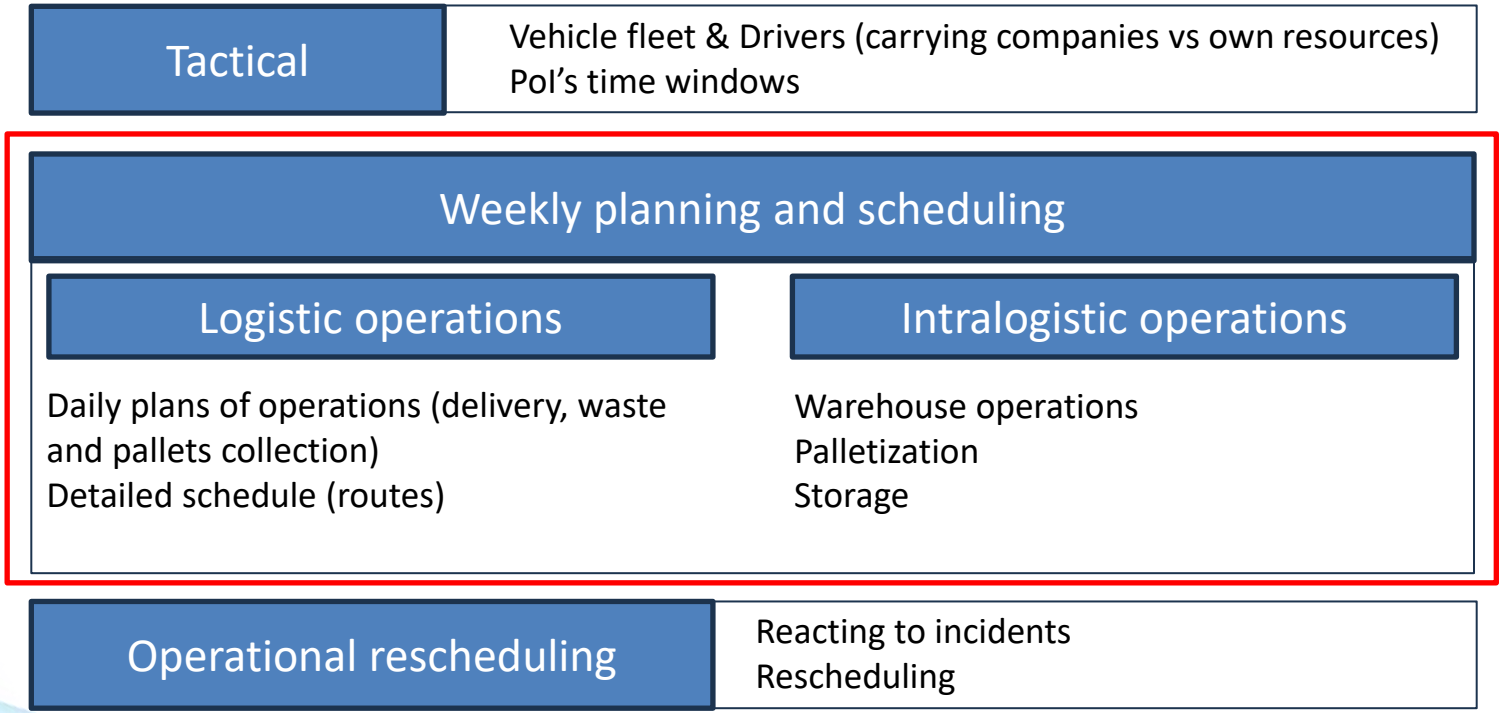
FINANCE

AVIVA, VIG, PZU, Provident, Bank Ochrony Środowiska, Bank Pekao, Citi Handlowy, DNB Bank Polska, ING Bank Śląski, PKO BP, Grupa SGB, Grupa BPS, Raiffeisen Bank, mBank

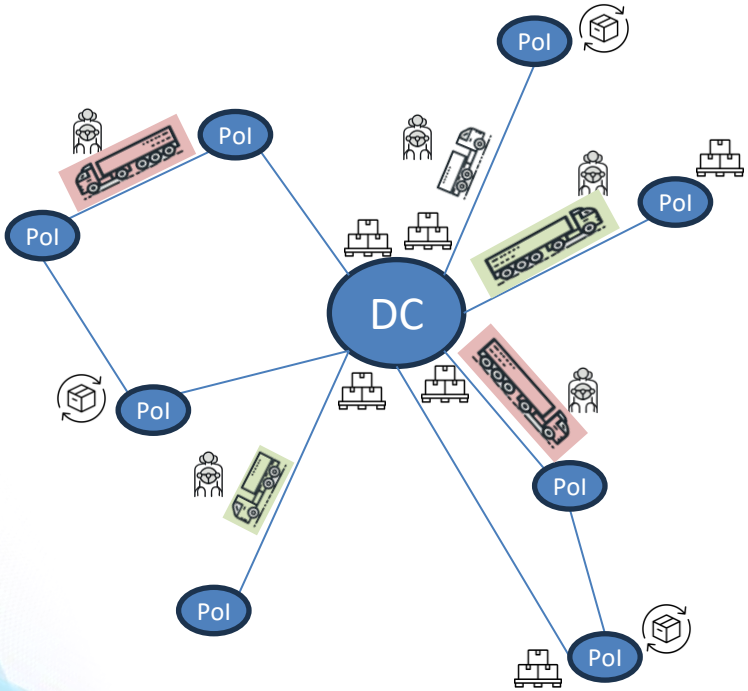
PUBLIC SECTOR

KNF, Miasto. st. Warszawa, Ministerstwo Finansów, Ministerstwo Skarbu Państwa, Ministerstwo Sprawiedliwości, ZUS, PKN Orlen

