POZNAN UNIVERSITY OF TECHNOLOGY

FACULTY OF CIVIL AND TRANSPORT ENGINEERING

ORSCDE SUSTAINABLE DEVELOPMENT CIVIL ENGINEERING

VILNIUS TECH Vilnius Gediminas Technical University

19th International Colloquium

Innovative Solutions in Sustainable Construction Management

9th Meeting of Euro Working Group Operational Research in Sustainable Development and Civil Engineering

May 28-29th 2024, Poznan, Poland

The colloquium proceedings- Abstracts

POZNAN UNIVERSITY OF TECHNOLOGY

19 TH INTERNATIONAL COLLOQUIUM

Innovative Solutions in Sustainable Construction Management

AND 9TH MEETING OF EURO WORKING GROUP OPERATIONAL RESEARCH IN SUSTAINABLE DEVELOPMENT AND CIVIL ENGINEERING

organized by

Division of Construction Engineering and Management

Institute of Building Engineering

Faculty of Civil and Transport Engineering

POZNAN UNIVERSITY OF TECHNOLOGY

PATRONAGE

ORGANIZING COMMITTEE

dr hab. inż. Jerzy Pasławski, prof. PUT
dr inż. Marcin Gajzler
dr inż. Piotr Nowotarski
mgr inż. Kinga Katafoni
mgr inż. Krzysztof Kotecki
mgr inż. arch. Kamila Włoch-Surówka

Dear Ladies and Gentlemen,

Dear Colleagues,

I am very happy about our meeting in Poznań. This is a special occasion – the founder and promoter of our Lithuania-Germany-Poland triangle is celebrating his 80th birthday.

Professor Edmundas Kazimieras Zavadskas celebrated this jubilee on May 12, 2024. This is also an opportunity for the 9th meeting of our Euro Working Group ORSCDE, which was also initiated by our Jubilant. From the perspective of my 40 years of work at the Poznań University of Technology, I would like to thank Professor Edmundas Kazimieras Zavadskas for many years of cooperation with our University. I admire the far-sighted policy of our Jubilant – focusing the work of our triangle on multi-criteria analysis and sustainable construction.

I fondly recall our first meetings in Poznań in this same Faculty Council Hall (though it was called differently then) – the visit to the Nadwarciańska Restaurant and the tour of the national gallery in Kórnik. It was a pleasure to meet regularly for over 30 years in Vilnius, Leipzig, and Poznań. Unfortunately, Professor Friedel Peldschus will not invite us to Leipzig anymore.

A typical meeting place for us was Kołobrzeg (we have our Creative and Recreational Workhouse there). I also remember meetings in Białystok and Kraków. Each of them was an opportunity to exchange views and encouraged further research work.

I wish all participants fruitful deliberations and a pleasant stay in Poznań.

dr hab. inż. Jerzy Pasławski, prof. PUT

Szanowni Państwo,

Drogie Koleżanki i Koledzy,

Jestem bardzo szczęśliwy z powodu naszego spotkania w Poznaniu. Jest to szczególna okazja – założyciel i animator naszego trójkąta Litwa – Niemcy – Polska obchodzi jubileusz 80-tych urodzin.

Profesor Edmundas Kazimieras Zavadskas odchodził 12 maja 2024 ten jubileusz. Jest to też okazja do 9-tego spotkania naszej Euro Working Group ORSCDE, która powstała także z inicjatywy Naszego Jubilata. Z perspektywy mojej 40-letniej pracy na Politechnice Poznańskiej chciałbym podziękować Panu Profesorowi Edmundasowi Kazimierasowi Zavadskasowi za wieloletnią współpracę z naszą Uczelnią. Podziwiam dalekowzroczną politykę naszego Jubilata – ukierunkowanie prac naszego trójkąta na analizę wielokryterialną i zrównoważone budownictwo.

Ze wzruszeniem wspominam pierwsze nasze spotkania w Poznaniu w tej samej Sali Rady Wydziału (wtedy nazywał się inaczej) – wizytę w Restauracji Nadwarciańskiej i zwiedzanie galerii narodowej w Kórniku. Miło było się spotykać systematycznie przez ponad 30 lat w Wilnie, Lipsku i Poznaniu. Niestety Pan Profesor Friedel Peldschus nie zaprosi nas więcej do Lipska.

Typowym dla nas miejscem spotkań był Kołobrzeg (mamy tam nasz Dom Pracy Twórczej i Wypoczynku). Pamiętam także spotkania w Białymstoku czy Krakowie. Każde z nich było okazją do wymiany poglądów i zachęcało do dalszej pracy badawczej.

Życzę wszystkim uczestnikom owocnych obrad i miłego pobytu w Poznaniu.

dr hab. inż. Jerzy Pasławski, prof. PUT

Content of abstracts

BIBLIOMETRIC ANALYSIS OF THE USE OF MULTI-CRITERIA DECISION-MAKING METHODS FOR FLOOD RISK MANAGEMENT IN URBAN AREAS

Gintarė Piaseckienė, Jurgita Antuchevičienė (VilniusTech, Lithuania)

KEYWORDS: floods, MCDM, IoT, AI, risk assessment

The ever increasing urbanization and changing climate patterns worldwide have led to an increase in the occurrence of floods, resulting in loss of life and significant economic damages in many areas. Various strategies are being developed for flood management and mitigation of its impacts by applying multi-criteria decision-making systems (MCDM), sentiment analysis research, and the latest technologies such as artificial intelligence (AI), Internet of Things (IoT). The key problem in reducing flood damage in urban areas becomes the selection of appropriate flood management strategies. This article reveals that in the last decade, the most significant issue has become the identification and mapping of flood-prone areas. Identifying the most flood-prone areas is crucial in order to implement the most appropriate nature-based solutions (NBS). Such as low-impact development systems (LID), storm water green infrastructure (SGI), sustainable urban drainage system solutions for flood management, as well as sustainable building and resilient urban planning strategies to adapt to climate change. By accurately mapping these areas, authorities can prioritize allocation of resources and investments towards implementing effective measures to mitigate the impact of flooding events on communities and infrastructure. Additionally, understanding flood-prone areas allows for better planning and decision-making when it comes to land use, development projects, and risk management.

According to the data from the Centre for Research on the Epidemiology of Disasters, in 2023, floods ranked first in terms of the number of natural disasters – with 164 incidents. Floods affected 32.4 million people, including those who lost their lives, were injured, lost their property or homes, or went missing. The cost of damages due to destroyed buildings, infrastructure, etc. in 2023 amounted to $20.4 billion U.S. Dollars. According to Statista data, economic losses for countries due to river-induced floods alone could increase by up to two or three times by 2100 if the temperature rises by 3 degrees Celsius. The collected data shows that economic losses in Europe can reach up to 48.6 billion euros per year. However, if adaptation and warming measures are implemented, economic losses could be reduced.

Solutions are being adopted for sustainable city planning that uses AI and IoT technologies. IoT devices collect and record data in real time. AI provides the ability to forecast and assist in decision-making (Samadi, 2022). Sentiment analysis studies are also used for decision-making, from which data can be obtained about infrastructure, drainage, and urban planning issues. The utilization and application of the research data and latest technologies can help in obtaining timely information that would assist MCDM decision-makers in making timely decisions by collecting indicators and creating strategies for sustainable city planning.

In this study, a bibliometric analysis was conducted. Articles from the Web of Science (//www.webofscience.com) and Scopus (//www.scopus.com) databases were selected. Ranging from 2015 to 2024 where analyzed. MCDM methods for flood risk management in urban areas were identified using the search term: ("flood" OR "flood*") AND ("Multi-criteria Decision Making" OR "Multi Criteria Decision-making" OR "Multi criterion Decision Makings" OR "MCDM"). After performing the initial search, 148 articles related to floods and MCDM were obtained. Then duplicates were removed, only early access and articles in the engineering category were selected in English language. After evaluating the obtained articles for the research, 41 articles were selected.

Based on the obtained bibliometric data, a keyword map was created using VOSviewer. Based on the obtained data, it was determined that the most frequently associated keywords with MCDM were flood controls, water management, land use, and mapping. Based on the grouping of articles according to objectives, it was determined that MCDM is most commonly applied for risk area identification/mapping, evaluation of LID solutions, and flood vulnerability assessment. In different regions, MCDM criteria are selected based on local and global significance. The most commonly used methods are fuzzy AHP, TOPSIS, and COPRAS, which were chosen for their simplicity and understandability.

The individuals, government institutions, and water management companies involved in flood management are increasingly faced with the challenges of addressing flood control, damage mitigation, sustainable building practices, and resilient urban planning due to climate change, urbanization, and decreasing available land for drainage. This means that they need to identify the most risk-prone areas, improve or their infrastructure, adopt NBS, LID and other sustainable building solutions that help address these issues in order to develop sustainable buildings, structures and cities. When searching for solutions, there arise many complex and precise problems in identifying vulnerable territories and selecting appropriate LID and NBS.

In this study, bibliometric data were reviewed, which showed that various MCDM methods are often used in solving flood management tasks, selected based on their simplicity, while indicators are chosen based on their local and overall importance. Finally, to enhance the success of MCDM in natural disaster management, decision-makers should consider incorporating sentiment analysis, as well as AI and IoT data, when selecting indicators in order to achieve optimal results in terms of sustainable buildings, integrated urban planning, and resilience in the face of natural disasters.

References:

CRED: Epidemiology of disasters. https://www.emdat.be/
Statista. https://www.statista.com/
Samadi, S. (2022). The convergence of AI, IoT, and big data for advancing flood analytics research. Frontiers in Water, 4, 786040. https://doi.org/10.3389/frwa.2022.786040

AUTOMATED VALUATION MODELS IN LITHUANIA – ADVANTAGES AND DISADVANTAGES

Audrius Šešplaukis (VilniusTech, Lithuania)

KEYWORDS: Automated Valuation Models, Real Estate, Advantages, Disadvantages.

