BOOK OF ABSTRACTS

20th International Conference on Operational Research

September 25-27, 2024, Brela Croatia

Editors: Tea Šestanović & Blanka Škrabić Perić

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20th International Conference on Operational Research
KOI 2024, September 25-27, Brela, Croatia

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20th International Conference on Operational Research
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20th International Conference on Operational Research
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P r e f a c e

Abstracts of plenary lectures and contributed talks, presented at the 20th International Conference on Operational Research KOI 2024, are included in this book. The International Conference on Operational Research (KOI) is the major event organized by the Croatian Operational Research Society (CRORS) since 1991. In the period from 1991 to 1996 it was organized annualy while from 1996 onwards, it is organized every two years.

The objective of the KOI conferences is connection of researchers and practitioners from operational research and related scientific disciplines (such as applied mathematics, statistics, quantitative methods in business, simulations, and machine learning) for introducing new operational research achievements in business process improvement. Conference topics include linear and non-linear programming, combinatorial and discrete optimization, multi-objective programming, stochastic models, game theory, statistics, econometrics, information and decision support systems, neural networks and fuzzy systems, data mining, business analytics, control theory simulations, practical OR and applications. The main purpose of the conference is dissemination of new ideas and experiences among researches of common interest, particularly young researchers in order to improve their scientific work.

KOI conferences were successfully held so far in different Croatian cities, such as: Rab, Rovinj, Trogir, Pula, Split, Šibenik, Zadar, Zagreb and Osijek. The conference KOI 2024, organized by Croatian Operational Research Society in collaboration with Faculty of Economics, Business and Tourism, University of Split, is held in Brela, Croatia, from September 25 to September 27, 2024. The conference KOI 2024 brings together various topics grouped into the following sessions:

Plenary sessions

Plenary lectures are given by eminent international experts:

- Veljko Jeremić, University of Belgrade, Faculty of Organizational Sciences, Serbia
- Marianna E.-Nagy, Department of Operations Research and Actuarial Sciences on Institute of Operations and Decision Sciences at Corvinus University of Budapest, Hungary and senior research fellow of Corvinus Centre for Operation Research, Corvinus Institute of Advanced Studies

at Corvinus University of Budapest, Hungary
- Boštjan Grabovšek, University of Ljubljana, Faculty of Mechanical Engineering, Slovenia

Special sessions on:

- Advances in theory and methods of convex optimization
- Applied graph theory and discrete optimization
- Assessing the transformation of the business landscape by applying methods of OR and statistics
- Game theory
- Multicriteria decision making under SDG context
- OR in forestry
- Smart tourism: Unlocking potential with metaverse and blockchain technologies
- Sustainability reporting, auditing and finance in operational research

Regular sessions on:

- Applied statistics and econometrics
- Behavioral operational research
- Machine learning and data mining
- Mathematical programming
- Multicriteria decision making
- Optimization in human environment

In addition to 3 plenary lectures there are 72 contributed talks. The total of 101 registered authors and co-authors participate the conference from 15 different countries: Bosnia and Herzegovina, Canada, Croatia, Czech Republic, France, Germany, Hungary, India, Portugal, Romania, Slovakia, Slovenia, Serbia, UK and US.

In addition to sessions, the KOI 2024 conference offers a workshop held by SUNY Professor Rajan Batta from the University of Buffalo, USA titled: "Using operations research methods to guide UAV search in a disaster area".

The round table "Economic disasters: frequency, determinants and effects" is organized by Professor Bruno Ćorić, where the results of the Croatian Science Foundation project IP-2020-02-9710 are presented and discussed.

The KOI 2024 conferences also includes special methodological workshop for

students enrolled in Postgraduate study programmes.

The conference has an international Program Committee and is held in English language.

After the conference, the authors can send full papers for possible publication in the Croatian Operational Research Journal - CRORR (indexed in WoS ESCI, SCOPUS and other important scientific databases). Full papers will be blindly reviewed by two independent reviewers and accepted ones will be published.