Multi-layered decision problem



Logistic operations

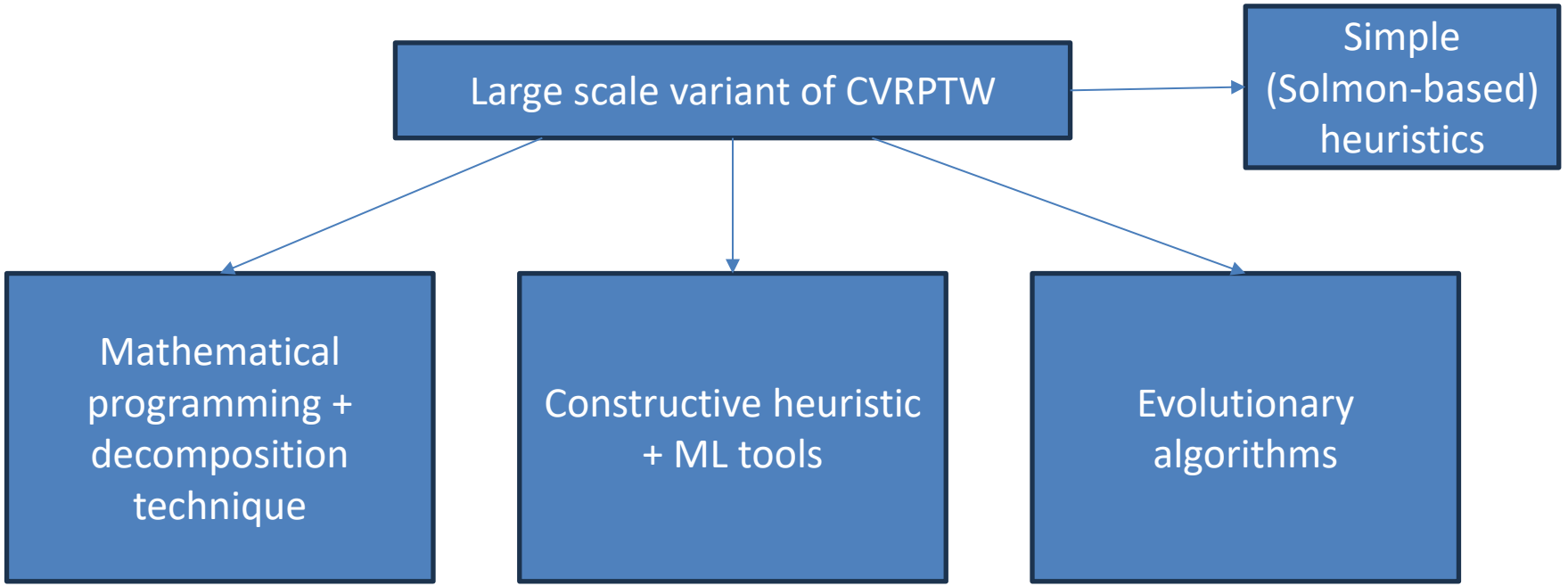


- Distribution Center
  - Capacities organized in shifts
- PoIs
  - Hard and soft time windows with priorities and constraints
- Vehicles
  - Solo (<=21EP)
  - Tractor + Semi-trailer (>21EP)
- Drivers
- Carrying companies
  - Different model costs
- Tasks
  - Volumes of pallet to be distributed
    - Orders
    - Allocations
  - Wastes to collect
  - Pallets to collect
- Horizon: week

KPIs

- Number of pallets not delivered
- Total cost
  - Distance
  - Driving time
  - Number of routes
  - ...
- Max and total time of late or early visits
- Pallet picking balance (regarding shift capacity)
- Carrying companies' balance
- Fill in ratio
- ...