The real estate market not only plays an important role in the global and Lithuanian real estate economy, but also accounts for a large share of global and national economic activity. Real estate valuation is important for banks and other lenders, developers, construction organisations, public authorities, taxpayers, home buyers and sellers, investors and other stakeholders involved in the real estate market. One of the largest investments in a person's life in Lithuania and in other parts of the world is in real estate. It is therefore no coincidence that much research has been carried out to develop automated valuation models to predict real estate sales prices as accurately as possible. Real estate appraisers currently value property using "manual" methods (*Lietuvos Respublikos turto* … 2012). Such methods usually involve site visits, surveys of property owners, and comparison of previous sale prices of similar neighbouring properties to establish a value. Of course, such appraisal and value determination takes longer compared to automated valuation models (AVMs). Manual methods can sometimes be subjective and lead to bias in the valuation of a property, especially when the valuers have different levels of experience and knowledge. Traditional valuation methods used in practice are based on an analysis of the cost of creating the asset or the financial performance of the business and do not take into account the influence of the many factors in the external environment that affect value. This can be addressed by multi-criteria methods, which provide a comprehensive assessment of the economic, legal, social, environmental, technological, political, psychological and other aspects. The use of AVMs can eliminate subjectivity, reduce the time spent on property valuation and thus reduce the need for site visits. The use of AVMs in real estate valuation can increase the accuracy of the valuation and eliminate bias in the valuations.

In the Republic of Lithuania, the most advanced in the development of an automated real estate valuation model is the State Enterprise Centre of Registers, which has developed a mass valuation system (since 2003 - land plots, since 2006 - buildings). This system, based on the efficient use of software and digital real estate data banks, is one of the most advanced not only in the Republic of Lithuania, but also in the world (Tumelionis, N.d). In Lithuania, regression analysis is used for mass valuation of land and buildings. Hybrid models are used to assess land and buildings. The specification of the constitutive model is based on data from a database of real estate transactions, and includes an analysis of the significance of the quantitative and qualitative characteristics of the assets and a decision on which characteristics of the assets are relevant to the value and need to be included in the model structure. In this mass valuation

model of the State Enterprise Centre of Registers, the individual characteristics of the property to be valued are taken into account: location (Value Zone), year of construction, year of reconstruction, wall material, floor of the apartment, number of floors of the building, heating, cellar (present/absent), sewage disposal, attic space and total floor area (VĮ Registrų centras, N.d.). Unfortunately, this model does not take into account the layout and number of rooms, the distances to kindergartens, schools, parks and shopping centres, the ratio of usable to ancillary floor space, the presence of all the utilities (gas, solar power, hot water), the energy efficiency, etc.

Automated valuation models used to quickly and inexpensively value real estate have a fundamental flaw: they only use data from submitted transactions, i.e. It does not take into account other information or its context; it does not perform an inspection of the property (the valuation is based on the implicit assumption that the property is in marketable condition); it is limited in the amount of data involved in some areas; it is limited in the amount of new data involved in some types of property; it is limited in its ability to take into account any unique characteristics of the property; and it is generally not suitable for specialised valuations. The advantages of the automated valuation model are: speed (more than 2.5 million land plots and more than 3.8 million buildings and premises are registered in Lithuania), no inspection of the object is required, the values determined are close to the market values, the valuation and the presentation of the results are maximally automated, the results of the valuation are objective, the valuator's bias is eliminated, the valuator's long-lasting experience and knowledge is not required, the accuracy of the valuation can be increased, and the valuation work requires minimal financial costs. Having identified and revealed the most important elements of mass valuation of real estate in Lithuania, the Lithuanian system of mass valuation of real estate can be described as a system of values and a natural system (based on the calculated area of real estate). This means that property is valued on the basis of the available digitised form, taking automated and transactional data obtained from notarial contracts, and mapping values. When considering how to obtain the most accurate calculation possible, additional factors such as correction factors become important.

References

Tumelionis, A. (N.d.). *Masinio vertinimo sistema. Lietuvos praktika 1990–2018*. Valstybės įmonė Registrų centras.

VĮ Registrų centras. (N.d.). *Masinio vertinimo dokumentų paieška*. Prieiga per internetą: https://www.registrucentras.lt/ntr/vertinimas/masinis/masvert.php

Lietuvos Respublikos turto ir verslo vertinimo pagrindų įstatymas. (2012), Nr. VIII-1202. Prieiga per internetą: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.82185/asr

Raslanas, S., & Šliogerienė, J. (2012). *Nekilnojamojo turto vertinimas*. Vilnius: Technika.

AN ANALYSIS OF ENVIRONMENT FACTORS AFFECTING THE ENERGY SECTOR IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT: THE MULTI-CRITERIA VALUATION

Jūratė Šliogerienė, Zenonas Turskis (VilniusTech, Lithuania)

Jūratė Šliogerienė - Institute of Sustainable of Construction, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania;
jurate.sliogeriene@vilniustech.lt

Zenonas Turskis - Institute of Sustainable of Construction, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania;
zenonas.turskis@vilniustech.lt

KEYWORDS: environment factors, sustainable development, energy sector, corporate value, multi-criteria analysis

The contemporary energy sector plays a pivotal role in ensuring the reliable production of safe, ecologically clean, efficient, and cost-effective energy. The development of energy companies, their increase in value, and their integration into international structures are all crucial aspects that stakeholders must base on monitoring environmental and value changes. The measures selected and applied for that purpose must consider performance, ecological integration, technological innovativeness, and ethical and socially responsible operation, underscoring the sector's vital role in sustainable development.

In the energy sector, the concept of sustainable development, which covers the aspects of economic, ecological and social evolution, is understood as an ability to reconcile economic growth from resource consumption and environmental pollution. The introduction of market principles in the energy sector should ensure efficient and sustainable use of resources. However, a market approach and an emphasis on economic interests do not provide sustainable energy sector development. The sustainable development of the energy sector becomes more significant in long-term economic growth because qualitative factors gain more weight. Activities of stakeholder groups that emphasize the importance of nature conservation, social responsibility and sustainable consumption are also practical. The future of the energy sector is a complex interplay of global politics and economic, social and environmental issues related to development, presenting a fascinating challenge for researchers and professionals.

The activities of the energy sector, or separate companies operating within it, are commonly analyzed using methods based on quantitative (primarily economic) indicators. However, to

truly understand the sector's dynamics, only those measures that enable evaluation of the entire set of factors which affect operation in the short term and the long term can be effective. It means that the measures must combine economic indicators of the period in question with indicators that describe a sector's (company's) ability to adjust to changing business conditions, solve its social tasks, and be a responsible part of the economy. For this task, stakeholders must compile a comprehensive system of criteria, enabling evaluation of qualitative and quantitative factors, and the most appropriate methods must be suggested to implement this task, highlighting the urgency and importance of your research in developing such a method.

The article presents a model for analyzing environmental factors affecting the energy sector. It suggests a method based on multi-criteria analysis to determine the impact of environmental factors on the value.

IDENTIFICATION OF THE KEY SUSTAINABILITY AREA FOR THE ASSESSMENT OF THE OFFICE BUILDINGS

Jolanta Tamošaitienė, Erikas Lenkevičius (VilniusTech, Lithuania)

Vilnius Gediminas Technical University, Saulėtekio ave., 11, Vilnius, Lithuania

KEYWORDS: sustainability, footprint, assessment, key area

The 2015 Paris Agreement marked the first global initiative requiring nearly 200 countries to act on climate change. The European Green Deal, launched in 2019, aims to further reduce greenhouse gas emissions by 2030. The construction sector contributes significantly to global emissions; consequently, it is scrutinised for its environmental performance at all building life cycle stages. The development of the real estate sector, where buildings are awarded environmental certificates, demonstrates the construction sector's commitment to sustainability and reducing environmental impacts. No precise sustainability indicators and parameters exist for assessing buildings, their construction processes and other relevant parameters. The assessment of the footprint, for example, for the office building, is related to the technical parameters with required assessment documents like the Environmental impact, Resource use and Primary energy, Waste categories, Output flows, etc.

Nowadays, sustainable development in construction focuses on environmental protection, economic efficiency, and social balance, emphasising energy efficiency improvement and environmental impact reduction.

Sustainability is a concept that refers to the long-term, wise and responsible use of resources to meet the needs of the present without compromising the ability to meet the needs of future generations. The concept is often described in terms of three key dimensions, known as the "three dimensions of sustainability":

- Social sustainability – including social justice, population health and well-being, community engagement;
- Economic sustainability – including resource management, profitability, and fostering innovation;
- Environmental sustainability – including conservation of natural resources and use of renewable energy sources.

INNOVATIVE METHODOLOGY FOR MULTI-CRITERIA LOCATION SELECTION IN CONSTRUCTION INVESTMENTS: A STRATEGIC APPROACH

Turskis Zenonas; Šaparauskas Jonas; Erdogan Seyit Ali; Thilina Ganganath Weerakoon (VilniusTech, Lithuania)

Turskis Zenonas - Institute of Sustainable of Construction, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania; zenonas.turskis@vilniustech.lt

Šaparauskas Jonas - Department of Construction Management and Real Estate, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania; ; jonas.saparauska@vilniustech.lt

Erdogan Seyit Ali - Institute of Sustainable of Construction, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania; ali_erdogan1907@hotmail.com

Thiliana Ganganath Weerakoon - Institute of Sustainable of Construction, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania; thilina.weerakoon@stud.vilniustech.lt .saparauska@vilniustech.lt

KEYWORDS: Investment Location Selection, Multi-Criteria Decision-Making, Hellwig rating method, Delphi study, CoCoSo, ARAS.

Abstract

In the fiercely competitive construction industry, the strategic selection of optimal investment locations is a critical determinant of project prosperity and yield maximisation. This research explores pioneering methodologies explicitly tailored to meet the nuanced requirements of stakeholders within the construction domain for multi-criteria location selection. The investigation delves into integrating cutting-edge decision-making frameworks, synthesising economic, environmental, social, and regulatory considerations to pinpoint the most conducive investment locales.

This study introduces an innovative methodology that fosters precision, efficacy, and strategic acumen in investment site selection within the construction sector. It leverages contemporary techniques such as multi-criteria optimisation and data-centric modelling.

Central to the presented approach is the deployment of sophisticated data-driven modelling techniques, including but not limited to the Delphi method, Eckenrode rating approach, ARAS

(Additive Ratio Assessment) methodology, Hellwig rating method (Wroclaw Taxonomy), and the CoCoSo method. The Delphi technique cultivates expert consensus through iterative structured communication rounds, facilitating a holistic understanding of diverse criteria. Meanwhile, the Eckenrode rating method enables methodical evaluation by assigning weighted scores to different factors commensurate with their significance. Furthermore, the ARAS methodology employs additive ratio assessment to systematically rank and prioritise potential investment sites, ensuring a comprehensive and data-rich decision-making trajectory.