Editors

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Plenary Speakers

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Education

2012 - Operations Research and Computational Statistics
2010 - Computational Statistics
2008 - Information Systems and Technologies

Profesional experience

2022 - present | Professor at the University of Belgrade – Faculty of Organizational Sciences
2017 - present | Visiting Professor at a range of European universities
2011 - present | PI/Manager/Researcher at various projects funded by international and national funding bodies
2009 - 2022 | Held different (TA, Assistant Professor, and Associate Professor) academic positions at the University of Belgrade – Faculty of Organizational Sciences

Additional info

Veljko Jeremić holds a Professor position at the University of Belgrade. His main tasks include research and teaching activities in the field of Applied Statistics and Data Science. He is teaching a wide range of undergraduate and graduate courses at the University of Belgrade. As a (co)mentor, he supervised two doctoral dissertations, while he is currently supervising one doctoral dissertation. Veljko Jeremić was a member of the defense committee of 13 doctoral dissertations. Veljko Jeremić was an external evaluator of four doctoral dissertations at international HEIs. He was a committee member for elections to teaching/research positions on more than a dozen occasions. He published 70 Web of Science-indexed papers cited 816 times in the Web

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2011-2012 | Postdoctoral Research Fellow, Research group Algorithms, Combinatorics and Optimization, CWI, Amsterdam, The Netherlands
2009-2011 | Postdoctoral Research Fellow, Department of Econometrics and Operations Research, Tilburg University, Tilburg, The Netherlands
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Additional info

Her research topic is mainly interior point algorithms, linear complementarity problems, and semidefinite programming. Besides the theoretical research, Marianna E.-Nagy considers the applications also very important. She was a member of a group of engineers and mathematicians at the Budapest University of Technology and Economics working on the day-ahead markets. Moreover, she also worked on production planning problems for MOL Plc. in the group of Tibor Illés for two years. She received the Gyula Farkas Memorial Award from the János Bolyai Mathematical Society in 2011.

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2013-2020 | Teaching assistant, University of Ljubljana, Faculty of Mechanical Engineering, Slovenia, Slovenia
2021-present | Assist. prof. and senior research fellow, University of Ljubljana, Faculty of Mechanical Engineering, Slovenia

Additional info

Research interests: Computational topology, application of topological methods to biological systems, machine learning, graph theory, operations research, optimization.
Research projects (PI):
2022-2025 Biological code of knots – identification of knotted patterns in biomolecules via AI approach (in collaboration with the Interdisciplinary Laboratory of Biological Systems Modelling, CeNT University of Warsaw, Poland and CEITEC Masaryk University, Czech Republic).
2023-2025 A computational library for knotted structures and applications (ARIS Research project)

Plenary Lectures

Synergizing research and policy: A comprehensive analysis of operations research trends and their impact on policymaking and funding strategies

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Abstract | We are witnessing a surge in the popularity of operations research topics among a number of stakeholders. Although researchers' interest prevails, the critical importance of the topic lies underneath the policymakers and scientific funding agencies. The intersection between hot research topics and the agenda of policymakers and scientific funding agencies is an issue of great concern. The talk will address several vital takeaways while fostering insights from CNRS-indexed operations research journals. Firstly, we will dig deep into a bibliometric analysis of leading researchers and institutions, underlying particularly productive and influential ones. Further, we will tackle the trending topics in leading journals through a two-stage approach: first, we will outline similarities and differences between journals ranked 1 or 2 and journals ranked 3 or 4; secondly, we will map the survival of trending topics in observed journals as important input for understanding the evolution of the research field. Finally, a wealth of knowledge obtained in previous phases will be matched to the agenda of policymakers and scientific funding agencies as the necessary input for drafting research programs and calls for applications. The talk will conclude with the guidelines for the successful helix of operations research academia, policymakers, and scientific funding agencies as essential assets for prosperous and successful adherents to society's needs.