Several methods developed simultaneously

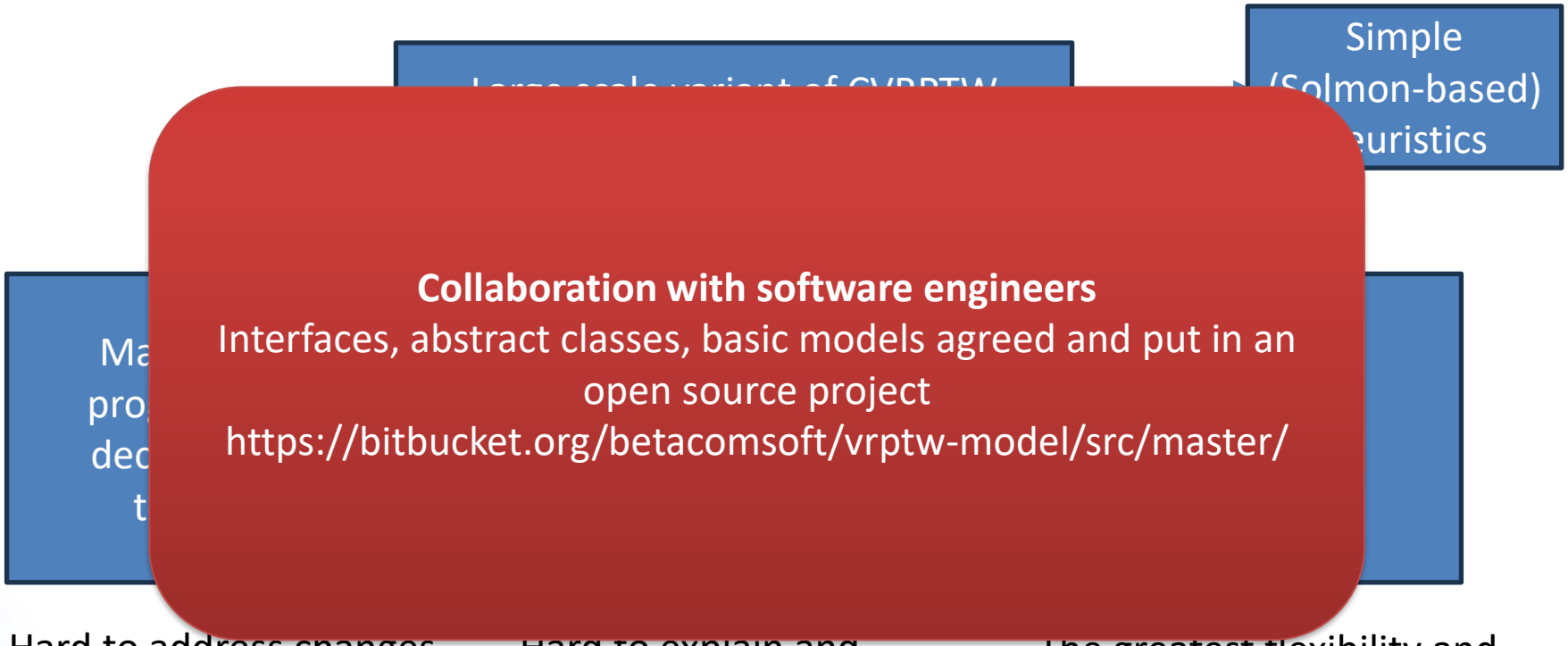


Hard to address changes in requirements

Hard to explain and control the behavior

The greatest flexibility and robustness toward unclear requirements

Several methods developed simultaneously



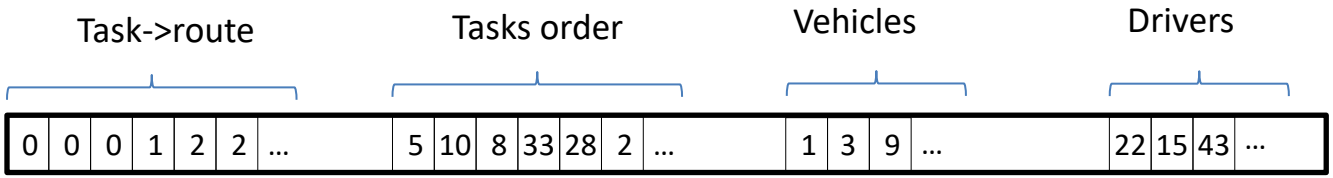
Hard to address changes in requirements

Hard to explain and control the behavior

The greatest flexibility and robustness toward unclear requirements

Genetic algorithm

- Coding



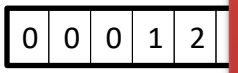
- Operators (mutations and crossovers)

Tasks order	Tasks switching between routes	Resources of a route	Mixed
Modification of task order on a route Modification of task order on a subroute Delay or advance the start of your route	Move request to another route Swap request between routes Merge routes Merge/split requests	Change a driver for a route Change a vehicle for a route Change a resurce for unschedule task Swap resources	Get route from another solution

Genetic algorithm

- Coding

Task->rout



- Operato

Tasks order

Collaboration with ML experts

Predictive models

- Estimators for distances and travel time for different vehicle profiles
- Estimators for loading, unloading and at gate times
- Estimators for order volumes

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Delay or advance the start of your route