Stakeholders are encouraged to apply pragmatic risk appraisal and mitigation strategies during collaborative evaluation and selection. Integrating risk assessment criteria into the multi-criteria decision-making framework enables a structured dissection of potential risks associated with each investment site, including environmental ramifications, regulatory ambiguities, and market vicissitudes. Transparent discussions are fostered through collaborative workshops and expert panels, aiding in the collective identification and appraisal of risks. Leveraging historical data and predictive analytics bolsters risk prognostication, facilitating the formulation of proactive risk mitigation strategies aligned with stakeholder risk thresholds.

Implementing the decision-making frameworks and methodologies outlined herein may pose challenges for stakeholders and investors. Ensuring the accessibility and integrity of diverse data sources (e.g., economic, environmental, social) mandates rigorous data collection and validation protocols. Stakeholder engagement and consensus-building may prove intricate, particularly in navigating disparate viewpoints and priorities. Addressing uncertainties regarding criteria weighting and decision parameters requires sensitivity analyses and scenario mapping. Operationalising selected investment sites mandates prudent resource allocation, regulatory adherence, and ongoing vigilance to pre-empt unforeseen risks and fortify project success.

These challenges underscore the need for interdisciplinary collaboration, technological assimilation, and adaptive managerial strategies to drive successful execution and optimise outcomes. Our findings provide invaluable insights and tools, empowering industry professionals and stakeholders to make well-informed investment decisions within the construction domain.

19 TH INTERNATIONAL COLLOQUIUM
Innovative Solutions in Sustainable Construction Management
AND 9TH MEETING OF EURO WORKING GROUP OPERATIONAL RESEARCH IN SUSTAINABLE DEVELOPMENT AND CIVIL ENGINEERING
MAY 28-29th 2024, Poznan, Poland

BIM-BASED PROTOTYPE OF A MATHEMATICAL MODEL OF CONSTRUCTION PLANNING

Robertas Kontrimovičius, Leonas Ustinovichius, Mantas Vaišnoras (VilniusTech, Lithuania)

Robertas Kontrimovičius - Department of Construction Management and Real Estate, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Vilnius, Lithuania; robertas.kontrimovicius@vilniustech.lt

Leonas Ustinovichius - Institute of Sustainable Construction, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Vilnius, Lithuania; leonas.ustinovicius@vilniustech.lt

Mantas Vaišnoras - Department of Construction Management and Real Estate, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Vilnius, Lithuania; mantas.vaisnoras@vilniustech.lt

KEYWORDS: BIM, photogrammetry, construction equipment selection, building information modelling, construction site planning.

Abstract

This article tackles the problem of rational and effective planning of the entire construction site, including the planning of mechanisms, equipment, warehouse space, temporary buildings, temporary engineering networks, etc. The authors propose the principles of creating a mathematical model to calculate the needs of construction objects, using the photogrammetry model. The problems raised can be solved with the use of BIM in the preparation for construction planning stage. The prototype mathematical model presented in this article addresses these issues: identify current situation, using photogrammetry model, define optimal number and location of construction site objects, avoid conflicts between cranes, detect possible hoisting problem, avoid overload of cranes, and of course construction site planning. Therefore, it becomes possible to perform a multicriteria decision-making analysis.

Extensive analysis in the pre-construction stage is often abandoned due to the lack of data on the current situation, difficult calculations of the need for mechanisms, equipment and simply due to the lack of time to analyze all possible rational solutions. The data received from the created mathematical prototype could also be used in further construction stages for planning human and material resources, the project schedule and cost estimate.

CONTRIBUTION OF EURO WORKING GROUP ON OPERATIONS RESEARCH IN SUSTAINABLE DEVELOPMENT AND CIVIL ENGINEERING TO THE DEVELOPMENT OF MULTI-CRITERIA DECISION-MAKING METHODS

Tatjana Vilutienė (VilniusTech, Lithuania)

Vilnius Gediminas Technical University, Lithuania

KEYWORDS: Multi-criteria decision-making; MCDM methods; EWG ORSDCE

Construction organisations operate in a constantly changing environment throughout their lifecycle. The various stakeholders involved in the construction process, as well as evolving and emerging technologies, have a significant impact on the efficiency of the construction sector. Obviously, the important role in the future development of the construction industry will have the application of new techniques and methods that can improve the efficiency of processes. Traditional optimisation approaches used in the engineering context are often based on the assumption that the problem under consideration is well formulated, and decision makers usually consider the existence of a single objective, assessment criterion, or viewpoint on which the conducted analysis is based. In reality, however, the modelling of engineering problems is based on a different logic that takes into account the conflicting objectives of decision-makers, the existence of multiple criteria, and the complex, subjective and heterogeneous nature of the evaluation process. Therefore, in the engineering context, multi-criteria methods contribute by identifying the optimal alternatives, taking into account the conflicts between criteria, and by revealing preferences.

The EURO Working Group on Operations Research in Sustainable Development and Civil Engineering (EWG ORSDCE) emphasises the importance of the aforementioned issues and strives to contribute to resolving the conflicts between the various competing objectives. The scientific school led by Professor Edmundas Kazimieras Zavadskas and strengthened by the establishment of the EWG ORSDCE raises the objective of developing and applying the multi-criteria methods in the fields of sustainable development and civil engineering. The paper aims to summarise the research on the developments of MCDM methods and to answer the question to what extent EWG members are contributing to this topic. This article presents an analysis of the contributions to the field of MCDM made using the data sets from Scopus database. The SciVal research performance assessment tool and VOSviewer tool were used to analyse the dataset of 6,507 publications on MCDM topic retrieved from Scopus.

The results of analysis show that researches from Vilnius Gediminas Technical University, University of Belgrade, University of Jaen, University of Granada, University of Portsmouth,

Polytechnic University of Valencia, University of Manchester and Poznan University of Technology are among top contributors to the development of MCDM in Europe (Figure 1).

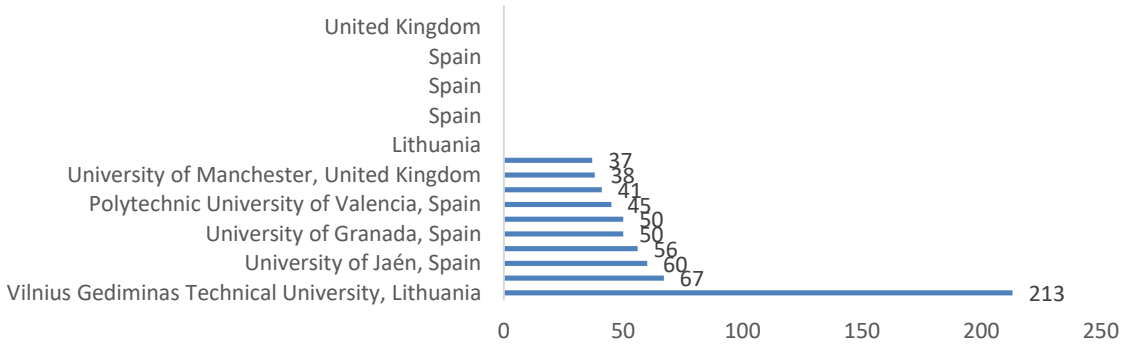


Figure 1. Top contributing institutions in Europe to the development of MCDM.

Research groups worldwide form several large clusters by topics, for example, largest cluster with 3021 publications focuses on decision making, fuzzy sets and models. Top 50 keywords by relevance based on 6,507 publications in analysed data set are presented in Figure 2. Top 5 authors in Europe contributing to the development of MCDM presented in Figure 3.

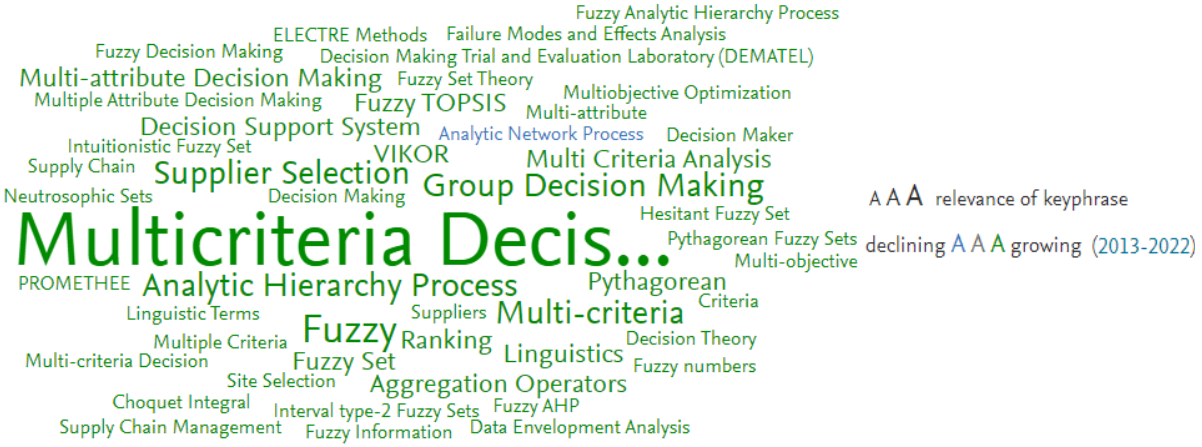


Figure 2. Top 50 keywords by relevance, based on 6,507 publications on MCDM topic (Scopus, SciVal, 2013-2022)

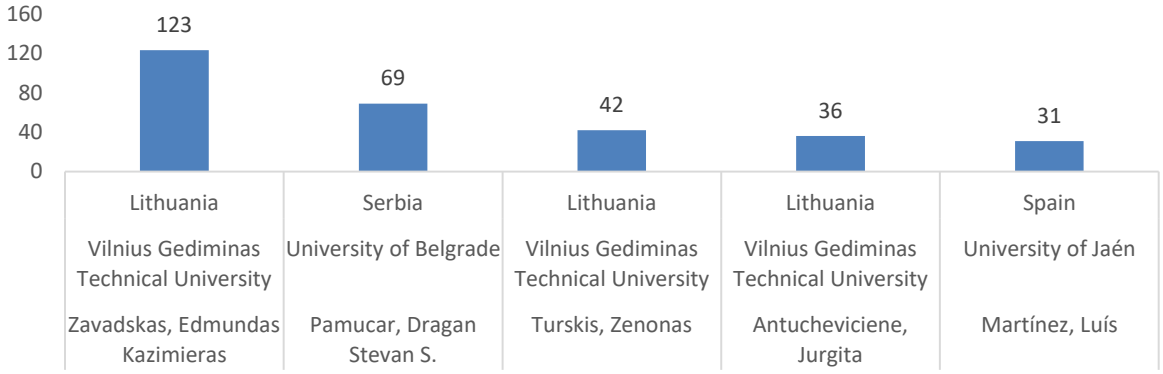


Figure 3. Top 5 contributing authors in Europe to the development of MCDM.