Key words | *bibliometric analysis, trending topics, operations research, CNRS, funding scientific research*

Linear complementarity problems and interior point algorithms

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Abstract | A wide variety of real-world problems - for example, in economics, engineering, and optimal control - can be formulated as linear complementarity problems (LCPs). This is not surprising, since LCP has been defined as the unified form of linear programming, quadratic programming, and bimatrix games. So, there is a real need for an algorithm that solves the LCP. However, it is an NP-complete problem, so we cannot provide an efficient algorithm to solve all LCP instances. Several special subclasses of LCP have been defined in the literature where we can guarantee some nice properties about the problem. One is the sufficient LCP, namely the LCP problem with a sufficient coefficient matrix. In this case, an interior-point algorithm (IPA) can solve the problem in polynomial time, but the number of iterations depends not only on the dimension and the coding size of the problem but also on a parameter of the coefficient matrix, the so-called handicap. We have already shown that it can be exponential in dimension. Now we prove the previous conjecture that it cannot be doubly exponential. Furthermore, we present some more observations about this class of matrices. On the other hand, a deeper understanding of the IPA may lead to variants of the IPA that can solve a larger subset of the LCP. One of the key questions of the algorithm is how to determine the search direction. In the case of the classical IPA, in each iteration, the search direction is the unique solution of a Newton system defined by the current iterate. We present three ways to modify the right-hand side of the Newton system, resulting in different search directions. In all cases, the complexity of the algorithm is in line with the best complexity results in the literature so far.

Key words | *linear complementarity problems, interior-point algorithm, search directions*

Leveraging combinatorial invariants and AI for classification of entangled structures in biopolymers

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Abstract | Spontaneous physical entanglement, especially the formation of knots, occurs in polymers that are sufficiently long and densely packed. This phenomenon is not exclusive to synthetic polymers; biopolymers, including proteins and viral DNA, have been recognized for exhibiting knots as well. Recent advancements in AI-driven models have predicted that millions of proteins could potentially have a non-trivial topology. As biopolymers possess a highly complex geometric structure, recognizing, identifying, and classifying these entanglements presents a computational challenge. To speed up the computation of #P-hard knot invariants, which can detect the entanglement types, we implement topological methods that simplify the geometric representation and drastically decrease the computational complexity. Additionally, we investigate the potential application of specific neural network architectures for predicting entanglement, further accelerating these computations. In the context of proteins, the AI approach also holds promise for unveiling amino-acid sequences that contribute to the formation of knots themselves.

Key words | *AI*, *biopolymers*, *classification*

Special session on Advances in theory and methods of convex optimization

Goran Lešaja, Tibor Illés & Petra Renáta Rigó

Comprehensive analysis of kernel-based interior-point methods for $P_*(\kappa)$- LCPs

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Abstract | We consider kernel based Interior-point methods (IPMs) for $P_*(\kappa)$-LCPs that are based on the class of the Eligible Kernel Functions (EKFs)

The importance of kernel-based IPMs stems from the fact that the iteration bounds of large-step IPMs are significantly improved for some instances of EKFs. However, the derivation of the iteration bounds for particular EKFs is usually long and quite involved which was the motivation to investigate whether this process can be further analyzed and the derivation of iteration bounds simplified and under what conditions. Hence, we define a subclass of EKFs that we call SKFs by introducing additional conditions on the class of EKFs, which are not very restrictive and are satisfied by all EKFs with rational and exponential barrier terms that appeared in the literature. However, these conditions allow for a further comprehensive and in-depth analysis of the complexity of IPM and simplified derivation of iteration bounds. We derive the iteration bounds for several families of parametric SKFs and in all cases we match the best iteration bounds obtained in the literature for these SKFs and their special cases.