Merge routes
Merge/split requests

Change a resurce for unschedule task
Swap resources

from
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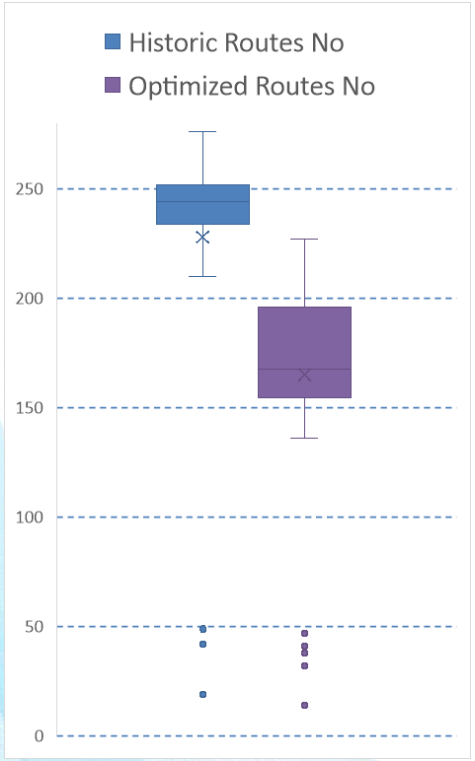
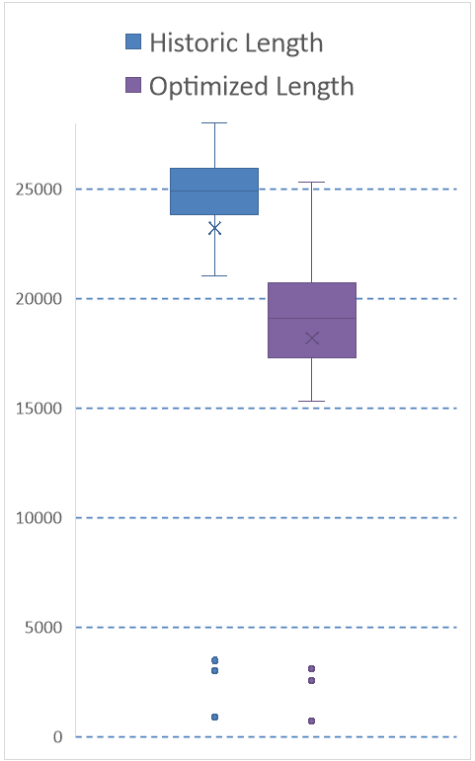
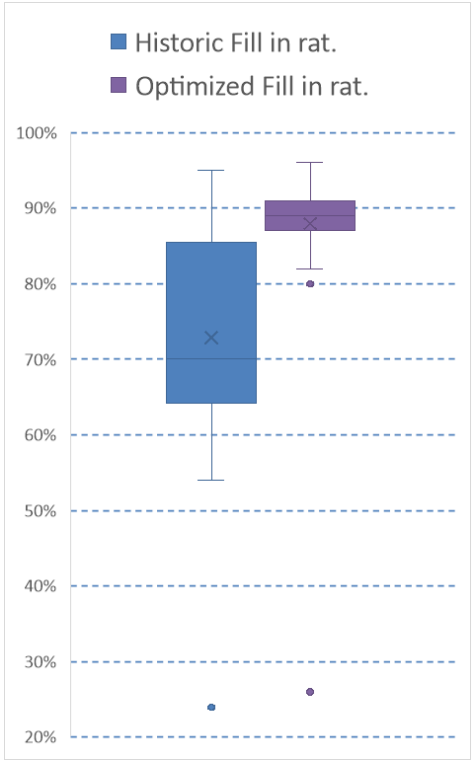
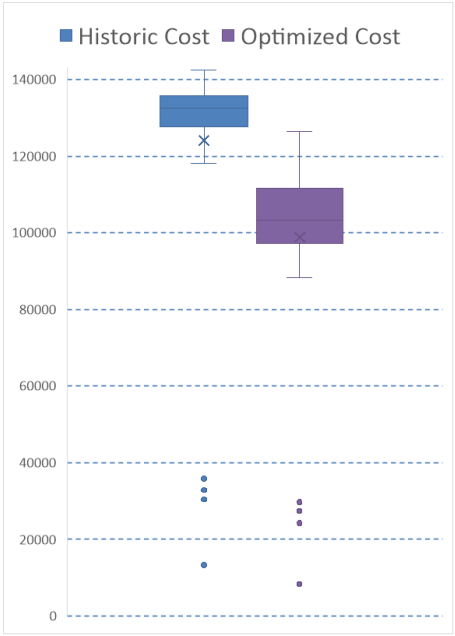
R&D initial results