A MACHINE LEARNING APPROACH THROUGH ANN TO PREDICT SUSTAINABLE DEVELOPMENT IN THE CONSTRUCTION

Thilina Ganganath Weerakoon, Zenonas Turskis, Jurate Silogeriene, Keshmin Senaratna, Sulaksha Wimalasena (VilniusTech, Lithuania)

KEYWORDS: artificial neural network, machine learning, sustainable development, construction industry

In recent years, the integration of artificial intelligence (AI) and machine learning (ML) approaches has emerged as a transformative force in a variety of fields, including sustainable development initiatives. AI-powered solutions provide exciting potential for optimizing resource use, reducing environmental impact, and increasing overall efficiency, especially in the built environment, where sustainability is critical. As developing countries strive to achieve sustainability goals in their built environments, using current technology such as Artificial Neural Networks (ANNs) becomes increasingly important.

In this sense, ML systems, especially those based on ANN, have gained appeal for their capacity to analyze vast datasets, detect patterns, and generate accurate predictions. By training ANNs on historical data relating to energy consumption, environmental performance, and infrastructure use, stakeholders in the built environment may get significant insights into current patterns and future scenarios. Moreover, ANNs allow the flexibility to adjust and enhance models over time, therefore boosting their predictive powers and guiding strategic planning efforts.

Despite growing interest in using AI for sustainable development in the construction industry, there is still a significant gap in the literature discussing the use of AI, specifically ANN, to forecast the efficiency of sustainability initiatives in this context. While numerous research studies have investigated the possibilities of AI in a variety of fields, there has been little study particularly focused on utilizing ANN to anticipate the consequences of sustainability programs in the construction sector. Therefore, this article aims to look at the predictive capabilities of ANN in analyzing the future success of sustainability solutions in the built environment.

The research used a questionnaire survey aimed at industry practitioners to collect data on nine sustainability issues related to the built environment, such as energy usage, waste management, supply chain optimization, resource efficiency, etc. The survey, which was performed online from September to November 2023, used a non-probability sampling approach and a 4-point Likert scale to assess AI's influence on sustainability. Neural network analysis was performed using IBM SPSS Neural Network 27 software using the Multilayer Perceptron (MLP) Model. The dataset was partitioned into two subsets: training (70%) and testing (30%), with the model trained using the scaled conjugate gradient optimization approach to reduce prediction error.

Before, moving toward the neural network results, the Pearson correlation coefficient was employed to assess the correlations between the generated variables. The Pearson correlation table shows substantial positive connections between factors related to resource efficiency, energy efficiency, smart green design alternatives, supply chain optimization, and construction material traceability in the built environment. There is a strong positive association between resource efficiency and smart green design choices, energy efficiency and smart green design options, supply chain optimization, and construction material traceability. Notably, no significant negative correlations are found, indicating the absence of strong inverse interactions between variables.

Developed ANN examined the pseudo-probability distribution and used a receiver operating characteristic (ROC) curve to assess the AI model's prediction skills for sustainability outcomes in the construction industry. The model showed high confidence in situations where significant patterns and links suggested AI's capacity to attain sustainability. However, it also revealed a low overall probability of AI achieving sustainability in the industry. The ROC curve, with an area under the curve (AUC) of 0.690, indicated that the model has modest discriminative performance. Both cases had identical AUC values, implying consistent model performance and the ROC curves were above the diagonal line, demonstrating effective performance across several choice criteria. According to the normalized importance graph, AI-driven gains in energy efficiency and resource optimization were important variables. Furthermore, AI's impact on data-driven decision-making and waste reduction was somewhat considerable. Other critical considerations were streamlining supply chain procedures, ensuring traceability of building materials, and prolonging equipment life through predictive maintenance. These factors highlight AI's numerous benefits and significant influence on improving accountability, efficacy, and sustainability in construction.

The study discovered that ANN-based ML systems excel in forecasting sustainability outcomes, with high accuracy rates of 94.9% during training and 93.1% in testing. Using an architecture with a single hidden layer and three units, the model efficiently captured complicated data linkages, allowing for exact forecasts of sustainable building methods. AI-driven improvements in energy efficiency, resource optimization, data-driven decision-making, and waste reduction are among the key factors found, highlighting AI's critical role in advancing industry sustainability.

This research helps to inform decision-making processes by offering perspectives on the success of sustainability programs, paving the path for the more resilient, ecologically conscientious, and socially equitable development of infrastructure. As stakeholders seek to harness technology to increase sustainability and productivity, this study highlights AI’s transformational potential in defining the future of the built environment.

POTENCJALNE MOŻLIWOŚCI WDROŻENIA UTRZYMANIA PREDYKCYJNEGO BUDYNKÓW DWORCÓW KOLEJOWYCH

Marcin Gajzler (Politechnika Poznańska, Polska)

SŁOWA KLUCZOWE: utrzymanie predykcyjne, strategie utrzymaniowe, budynki dworcowe, protokoły przeglądów technicznych

Strategia utrzymania predykcyjnego jest jedną z bardziej efektywniejszych strategii utrzymania obiektów. Dokładna analiza właściwości strategii predykcyjnej pozwala stwierdzić, że gwarantuje ona pełną oraz ciągła sprawność obiektu poprzez wdrożenie działań wyprzedzających zjawiska niezdatności. Uwzględniając inne strategie utrzymaniowe, a w szczególności strategię reakcyjną warto zwrócić uwagę na wysoki koszt inicjalny implementacji strategii predykcyjnej. Koszt ten jest związany z zastosowaniem infrastruktury monitorującej i sensorycznej pozwalającej na akwizycję danych o aktualnym stanie obiektu. Oprócz tego implementacja strategii predykcyjnej wiąże się z magazynowaniem i przetwarzaniem danych o obiekcie w jednostce centralnej operującej w oparciu o ustalony model. Analiza możliwości jakie daje implementacja strategii predykcyjnej pozwala ją wdrożyć dla obiektów, względem których oczekuje się pełnej i ciągłej sprawności. Na etapie operacyjnym strategia predykcyjna pozwala podejmować decyzje i działania wyprzedzające ewentualne zjawiska zawodności obiektu.

Prowadzone w 2023 r. badania w zakresie dostępności w budynkach dworców kolejowych infrastruktury, jaka mogłaby być wykorzystana we wdrożeniu utrzymania predykcyjnego pozwala stwierdzić brak gotowości i ubogą infrastrukturę nawet na nowo modernizowanych dworcach. Stwierdzono, że dominującymi systemami jakie występują w budynkach dworcowych są systemy wizyjne CCTV (96,67% udziału w reprezentacji). Systemy te jednak skupiają się na zapewnieniu bezpieczeństwa ruchu podróżnych, a w marginalnym stopniu na obserwacji stanu obiektu. Po przeciwnej stronie liczebności reprezentacji (tylko 6,67% w badanej reprezentacji) występują zautomatyzowane systemy HVAC, które operują w ramach systemów BMS. Ich zastosowanie pozwala powziąć wiedzę o stanie samych urządzeń HVAC jak i stanie oddziaływań wewnątrz obiektu (temperatura, wilgotność).

Wobec ubogiej infrastruktury monitorującej i sensorycznej zaproponowano wykorzystanie podejścia systemowego opierającego się o cyklicznej i wynikające z obowiązku prawnego kontrole stanu technicznego. Elementem nowatorskim jest budowa aplikacji wspomagającej prowadzenie kontroli technicznej, a ponadto przekazującej w sposób skompresowany dane do magazynu danych (data lake), gdzie wykorzystywane są one w budowie bazy przypadków (CBR). Wykorzystanie podejścia systemowego jest możliwe zwłaszcza przy uwzględnieniu ujednolicenia standardów co do samej kontroli jak i wynikających z ładu korporacyjnego.

POTENTIAL POSSIBILITIES OF IMPLEMENTING PREDICTIVE MAINTENANCE OF RAILWAY STATION BUILDINGS

Marcin Gajzler (Poznan University of Technology, Poland)

KEYWORDS: predictive maintenance, maintenance strategies, station buildings, technical inspection protocols

The predictive maintenance strategy is one of the most effective facility maintenance strategies. A thorough analysis of the properties of the predictive strategy allows us to conclude that it guarantees the full and continuous efficiency of the facility by implementing actions that anticipate the phenomena of unfitness. Taking into account other maintenance strategies, and in particular the reactionary strategy, it is worth paying attention to the high initial cost of implementing the predictive strategy. This cost is related to the use of monitoring and sensor infrastructure enabling the acquisition of data about the current condition of the facility. In addition, the implementation of a predictive strategy involves storing and processing data about the object in a central unit operating based on an established model. Analysis of the possibilities offered by the implementation of a predictive strategy allows it to be implemented for facilities that are expected to be fully and continuously operational. At the operational stage, the predictive strategy allows you to make decisions and actions that anticipate possible failures of the facility.

Research conducted in 2023 on the availability of infrastructure in railway station buildings that could be used in the implementation of predictive maintenance allows us to determine the lack of readiness and poor infrastructure even in newly modernized stations. It was found that the dominant systems in station buildings are CCTV vision systems (96.67% of the representation). However, these systems focus on ensuring the safety of travelers' traffic, and to a marginal extent on monitoring the condition of the facility. On the other side of the representation size (only 6.67% in the surveyed representation) there are automated HVAC systems that operate within BMS systems. Their use allows you to obtain knowledge about the condition of the HVAC devices themselves and the state of interactions inside the facility (temperature, humidity).