Key words | *linear complementarity problems, interior-point methods, kernel functions*

New class of search directions for symmetric cone horizontal linear complementarity problems

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Abstract | In 2023, Illés, Rigó and Török proposed a new class of algebraically equivalent transformations (AETs) in order to determine search directions in primal-dual interior-point algorithms (IPAs) for solving $P_*(\kappa)$-linear complementarity problems (LCPs). The method was extended by Darvay and Rigó (2024) to solve Cartesian $P_*(\kappa)$-symmetric cone horizontal linear complementarity problems ($P_*(\kappa)$-SCHLCPs). Recently, Illés, Rigó and Török presented a class of AETs for predictor-corrector $P_*(\kappa)$-LCPs. In this talk we generalize their new approach to $P_*(\kappa)$-SCHLCPs.

Key words | *interior-point algorithm, symmetric cone, search direction, linear complementarity problem*

Parabolic target-space interior-point algorithm for weighted monotone linear complementarity problem

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Abstract | In this talk we present a generalization of the result of Nesterov (2008), the primal–dual interior-point algorithm (IPA) for LP problems. Similarly to the paper of Nesterov, our approach is based on the concept of parabolic target space (PTS). The concept of weighted central path (WCP) in the literature of LCPs, first occurs in a paper of Illés, Roos, Terlaky (1997). We introduce a relaxation of WCP and show that the solution set of the relaxed problem is convex. Later an additional (convex) constraint on the duality gap of the MLCP has been added. Finally, we arrived at a convex feasibility problem (CFP) that has original variables of the MLCP, and those related to the relaxation and the additional constraint. The new variables, naturally satisfies an extra condition leading to the observation of a PTS. The use of the PTS allows us to discuss the new IPA for both the weighted and classical MLCP at the same time. The solution of an MLCP reduces to the solution of a sequence of CFPs. The driving force of our new IPA lies in the structure of CFPs and the assigned self-concordant barrier function of CFP, and its properties.

Key words | *interior-point algorithms, weighted monotone linear complementarity problems, parabolic target space, self-concordant barriers*

Parabolic target space method for linear optimization based on affine scaling directions

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Abstract | We propose new predictor-corrector interior-point algorithm for linear optimization using affine-scaling directions. The method is based on the idea of parabolic target space. Our approach differs from the classical algorithms in the sense that it is based on a parabolic barrier function. This barrier function turned out to be very promising, as it treats properly the primal-dual pairs of variables. Our computational experiments are promising and the theoretical complexity coincides with the best known ones for interior-point methods. We also discuss the local convergence properties of the proposed method.

Key words | *linear optimization, parabolic target space, interior-point algorithm, affine-scaling directions*

Special session on Applied graph theory and discrete optimization

Darja Rupnik Poklukar & Janez Žerovnik

A unified framework for overlapping community detection in graphs

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Abstract | Community detection is a classical task in graph based mining and analytics even though no mathematically rigorous definition exists. Roughly speaking communities are densely connected subgraphs and community detection can be mainly categorized as overlapping and non-overlapping problems. Solution methodologies are strictly related to the mathematical formulation of optimal community detection: heuristic approaches are targeting to optimize an objective function (e.g. modularity maximization), whereas model based approaches are tending to identify the best-fit community structure according to a generative model (e.g. Stochastic Block Model). However, a unified view of these methods is missing. In this talk, using the idea of Bóta, Csizmadia and Pluhár (2010), we are providing a comprehensive review of overlapping community detection methods through a unified view. Moreover, this approach is extended to a framework integrating the heuristic and model based approaches in such a way that community definition is based on a deterministic generative models, while optimal solutions are defined by appropriate objective functions.

Key words | *community detection, graph mining*

Acknowledgements | The research was partially supported by the BioLOG project: Miklos Kresz is grateful for the support of the National Center of Science (NCN) through grant DEC-2020/39/I/HS4/03533, the Slovenian Research and Innovation Agency (ARIS) through grant N1-0223 and the Austrian Science Fund (FWF) through grant I 5443-N. Miklos Kresz has been also supported by the research program CogniCom (0013103) at the University of Primorska and by the ARIS grant N2-0171.