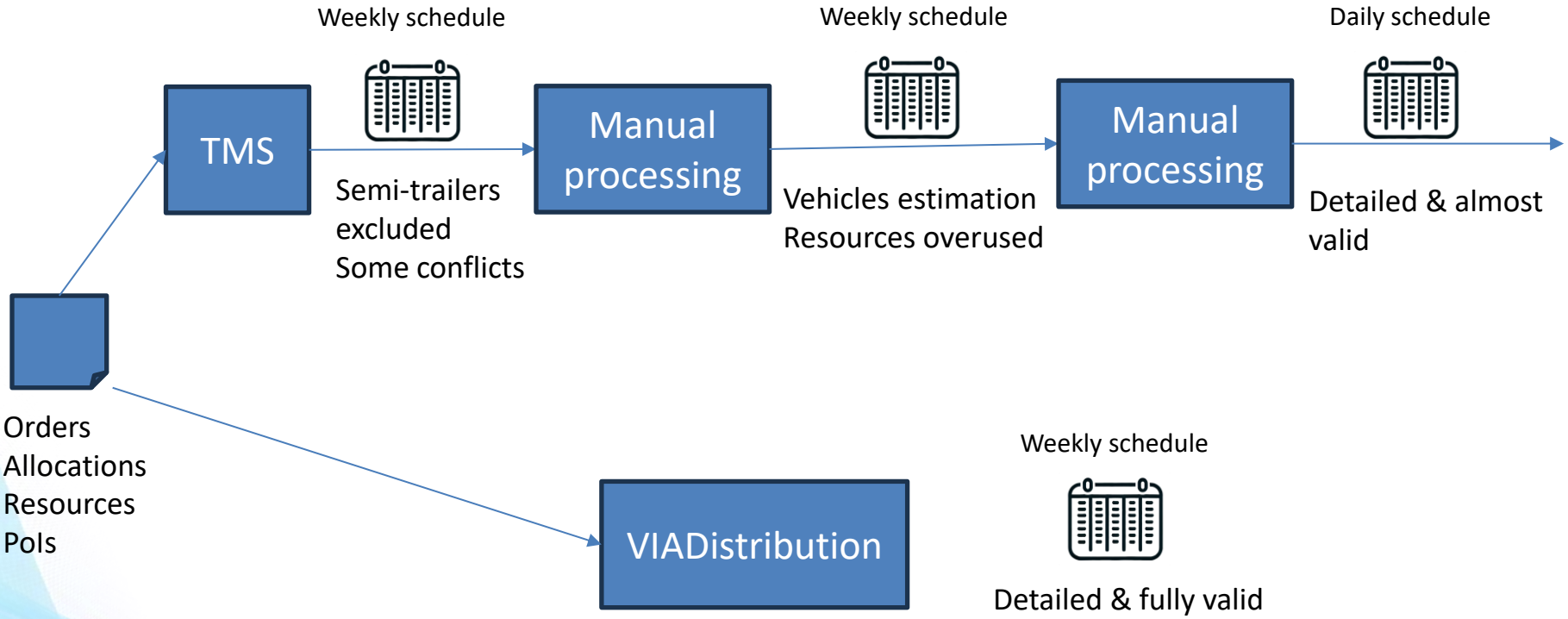








Is it good enough?