Due to the poor monitoring and sensory infrastructure, it was proposed to use a systemic approach based on cyclical inspections of the technical condition resulting from legal obligations. An innovative element is the construction of an application supporting technical inspection and transmitting compressed data to a data warehouse (data lake), where it is used to build a case database (CBR). The use of a systemic approach is possible, especially when taking into account the unification of standards regarding control itself and those resulting from corporate governance.

POZNAŃSKA KOLEJ METROPOLITALNA – SZANSE ROZWOJU MA BAZIE ANALIZY PORÓWNAWCZEJ

Krzysztof Kotecki, Jerzy Pasławski (Politechnika Poznańska, Polska)

SŁOWA KLUCZOWE: analiza porównawcza, transport zrównoważony, kolej aglomeracyjna,

Głównym celem przyświecającym powstaniu artykułu jest rozpoznanie szans na rozwój Poznańskiej Kolei Metropolitalnej w świetle zmian w transporcie i podejściu pasażerów na podstawie porównania do innych istniejących w kraju sieci aglomeracyjnych. Konieczność ciągłego doskonalenia transportu w obrębie aglomeracji wynika nie tylko z uwarunkowań prawnych, które mogą mieć także duży wpływ na ten proces, ale także bezpośrednio z postulatów idei transportu zrównoważonego.

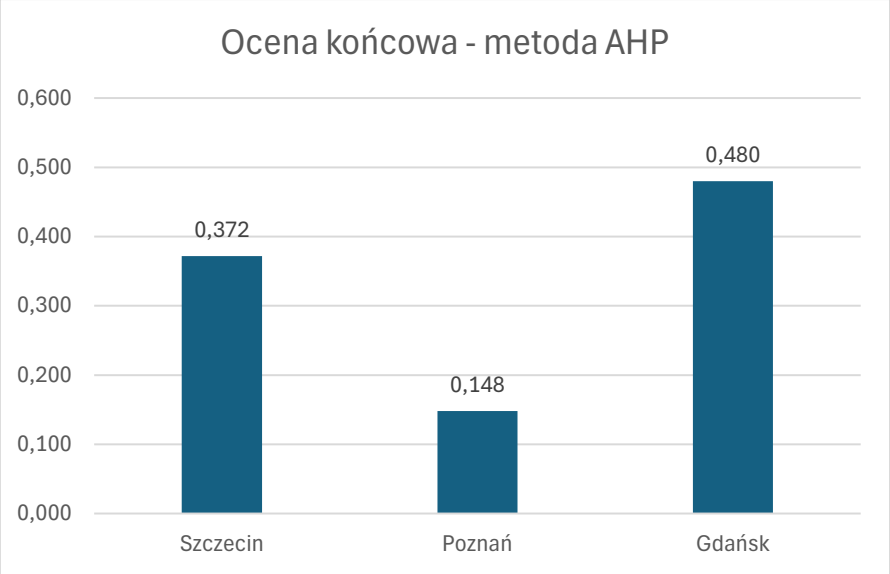
Zamieszczony w artykule krótki wstęp dotyczący transportu zrównoważonego ukazuje nie tylko wizje przyszłych sposobów przemieszczania się w obszarach wielkomiejskich, ale także nakreśla pewną oś czasu i zmiany, które na przestrzeni lat kreowały obraz transportu aglomeracyjnego.

Aby uwypuklić szanse, jakie stoją przed Poznańską Koleją Metropolitalną, wykonano uproszczoną analizę porównawczą przy użyciu metody AHP. Sama metoda i jej założenia zostały także opisane w artykule. Poza Poznańską Koleją Metropolitalną analiza uwzględniła też Szczecińską Kolej Metropolitalną oraz Pomorską Kolej Metropolitalną. W pierwszej kolejności opisano każdą z prezentowanych sieci, zasygnalizowano jej mocne i słabe strony. Ze względu na cel artykułu szczególną uwagą objęto sieć poznańską, wraz z jej planowaną rozbudową o Obwodnicę Towarową Poznania. Bazując na przykładach ukazano problemy z jakimi boryka się Poznańska Kolej Metropolitalna obecnie.

Analizę AHP wykonano przyjmując za kryteria częstotliwość kursowania pociągów w godzinach szczytu, koszt budowy kluczowej infrastruktury intermodalność, cenę biletów oraz zagęszczenie przystanków. W związku z tym, że wszystkie trzy sieci są w stanie ciągłej rozbudowy, trudno porównywać do siebie wartości liczbowe powiązane z tymi kryteriami. Zamiast tego przyjęto rosnącą skalę od 1 do 5, która posłużyła do wykazania różnic pomiędzy różnymi wariantami pod kątem każdego z analizowanych kryteriów. Sam charakter metody AHP, bazującej na subiektywnie przyjętych ocenach wzajemnych porównań między wariantami i kryteriami, odpowiada założeniu tej prostej analizy.

Uzyskane wyniki wykazały olbrzymią przewagę Pomorskiej Kolei Metropolitalnej w porównaniu do sieci poznańskiej i szczecińskiej w świetle analizowanych kryteriów. Przyczyn takiego stanu rzeczy należy szukać u podstaw procesu powstawania samych tych systemów transportowych. O ile bowiem koleje metropolitalne miast Poznania i Szczecina powstały na bazie istniejącej

infrastruktury kolejowej i były jedynie uzupełniane i modernizowane o dodatkowe funkcjonalności, o tyle gdańska PKM powstała jako linia aglomeracyjna od samego początku i już na etapie jej planowania wzięto pod uwagę najważniejsze aspekty dotyczące kolei metropolitalnych.



Rys 1. Wyniki analizy AHP trzech sieci kolei metropolitalnej

Stosunkowo niski wynik Poznańskiej Kolei Metropolitalnej spowodowany jest przede wszystkim ograniczoną częstotliwością połączeń w godzinach szczytu, słabym powiązaniem różnych środków transportu na obszarze wielu przystanków a także stosunkowo niewielkim zagęszczeniem punktów obsługi pasażerskiej.

Wnioski płynące z przeprowadzonej analizy porównawczej dotyczą przede wszystkim konieczności zapewnienia większej dbałości o połączenia kolej-autobus, kolej-tramwaj, czy też kolej-rower. Pod względem infrastruktury uwypukla się rola planowanego włączenia Obwodnicy Towarowej Poznania do ruchu pasażerskiego, a także zapewnienia w przyszłych koncepcjach przebudowy stacji Poznań Główny odpowiedniej przepustowości, która pozwoli na zwiększenie częstotliwości kursowania pociągów aglomeracyjnych.

POZNAŃ METROPOLITAN RAILWAY - DEVELOPMENT OPPORTUNITIES BASED ON COMPARATIVE ANALYSIS

Krzysztof Kotecki, Jerzy Pasławski (Poznan University of Technology , Poland)

KEYWORDS: comparative analysis, sustainable transport, metropolitan railway

The main goal of this article is to identify the development opportunities for the Poznań Metropolitan Railway in light of changes in transportation and passenger attitudes, based on a comparison with other existing metropolitan networks in the country. The need for continuous improvement of transportation within metropolitan areas arises not only from legal conditions, which can also significantly influence this process, but also directly from the demands of sustainable transport ideas.

The brief introduction to sustainable transport included in the article not only presents visions of future modes of movement in urban areas but also outlines a timeline and changes that have shaped the image of metropolitan transport over the years.

To highlight the opportunities facing the Poznań Metropolitan Railway, a simplified comparative analysis was conducted using the AHP method. The method and its assumptions are also described in the article. In addition to the Poznań Metropolitan Railway, the analysis included the Szczecin Metropolitan Railway and the Pomeranian Metropolitan Railway. Each of the presented networks was first described, with their strengths and weaknesses highlighted. Due to the aim of the article, special attention was given to the Poznań network, along with its planned expansion to include the Poznań Freight Bypass. Based on examples, the current issues faced by the Poznań Metropolitan Railway were illustrated.

The AHP analysis was conducted using criteria such as the frequency of train operations during peak hours, the cost of building key infrastructure, intermodality, ticket prices, and the density of stations. Since all three networks are continuously expanding, it is difficult to compare numerical values related to these criteria directly. Instead, a growing scale from 1 to 5 was adopted to show differences between various options in terms of each analyzed criterion. The nature of the AHP method, based on subjectively adopted assessments of mutual comparisons between options and criteria, fits the purpose of this simple analysis.

The results showed a significant advantage of the Pomeranian Metropolitan Railway compared to the Poznań and Szczecin networks in light of the analyzed criteria. The reasons for this state of affairs lie at the foundation of the development process of these transport systems. While the metropolitan railways of Poznań and Szczecin were based on existing railway infrastructure and were only supplemented and modernized with additional functionalities, the Gdańsk PKM

was created as a metropolitan line from the very beginning, taking into account the most important aspects of metropolitan railways at the planning stage.

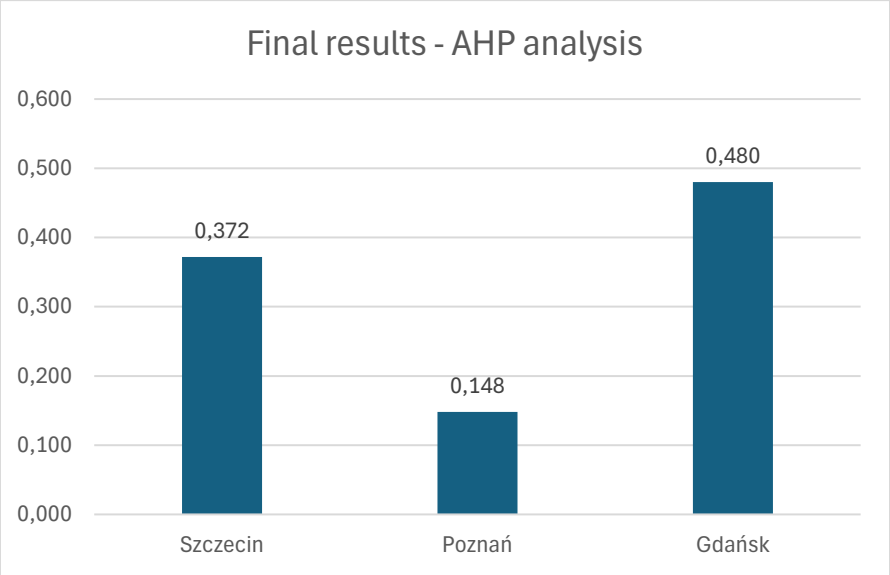


Figure 1. Results of the AHP analysis of the three metropolitan railway networks

The relatively low score of the Poznań Metropolitan Railway is mainly due to the limited frequency of connections during peak hours, weak integration of different modes of transport in many station areas, and relatively low density of passenger service points.