A multi-echelon vehicle routing problem for waste wood collection and processing

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Abstract | Wood waste from construction and demolition sites or industrial processing can be recovered and transformed into valuable products. However, since this waste comes from various sources, it requires certain pre-processing steps before actual remanufacturing. The first step is the collection and transport of the waste from collection points, construction sites and industrial facilities to the processing facilities. Once there, the material has to undergo pre-processing steps (sorting, cleaning/decontamination) before it can be manufactured into a new product. Finally, the finished products are transported to their final destination, such as customers. This research focuses on the problem of optimizing collection and transport of wood waste to pre-processing and processing facilities, as well as the distribution of final products to customers. The above optimization question will be modelled as a vehicle routing problem (VRP) with multiple echelons. A mathematical model is formulated for the problem, and a neighborhood search heuristic is presented for its efficient solution.

Key words | *multi-echelon vehicle routing, wood waste, mathematical model, neighborhood search*

Acknowledgements | The research was supported by the BioLOG project: the authors are grateful for the support of National Center of Science (NCN) through grant DEC-2020/39/I/HS4/03533, the Slovenian Research and Innovation Agency (ARIS) through grant N1-0223 and the Austrian Science Fund (FWF) through grant I 5443-N. The authors also gratefully acknowledge the Slovenian

Research and Innovation Agency (ARIS) and the Ministry of Economy, Tourism and Sport (METS) for the grant V4-2351 from the CRP 2023 programme. Balázs Dávid is grateful for the support of the Slovenian Research and Innovation Agency (ARIS) through grant J1-50000.

Bus bunching in max-plus algebra

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Abstract | Bus bunching is a phenomenon occurring on high-frequency bus lines in urban public transport systems. The underlying principle is the variability in passenger arrivals at stops. On a route with short headways between successive buses, it can happen that a larger number of passengers arrive at a stop while waiting for a bus. This means that the total passenger boarding time, and consequently the bus dwell time, is prolonged. Because the bus is behind the schedule, more passengers will arrive at the next stop, while at the same time, less passengers will board the following bus at the original stop. This eventually leads to the bus bunching, negatively impacting the system reliability. We present a max-plus-algebraic model of bus bunching for a dedicated high-frequency line with equidistant stops under the assumptions of unperturbed conditions on links and disallowing bus overtaking. Since the number of boarding passengers is dependent on the difference between arrival times of successive buses, the equations become max-plus non-linear. Numerical results for a simulated example are shown. Extensions of the model with bus holding control and stochastic modelling are indicated.

Key words | *bus bunching, max-plus algebra, optimal control, public transport*

On the generalized traveling salesman problem

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Abstract | The generalized traveling salesman problem (GTSP) is a variation of TSP in which the vertex set is partitioned into clusters and the task is to find a shortest cycle that meets at least one vertex of each cluster. The problem is also called the traveling politician problem. The GTSP has a host of applications: warehouse order picking with multiple stock locations, sequencing computer files, postal routing, airport selection and routing for courier planes, and others. It also models optimization of the order of tasks in a flexible assembly workstation. A comprehensive study of local search heuristics for GTSP was reported by Karapetyan and Gutin (2012). We discuss another heuristics that has been previously applied to asymmetric TSP (Brest and Žerovnik, 2005) and probabilistic TSP (Žerovnik, 2015).

Key words | *discrete optimization, constructive heuristics, local search*

An optimization strategy for a magnetic levitation system

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Abstract | Magnetic fields are crucial in various electro-mechanical applications like transformers, sensors, magnetic bearings, medical imaging devices just to name a few. The core of each of these applications is some form of a coil. While a rather simple structure, yet there are several dimensions that affect the performance of the system this coil is a part of. Multi-objective algorithms are a part of optimization theory that deals with processes which have multiple output features to optimize. Often these problems require optimization of two output parameters for which the visual representation is a two-dimensional Pareto set. However for higher dimensional problems, while not as visual, the main idea remains. In this work we present an algorithmic optimization procedure of both physical dimensions and controller parameters for a magnetic levitation system. The sampling part of the algorithm is built upon fast transient response analysis based on a technique we have developed. We show how this approach is suitable for designing processes that have multiple variable parameters to optimize.