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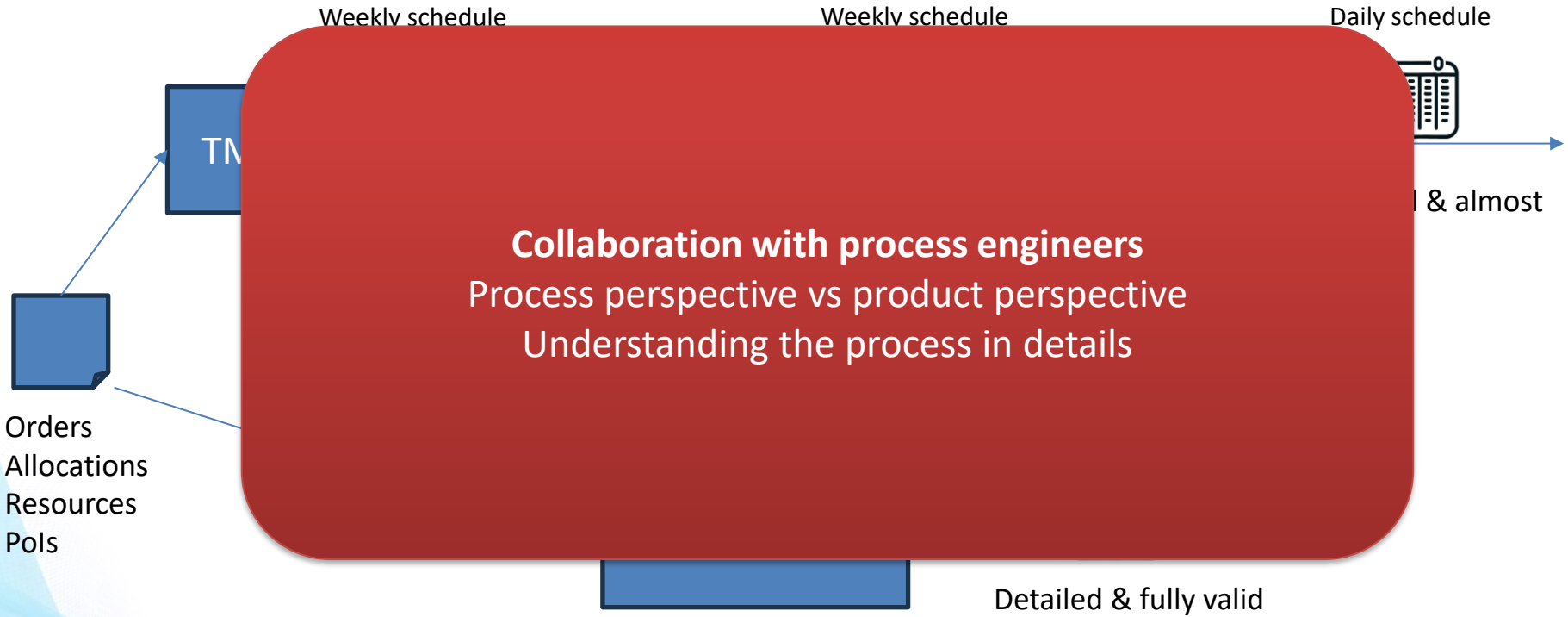
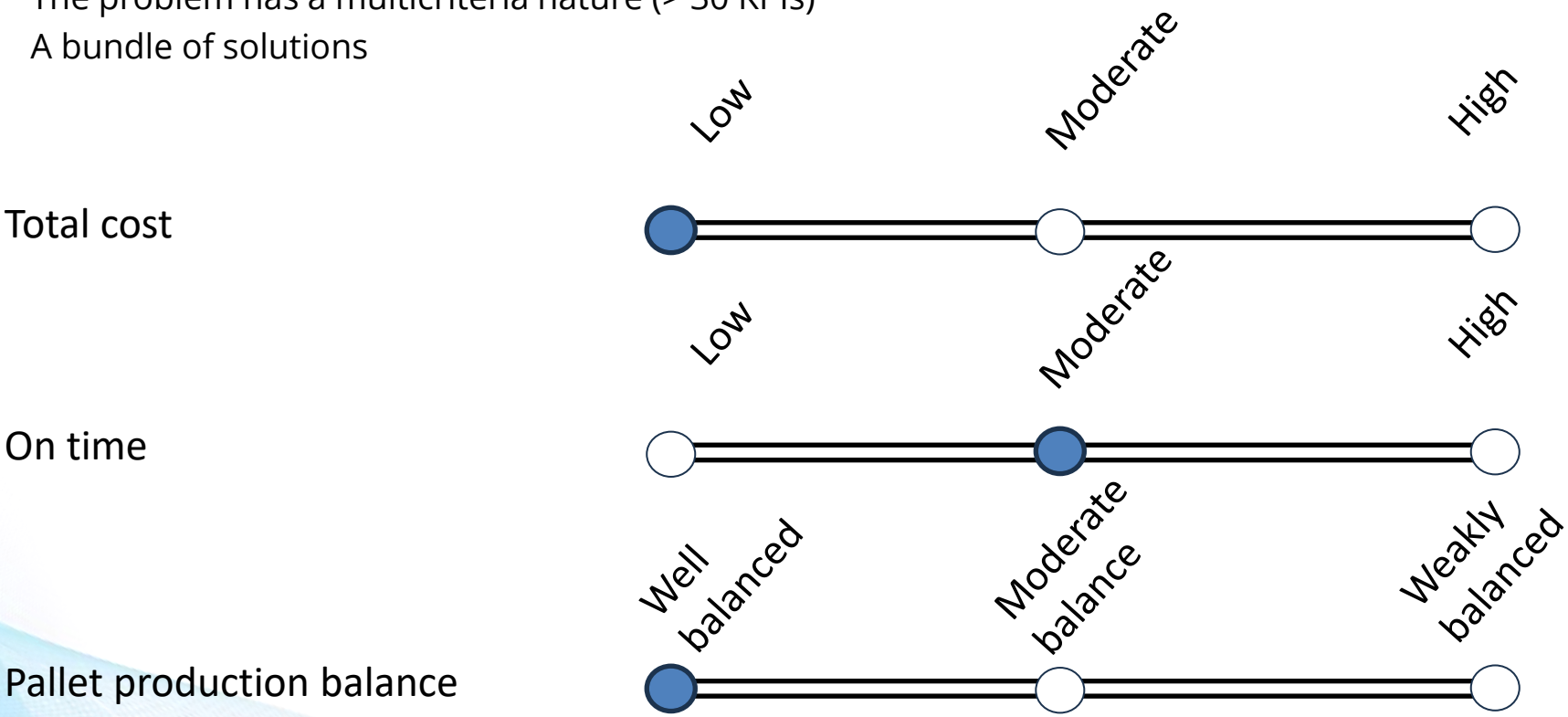


Is it good enough?

- The problem has a multicriteria nature (> 30 KPIs)
- A bundle of solutions



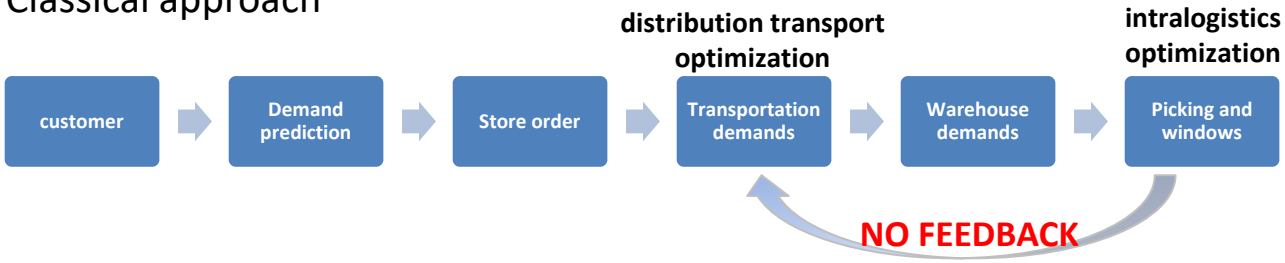
Intralogistics integration

- Schedule of logistic tasks should be feasible in regard to pallets collection capacities
  - Pallets cannot be prepared too early
  - Space for pallets storage is limited
  - Shifts at DC are not equal
  - Capacity of a shift is not static
- Different attempts to consider intralogistics capacities
  - Simple constraints
    - Max number of routes per hour
    - Max number of pallets per hour
    - Difference between min and max of above
  - Simplified model for intralogistics operations optimization
  - Agent-based model for detailed simulation