The conclusions from the comparative analysis primarily concern the need to ensure better connections between rail and bus, rail and tram, or rail and bicycle. In terms of infrastructure, the role of the planned inclusion of the Poznań Freight Bypass in passenger traffic stands out, as well as ensuring adequate capacity in future concepts for the redevelopment of Poznań Main Station, which will allow for increased frequency of metropolitan train operations.

ETICS SYSTEM - EXECUTION ERRORS IN TERMS OF LACK OF SUPERVISION OVER THE IMPLEMENTATION OF CONSTRUCTION WORKS

Piotr Nowotarski (Poznan University of Technology, Poland)

KEYWORDS: ETICS, BSO, light wet method, errors during façade execution

Streszczenie

ETICS (External Thermal Insulation Composite System) stanowi obecnie jeden z najpopularniejszych sposobów wykonania elewacji, gdyż łączy w sobie możliwość zapewnienia odpowiedniej izolacyjności termicznej budynków oraz dopasowany do oczekiwań użytkowników sposób wykończenia elewacji. Technologia znana na rynku od lat 60-tych nadal nastręcza wykonawcom oraz inwestorom kłopotów, których efektem jest realizacja prac niezgodnie z zasadami sztuki budowlanej i z wadami wpływającymi na ostateczny koszt oraz trwałości wykonanej elewacji. W artykule przedstawiono podstawowe, cały czas spotykane na budowach, błędy przy wykonaniu elewacji w system ETICS ze szczególnym uwzględnieniem etapu wykonania warstwy klejąco-zbrojącej. Poruszone zostały kwestie związane z wpływem odpowiedniego nadzoru nad pracami na ich jakość ze zwróceniem uwagi na niską świadomość inwestorów w zakresie obowiązków ciążących na nich i wynikających z ustawy Prawo budowlane. Całość podsumowano wskazując kierunki działań, które winny wpłynąć na redukcję błędów przy realizacji robót budowlanych, nie tylko w zakresie wykonania elewacji.

Summary

ETICS (External Thermal Insulation Composite System) is currently one of the most popular methods of constructing facades because it combines the function of ensuring adequate thermal insulation of buildings and methods of finishing the facade tailored to the users' expectations. The technology, known on the market since the 1957, still causes problems for contractors and investors, resulting in work being carried out contrary to the principles of construction practice and with defects affecting the final cost and durability of the completed façade. The article presents the basic errors that are constantly encountered on construction sites when constructing facades using the ETICS system, with particular emphasis on the adhesive and reinforcing layer. Issues related to the impact of appropriate supervision of the works on their quality were raised, with attention to the low awareness of investors regarding their obligations under the Construction Law. The findings were summarized by indicating the directions of actions that should reduce errors during the implementation of construction works, not only in the field of façade construction.

MODELOWANIE 3D BIM W UJĘCIU 4D/5D BIM I KOMPONENTÓW PRZY UWZGLĘDNIENIU KOMPROMISÓW MONTAŻOWO-LOGISTYCZNYCH

Tomasz Wiatr (Politechnika Poznańska, Polska)

SŁOWA KLUCZOWE: modelowanie informacji budowlanej 3D BIM, optymalizacja czasoprzestrzenno-kosztowa, harmonogram budowlany 4D/5D BIM

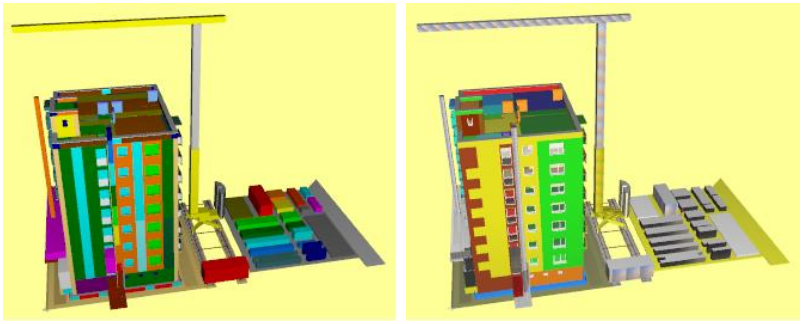
Podstawą rozważań są przedsięwzięcia w budownictwie ogólnym z optymalizacją budynków w kontekście 3D BIM ukierunkowanym na analizy czasoprzestrzenne 4D/5D BIM prowadzące do optymalnej budowy. We współczesnym budownictwie uprzemysłowionym budynki można postrzegać jako złożone kompleksy komponentów, gdzie zarówno sam budynek, jak i jego komponenty podlegają projektowaniu metodami naukowymi inżynierii. Komponenty nazywane tutaj projektowo-wykonawczymi stanowią umowne elementy obiektu budowlanego harmonizujące z modelem analitycznym konstrukcji (nie tylko statyczno-wytrzymałościowym, ale również akustyczno-termicznym), które stanowią podstawę podziału obiektu na działki robocze, jako elementy niepodzielne na swym poziomie logicznym modelu.

Komponenty typowe są zbiorem elementów o parametrach stałych, natomiast komponenty nietypowe posiadają parametry zmienne, przy czym zarówno parametry stałe, jak i zmienne podlegają analizom w oparciu o zbiór kryteriów i ograniczeń montażowo-transportowych. W przypadku komponentów, które nie są prefabrykowane warunkiem koniecznym lecz nie wystarczającym ich zdefiniowania w modelu BIM jest zgodność z komponentami istniejącymi, także niewyrażonymi wprost, którymi można operować w planowaniu, jako komponentami zastępczymi czego przykładem są scalone wielowymiariowe urządzenia formujące przy założeniu ich przenoszenia pomiędzy działkami bez demontażu na części proste, gdzie żuraw jest urządzeniem montażowo-transportowym a pojazdy urządzaniami transport dalszego.

Podstawę badań stanowi przedsięwzięcie obejmujące 50 budynków, w tym 10 budynków mieszkalnych powtarzalnych i 10 niemieszkalnych. Szczególnym rodzajem komponentów są tu prefabrykaty różnego rodzaju zastosowane w części nadziemnej, także wielokowymiariowe. W przypadku stanów zerowych są to przegrody żelbetowe monolityczne jako odcinki i węzły łączące, ponadto także stropy zespolone, jako forma mieszana komponentów z częścią prefabrykowaną definiującą wydzielenie komponentu. Przykładem dyskretyzacji komponentów pomocniczych jako pakietów logistycznych, w tym transportowych, są ładunki paletyzowane będące przejawem kompletacji logistycznej, zwłaszcza w zakresie wykończeń.

Budynek przedstawiony na rysunku jest rozważany w kontekście montażowym w ramach wyselekcjonowanego typoszeregu żurawi wieżowych samomontujących przy uwzględnieniu ograniczeń transportowych w oparciu o zdefiniowane klasy logistyczne L0-L4 oparte na przyjętym podziale urządzeń transportowych. Aspekt logistyczny stanowi wąskie gardło

budownictwa i w rozważaniach przyjęto jako paradygmat wykluczenie transportu specjalnego, gdyż celem jest wypracowanie podejścia uniwersalnego w ramach szerszej koncepcji własnej modelu logistyczno-finansowego przedsięwzięć budowlanych IVO (Input-Value-Output).



Rysunek 1. Widok budynku z podziałem na komponenty oraz działki robocze

Aby możliwe było uzyskanie dopuszczalnego w sensie wykonalności rozwiązania potrzebna jest analiza w ujęciu czasoprzestrzennym 4D BIM włączając w to wykrywanie kolizji, jednakże nie każdy obiekt musi być reprezentowany geometrycznie w ujęciu 3D BIM aby móc zostać uwzględnionym w analizie czas-koszt 4D/5D. Dotyczy to zwłaszcza konstrukcji tymczasowych wielokrotnie przestawnych, które zmieniają swe położenie bez zmiany właściwości. W tym sensie analiza 3D/4D BIM skupia się na problemach konstrukcyjno-technologicznych, natomiast reprezentacja czasowo-kosztowa w ujęciu 4D/5D BIM uwzględnia także pozostałe komponenty, które w zaawansowanej fazie budowy nie są już widoczne w symulacji 4D BIM.

Kluczowe znaczenie dla analizy kosztowej ma wyjście poza paradygmat kosztów pośrednich i bezpośrednich znany z kosztorysowania klasycznego na rzecz rachunku kosztów stałych i zmiennych w rozumieniu zmienności kosztów w ujęciu czasowym, jak również zmienności w aspekcie skali produkcji. W pierwszym aspekcie wyzwaniem jest uwzględnienie ryzyka w ujęciu probablistycznym rozważanego w badaniach wcześniejszych (przed podjęciem przez autora problematyki BIM), jednakże w modelu ryzyko czasowe brane pod uwagę jest jako rezerwa gorąca lub zimna wyrażona buforami czasu w myśl założeń łańcucha krytycznego poszerzającego metodę ścieżki krytycznej o aspekt zasobowo-kosztowy. W przedstawionej koncepcji łącznikiem analizy czasu i kosztów są zasoby czynne i bierne.

Przedstawiana analiza prowadzi do podziału suboptymalnego na komponenty w modelu 3D BIM a w dalszej kolejności do podziału suboptymalnego na działki robocze przy ich uwzględnieniu lub do optymalizacji całościowej uwzględniającej oba etapy łącznie. W tym sensie podział na komponenty projektowo-wykonawcze 3D BIM jest immanentną częścią projektowania budowlanego. Jeśli podział dokonany jest też wobec elementów traktowanych tradycyjnie jako niepodzielne (np. tzw. monolityczne), możliwe jest prowadzenie szczegółowej optymalizacji w każdej fazie planowania. Koncepcja komponentów projektowo-wykonawczych pozwala uzyskać modele przydatne wprost w analizie 4D/5D BIM bez wtórnej edycji modelu źródłowego harmonizując z analizami konstrukcji budynku w ujęciu 3D FEA.