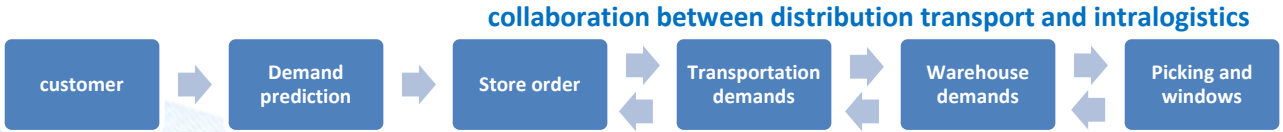
Collaboration with ML team
More estimators….

Intralogistic and optimization

- Perspective #1: INTRALOGISTIC DECISION SUPPORT
  - analysis of the intralogistic processes and their optimization: picking path planning
- Perspective #2: COLLABORATION challenge
  - Classical approach

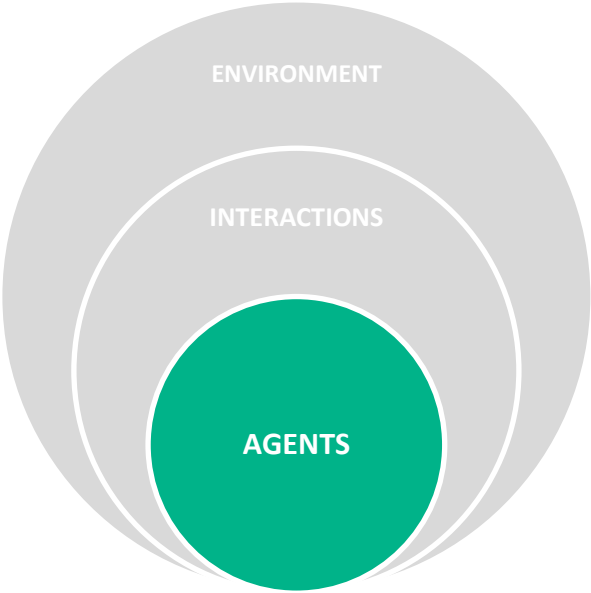


  - ITERATIVE AGENT COLLABORATION



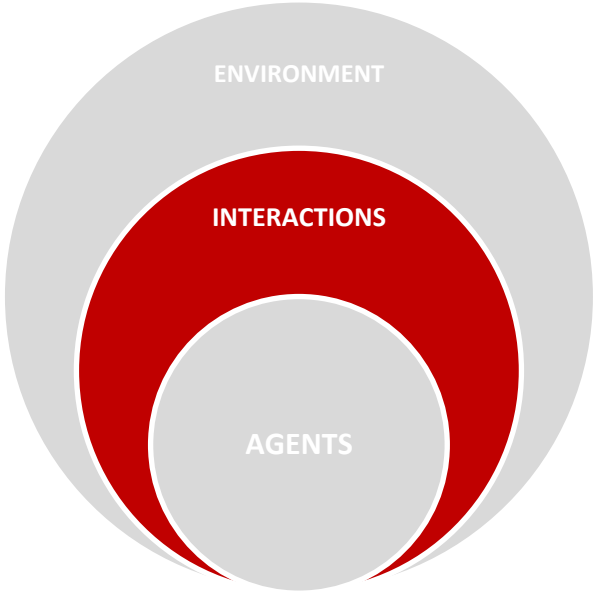
AGENTS

- Represent inanimate objects
- Represent active people
- Attributes based on data (geo-spatial model)
- Manipulate and use data
- Use data for planning
- Their functionality determines actions and sequence



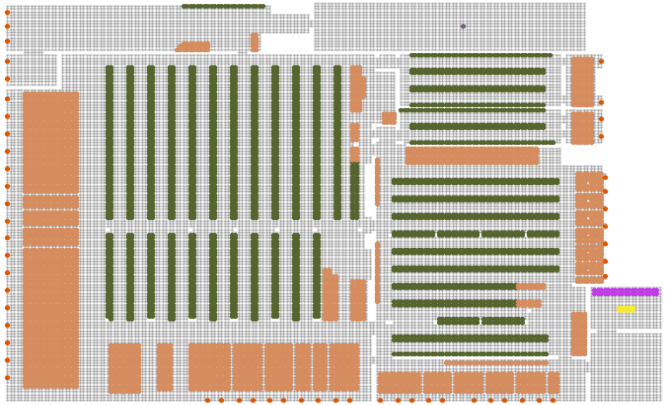
INTERACTIONS

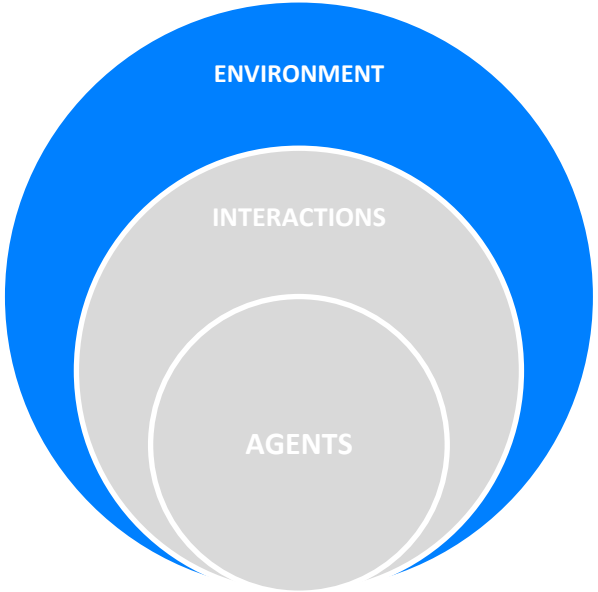
- Set of possible actions and methods for data exchange
- Cooperation with other agents
- Introduction of the concept of time and action in time
- Actions in space
- Calibration with respect to reality
- Learning ability :: adaptation and evolution
- Deterministic action
- Stochastic models of uncertainty



ENVIRONMENT

- Virtual world for agents
- Passive element
- Geo-spatial model
  - warehouse
  - road network
  - stadium or plane plan

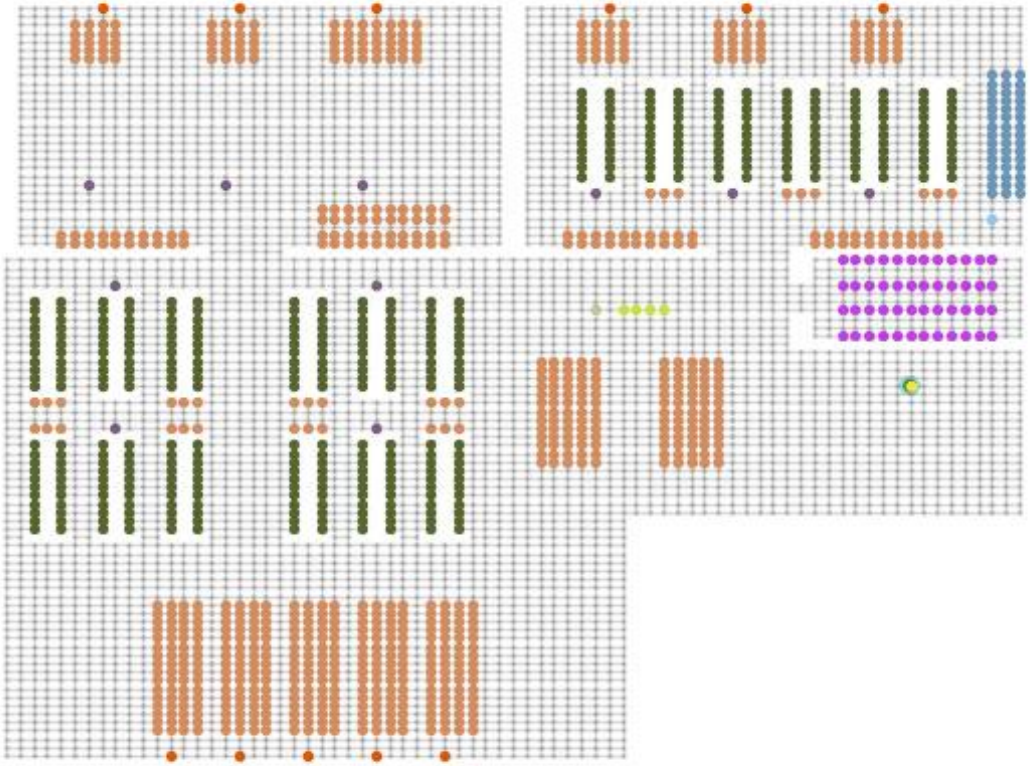




ADVANTAGES

- Scalable and explainable model
- Homogeneous approach to intralogistics and transport network
- Agents' self-adaptation using machine learning
- Data analytics (*what-if*)
- Analysis in various perspectives: time, space, complexity
- Allows optimization (decision-making support) both static (off-line) and dynamic (on-line)
- Statistical models for uncertainty – risk analysis

WAREHOUSE SIMULATION



Summary

- Crucial moments and decisions
  - Building common interfaces and models at the beginning with software engineers
  - Choosing an evolutionary algorithm for VRP, robust regarding changing business requirements (importance of a hot-start)
  - ML involved – estimators with well-defined interfaces
  - Process engineering involved – understanding the current process and common points
- Potentially crucial decisions
  - Agent-based warehouse operations model
- Potential obstacles
  - Process convergency not yet proved

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Thank you for your attention!

Mariusz Kaleta
Warsaw University of Technology
Paweł D. Domański
Betacom SA