3D BIM MODELLING IN TERMS OF 4D/5D BIM AND COMPONENTS TAKING INTO ACCOUNT ASSEMBLY AND LOGISTIC TRADE-OFFS

Tomasz WIATR (Poznan University of Technology, Poland)

KEYWORDS: 3D BIM building information modelling, project space-time and cost optimisation, 4D/5D BIM construction scheduling

The basis of the consideration is general construction projects with building optimisation in 3D BIM context focused on 4D/5D BIM time-space analyses leading to optimal construction. In modern industrialised construction, buildings can be seen as complex component compositions, where both the building itself and its components are subject to design by scientific engineering methods. The components referred to here as design-build, are the contractual elements of the building object that harmonise with the analytical model of the structure (not only static-strength but also acoustic-thermal), which form the basis for the division of the building into working units, as indivisible elements at their logical model level.

Typical components are a set of elements with fixed parameters, while atypical components have variable parameters, with both fixed and variable parameters subject to analysis based on a set of assembly and transport criteria and constraints. In the case of components that are not prefabricated, a necessary but not sufficient condition for defining them in the BIM model is their compatibility with existing components, even those not explicitly expressed, which can be operated in the planning as substitute components, as exemplified by integrated multidimensional formworks, assuming their transfer between units without disassembly into straight parts, where the crane is an assembly-transport device and the vehicles are longer-distance transport devices.

The basis of the research is a project involving 50 buildings, including 10 repetitive residential and 10 non-residential buildings. The special type of components here are precast elements of various types used in the above-ground state, including multidimensional. In the case of zero states, these include monolithic reinforced concrete partitions as sections and connecting nodes, in addition also composite floors as a mixed form of components with a precast part defining the component separation. An example of the discretisation of ancillary components as logistical packages, including transport, are palletised loads which are a manifestation of logistical completion, especially in terms of finishes.

The building presented in the figure is considered in an assembly context within a selected range of self-mounting tower cranes, considering transport constraints based on defined logistic classes L0-L4 based on the adopted division of transport equipment. Logistics aspect is a bottleneck of the construction industry, and the exclusion of special transport is adopted as a paradigm in the considerations, as the aim is to develop a universal approach within the

framework of the broader own concept of the IVO (Input-Value-Output) logistics-financial model of construction projects.

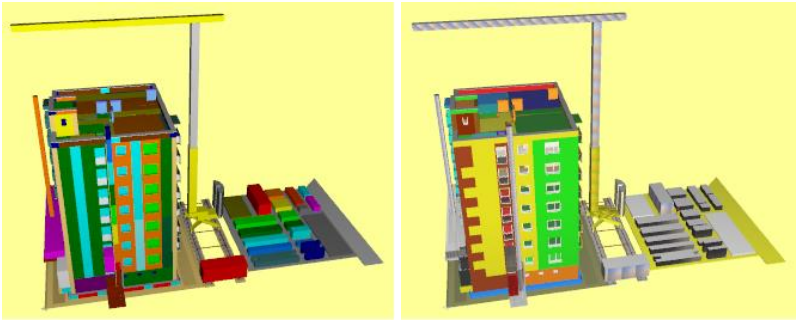


Figure 1. View of building with breakdown of components and working units

A 4D BIM time-space analysis, including detection of collisions, is required to arrive at an acceptable solution in terms of feasibility, but not every object needs to be geometrically represented in 3D BIM to be included in the 4D/5D time-cost analysis. This is especially true for temporary structures that are repeatedly repositioned without changing their properties. In this sense, the 3D/4D BIM analysis focuses on structural-technological problems, whereas the time-cost representation in 4D/5D BIM terms also considers other components that are no longer visible in the 4D BIM simulation during the advanced construction works.

It is crucial for cost analysis to move beyond the direct and indirect cost paradigm known from classical cost estimation to fixed and variable costing in the understanding of cost variability in terms of time, as well as variability in terms of production scale. In the first aspect, the challenge is to consider the risk in probablistic terms considered in earlier studies (before author took up BIM), however, in the model, the time risk is taken into account as a hot or cold reserve expressed by time buffers according to the assumptions of the critical chain extending the critical path method to the resource-cost aspect. In the concept presented, the link between time and cost analysis is active and passive resources.

The analysis presented leads to a sub-optimal subdivision into components in the 3D BIM model and then to a sub-optimal subdivision into working units when considering them or to an overall optimisation considering both stages together. In this sense, the division into 3D BIM design-build components is an intrinsic part of construction design. If division is also made with respect to elements traditionally treated as indivisible (e.g. so-called monolithic), it is possible to carry out detailed optimisation in each planning phase. The concept of design-building components makes it possible to obtain models that are directly useful for 4D/5D BIM analysis without secondary editing of the source model, harmonising with the 3D FEM analyses of the structure.

SYNERGIA ZASTOSOWANIA ELASTYCZNOŚCI W POWIĄZANIU Z INNYMI METODAMI ZARZĄDZANIA W BUDOWNICTWIE

Jerzy Pasławski (Politechnika Poznańska, Polska)

KEYWORDS: elastyczność, procesy budowlane, przedsięwzięcia, lean management, industry 5.0, harmonogram, model sieciowy

Elastyczność spotykamy w naszym codziennym życiu (np. elastyczny system pracy w przedsiębiorstwach), jednak zastosowanie elastyczności w zarządzaniu w budownictwie jest jeszcze znacznie ograniczone. Tymczasem, w warunkach działania zmiennego otoczenia jest to rozwiązanie pozwalające na znaczne zwiększenie efektywności działania zarówno na poziomie procesów, jak i przedsięwzięć budowlanych, czy strategii organizacji (przedsiębiorstwa).

Elastyczność może być także stosowana na różnych poziomach zarządzania:

- operacyjnym – kiedy dotyczy niepewności/ryzyka dotyczącej procesów budowlanych

- taktycznym – dotyczącym przedsięwzięcia – np. realizacja przedsięwzięcia etapami w zależności od zmiennego zapotrzebowania

- strategicznym – dotyczącym działalności przedsiębiorstwa – np. dostosowania zakresu produkcji do zmiennego zapotrzebowania klientów.

Elastyczność na poziomie operacyjnym umożliwia kontynuację prac pomimo zmian w otoczenie (zakładamy minimalne zmiany pod względem czasu, kosztów czy zakresu przy utrzymaniu wymagań jakościowych. W przypadku elastyczności na poziomie przedsięwzięcia elastyczność pozwala na podejmowanie decyzji (z założenia o rozbudowie) stosownie do zmieniającego się zapotrzebowania. Umożliwia uniknięcie efektu białego słonia (white elephant), który jest synonimem niepotrzebnej, kosztownej inwestycji (np. obiekty sportowe wybudowane na potrzeby rozgrywek olimpijskich). Kluczową przesłanką niniejszego artykułu jest wykazanie, że umiejętne połączenie różnych metod zarządzania może pozwolić na osiągnięcie efektu synergii. Przykładowo podczas realizacji procesów na budowie połączenie Lean Management i Agile Management (opartej na elastyczności) pozwala z jednej strony zredukować straty związane z obecnością zbędnych elementów w systemie (zapobieganie marnotrawstwu), a jednocześnie – dzięki elastyczności jako bazowemu elementowi zwinnego zarządzania – pozwolić na ograniczenie ryzyka i wykorzystanie nadarzających się okazji przy realizacji przedsięwzięć w zmiennym otoczeniu. Z kolei zastosowanie idei industry 5.0 pozwala na wykorzystanie możliwości śledzenia otoczenia i procesów w toku, co umożliwia wykorzystanie digital twin do zarządzania procesami w czasie rzeczywistym.

Tradycyjne metody zarządzania (harmonogram, model sieciowy) umożliwiają z kolei wizualną prezentację planu, kontrolę dostępnych zasobów i opracowanie ścieżki krytycznej jako

podstawy podejmowania decyzji. Tradycyjne metody umożliwiają przyjęcie planu bazowego, który później będzie podlegał modyfikacjom.

Warto podkreślić, że zastosowanie elastyczności jest uzasadnione w przypadku warunków realizacji w zmiennym otoczeniu (opisywanych za kompleksowe z elementami chaosu (unknown unknowns) w odróżnieniu od typowych i prostych (known knowns).

Jak wykazały badania przypadków na poziomie operacyjnym istotną zaletą wykorzystania czujników i systemów monitoringu jest możliwość wykorzystania digital twin do zarządzania zmiennością procesów w czasie rzeczywistym. W przypadku poziomu przedsięwzięcia system ten może być wykorzystany w ograniczonym zakresie (np. elastyczność logistyczna czy predykcyjne zarządzanie utrzymaniem obiektów), natomiast przy zmienności zapotrzebowania (np. dworce kolejowe) należy wykorzystać elastyczne podejście w formie projektu modułowego. Podejście to opiera się na przyjęciu elementarnego rozwiązania na początku z możliwością dalszej rozbudowy w przypadku zwiększenia zapotrzebowania (opcja expand). Nie wyklucza to możliwości zastosowania redukcji w razie spadku zapotrzebowania (np. wykorzystanie alternatywnych środków transportu.

SYNERGY OF THE USE OF FLEXIBILITY IN CONNECTION WITH OTHER MANAGEMENT METHODS IN CONSTRUCTION

Jerzy Paslawski (Poznan University of Technology, Poland)

KEYWORDS: elastyczność, procesy budowlane, przedsięwzięcia, lean management, industry 5.0, harmonogram, critical path model

We encounter flexibility in our everyday lives (e.g. flexible work systems in enterprises), but the use of flexibility in management in construction is still significantly limited. Meanwhile, in the conditions of a changing environment, this is a solution that allows for a significant increase in efficiency, both at the level of processes, construction projects and organizational (enterprise) strategy.

Flexibility can also be applied at different levels of management:

- operational – when it concerns uncertainty/risk regarding construction processes

- tactical - related to the project - e.g. implementation of the project in stages depending on changing demand

- strategic - relating to the company's activities - e.g. adapting the scope of production to changing customer demand.

Flexibility at the operational level enables continuation of work despite changes in the environment (assuming minimal changes in terms of time, costs or scope while maintaining quality requirements. In the case of flexibility at the project level, flexibility allows making decisions (assuming expansion) in accordance with changing demand. It allows to avoid the white elephant effect, which is synonymous with unnecessary, expensive investment (e.g. sports facilities built for the Olympic games).

The key premise of this article is to demonstrate that a skillful combination of various management methods can achieve a synergy effect.

For example, when implementing processes on a construction site (building a highway), the combination of Lean Management and Agile Management (based on flexibility) allows, on the one hand, to reduce losses related to the presence of unnecessary elements in the system (preventing waste), and at the same time - thanks to flexibility as a basic element of agile management - allows for risk reduction and taking advantage of opportunities when implementing projects in a changing environment. In turn, the application of the idea of industry 5.0 allows for the use of the ability to track the environment and processes in progress, which enables the use of a digital twin to manage processes in real time.

Traditional management methods (schedule, network model), in turn, enable visual presentation of the plan, control of available resources and development of a critical path as the basis for decision-making. Traditional methods make it possible to adopt a baseline plan that will later be subject to modifications.

It is worth emphasizing that the use of flexibility is justified in the case of implementation conditions in a variable environment (described as complex with elements of chaos (unknown unknowns) as opposed to typical and simple (known knowns).

As case studies at the operational level have shown, an important advantage of using sensors and monitoring systems is the ability to use a digital twin to manage process variability in real time (based on simulation). At the project level, this system can be used to a limited extent (e.g. logistic flexibility or predictive facility maintenance management), while when demand varies (e.g. railway stations), a flexible approach in the form of a modular design should be used. This approach is based on adopting a basic solution at the beginning with the possibility of further expansion if demand increases (expand option). This does not exclude the possibility of applying reductions in the event of a drop in demand (e.g. use of alternative means of transport).

MODUŁOWE DWORCE SYSTEMOWE JAKO ELEMENT REALIZACJI ZRÓWNOWAŻONEGO TRANSPORTU W AGLOMERACJI

Jerzy Pasławski, Kamila Włoch-Surówka (Politechnika Poznańska, Polska)

KEYWORDS: elastyczność, dworce kolejowe, budownictwo modułowe

Artykuł koncentruje się na koncepcji rozwoju małych i średnich dworców kolejowych w Polsce, z wykorzystaniem budownictwa modułowego jako metody, która może przynieść znaczące korzyści w porównaniu do tradycyjnych metod budowy. Główne zalety budownictwa modułowego to: 1. elastyczność projektowania i realizacji umożliwiająca dostosowanie do zmieniających się potrzeb użytkowników, co przekłada się na efektywność i redukcję kosztów. 2. Szybkość wdrożenia: moduły mogą być przygotowywane poza miejscem budowy i instalowane szybciej niż w tradycyjnym budownictwie, co jest kluczowe przy ograniczonym czasie. 3. Optymalizacja kosztów: skrócenie czasu budowy i standaryzacja modułów wpływają na obniżenie kosztów inwestycji i utrzymania, a także na możliwość zamknięcia obiegu materiałów, co sprzyja rozwiązaniom zeroemisyjnym.

Analizując inwestycje infrastrukturalne, w szczególności związane z koleją, można zauważyć pewien paradoks, gdzie wysokie nakłady początkowe i koszty utrzymania nie znajdują odzwierciedlenia w szybkości zwrotu inwestycji. Kolej, niegdyś symbol nowoczesności, obecnie stracił na popularności na rzecz transportu drogowego i lotniczego. Transformacje po 1989 roku doprowadziły do degradacji infrastruktury kolejowej, co w konsekwencji spowodowało wykluczenie transportowe w niektórych regionach kraju. W opinii autorów budownictwo modułowe może znacznie przyczynić się do modernizacji i ożywienia polskiej infrastruktury kolejowej, przyczyniając się do zrównoważonego rozwoju transportu.

Kolei to środek transportu o najniższym śladzie węglowym w istniejącej infrastrukturze. Jednak konkurencja ze strony samolotów i pojazdów kołowych stanowi wyzwanie, wymagając innowacyjnych działań. Transformacja Holandii, gdzie rezygnacja z masowego używania samochodów trwała kilka dekad, pokazuje, że zmiany społeczne są kluczowe. Na poziomie legislacyjnym działania Unii Europejskiej wspierają rangę transportu kolejowego. Optymalne wykorzystanie istniejących systemów transportowych, w tym systemu opartego na kolei, pozwoli na ograniczenie zużycia gruntów, oszczędzanie zasobów i minimalizowanie emisji. Współpraca międzysektorowa i cele związane z zrównoważonym transportem są kluczowe dla przyszłości mobilności. Badania ankietowe pomogły określić wymagania użytkowników dworców kolejowych, a koncepcja systemowych dworców modułowych może przyczynić się do zrównoważonego rozwoju. Założenia Zielonego Ładu dodatkowo wpłyną na ograniczenie transportu indywidualnego i promocję zrównoważonych rozwiązań.

Koncepcja Systemowych Dworców Modułowych (SDM) opiera się na elastycznym dostosowaniu do zmieniających się wymagań, uwzględniając zmiany natężenia ruchu pasażerskiego zależne od czynników społecznych, ekonomicznych i technologicznych. W optymistycznym scenariuszu przewiduje się wzrost, ale istnieje również możliwość utrzymania lub redukcji ruchu na stacjach. Badania w aglomeracji poznańskiej pokazują, że rozwój małych przystanków i dworców kolejowych wymaga współpracy różnych interesariuszy PKP, samorządów i lokalnych firm. Koncepcja systemowych dworców kolejowych zakłada modułową budowę, umożliwiającą rozbudowę i dostosowanie do potrzeb użytkowników. Głównym celem jest tworzenie intermodalnych węzłów przesiadkowych i usług “door-to-door”. Zmiany demograficzne i społeczne, jak zdalna praca czy AI, wpływają na mobilność i nawyki użytkowników. Katalog systemowych dworców oparty na modułach prefabrykowanych uwzględnia rozbudowę stacji i obiekty towarzyszące. Kluczowe jest ukierunkowanie przestrzeni dworcowej na realizację usług transportowych oraz tworzenie intermodalnych węzłów przesiadkowych. Współczesne wyzwania to demografia, zmiany społeczne, technologie i skrócenie czasu podróży. Analiza scenariuszy rozwoju ruchu pasażerskiego uwzględnia przewidywane w najbliższym czasie regulacje związane z dążeniem do zero emisyjności oraz alternatywne technologie napędowe. Modułowość i typizacja są stosowane przy projektowaniu małych i średnich stacji, podczas gdy duże dworce wymagają indywidualnych rozwiązań przestrzennych i zaawansowanych prac projektowych.

SYSTEMIC MODULAR STATIONS AS A COMPONENT OF SUSTAINABLE TRANSPORT IN URBAN AREAS

Jerzy Pasławski, Kamila Włoch-Surówka (Poznan University of Technology, Poland)

KEYWORDS: flexibility, railway station, modular building

This article focuses on the concept of developing small and medium-sized railway stations in Poland, utilizing modular construction as a method that can bring significant benefits compared to traditional building methods. The main advantages of modular construction include: 1. Design and implementation flexibility that allows for adaptation to changing user needs, translating into efficiency and cost reduction. 2. Implementation speed: modules can be prepared off-site and installed faster than in traditional construction, which is crucial when time is limited. 3. Cost optimization: reducing construction time and standardizing modules lower investment and maintenance costs, and also allowing for the closure of material cycles, favoring zero-emission solutions.

Analyzing infrastructure investments, particularly those related to railways, reveals a paradox where high initial outlays and maintenance costs are not reflected in the speed of investment return. The railway, once a symbol of modernity, has now lost popularity to road and air transport. Transformations after 1989 led to the degradation of railway infrastructure, resulting in transport exclusion in some regions of the country. According to the authors, modular construction can significantly contribute to the modernization and revitalization of Polish railway infrastructure, contributing to sustainable transport development.

The railway as a means of transport has the lowest carbon footprint in existing infrastructure. However, competition from airplanes and wheeled vehicles poses a challenge, requiring innovative actions. The transformation of the Netherlands, where the abandonment of mass car use took several decades, shows that social changes are crucial. At the legislative level, actions of the European Union support the status of railway transport. Optimal use of existing transport systems, including rail-based systems, will allow for the reduction of land use, resource saving, and emission minimization. Intersectoral cooperation and goals related to sustainable transport are key to the future of mobility. Surveys helped determine the requirements of railway station users, and the concept of systemic modular stations can contribute to sustainable development. The assumptions of the Green Deal will further influence the reduction of individual transport and the promotion of sustainable solutions.

The development of the Systemic Modular Stations (SMS) concept pertains to the design of railway infrastructure at stops as well as small and medium-sized stations. The adopted concept

is based on flexible adaptation to changing requirements—primarily considering changes in passenger traffic intensity, which depend on prior social, economic, or technological factors.

In an optimistic scenario, an upward trend is expected (assuming the implementation of sustainable development ideas in construction and transportation). Additionally, it is possible to assume the maintenance of the current traffic at the station in question, as well as its reduction. Such a situation may result from demographic changes, a reversal of migration trends (currently from the city to the surrounding agglomeration), changes resulting from the expansion of the existing railway network (e.g., the expansion project of the Poznań Metropolitan Railway considering the construction of a railway ring in the agglomeration), etc.

Conducted surveys and case analyses of functioning small stops and railway stations in the vicinity of the Poznań agglomeration have proven the necessity of cooperation among various stakeholders (both on the side of transport companies—PKP companies, as well as local governments and local enterprises/organizations (local public transport, commercial and service enterprises, police stations, Railway Security Service, etc.).

Part of the concept is a catalog of systemic railway stations, which is based on an elementary solution that meets the current needs of users, and the possibility of gradual development based on modules produced in the prefabrication plant, whose assembly (or possible disassembly) does not significantly disrupt the current functioning of the station facility. It is important to emphasize the inclusion of options for expanding the station with accompanying facilities (public and individual communication terminals, primarily bicycles).

Its main assumption is based on the thesis that the organization of station space and platforms should be primarily focused on providing transport services as the basic tasks of the railways, as well as in cooperation with local governments—on creating intermodal transfer hubs in collective communication, integrated into a larger system, with the ultimate intention of enabling “door-to-door” travel. Expanding the program to include other services—commercial—should occur in cooperation with local governments (municipalities) and private entities. They can then create a local commercial-service center.