Key words | *multi-objective optimization, magnetic levitation, control systems*

On 2-Rainbow domination of generalized Petersen graphs P(ck,k)

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Abstract | The concept of 2-Rainbow domination extends traditional domination in graphs, where each vertex in the graph must be "dominated" by at least two distinct colors, thus ensuring a more complex and refined form of coverage. This is particularly relevant in applications where diverse resources or services need to be accessible within a network. In the talk, we will survey the results on 2-Rainbow domination number of generalized Petersen graphs $P(ck, k)$ as well as represent some our recent studies on 2-Rainbow domination of some graph families. Our study yields new results by establishing exact values for infinite families of these graphs where the general lower bound is attained. Specifically, we determine that for all infinite families, the lower bound of $\frac{4}{5}ck$ is achieved. For other cases, we provide both lower and upper bounds with minimal gaps, thereby refining the understanding of 2-Rainbow domination in these structures. Our findings have potential applications in network theory, particularly in scenarios requiring efficient resource distribution across complex networks.

Key words| *2-Rainbow domination, generalized Petersen graphs, graph theory, network optimization*

Special session on Assessing the transformation of the business landscape by applying methods of OR and statistics

Milica Maričić

Navigating AI-induced workplace transformation: An econometric study of layoff anxiety

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Abstract | The fast development and integration of artificial intelligence (AI) within the workplace led to significant transformations and disruptions across industries. Alongside its promises of improved efficiency and innovation, AI adoption has raised concerns regarding potential job displacement and workforce anxiety. One of the industries which has especially been transformed by AI is the IT industry. This study has the goal of assessing the IT employee's layoff anxiety in the two-year and ten-year period, taking into account their attitudes and perceptions of how AI changes and complements their skills. An econometric approach will be employed to model how perceptions of the transformational power of AI impact workforce anxiety. The results indicate that workforce anxiety can be successfully modeled and that the perception of one's skills being less valuable is a significant predictor. It is hoped that the research findings will shed light on the complex nature of layoff anxiety in the context of AI-driven skill transformations, providing valuable insights for IT employees, human resource managers, organisational leaders and other stakeholders.

Key words | *turnover intention, artificial intelligence, workplace transformation, econometric modelling*

Acknowledgement | This research was supported by the University of Belgrade - Faculty of Organizational Sciences.

Navigating urban mobility: Clustering European cities based on shared vehicle systems complexity

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Abstract | The evolution of sharing economy and sustainability-focused models, driven by digital innovation, has prompted extensive research to dissect their essential components. Consequently, shared vehicle systems (SVS) and business models promote efficient and sustainable urban mobility by providing collaborative and accessible transportation solutions. This study aims to segment 173 European cities based on the number of bikes, cars, scooters and mopeds available to share via platforms, alongside population and area coverage metrics. The results should indicate which cities lead the way and the available shared vehicle portfolio in the leading ones. As a segmentation algorithm, K-means was chosen. Three clusters emerged: townies comprises 151 smaller cities with abundant cars, solaris occupies solely Paris whose scores are the leading ones, while capitalis includes 21 larger cities excelling in the number of scooters. Significant disparities between clusters underscore the need for sustainable urban mobility strategies. The results unravel distinctness among SVS in European cities, providing valuable insights for future developments in urban mobility transformations.

Key words | *sharing economy, shared mobility, sustainable transport, segmentation analysis*

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Layoffs in the shared mobility industry: Trend analysis

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Abstract | The sharing economy is a novel business model which allows individuals to share assets with others via platform for a predefined price and period. The sharing economy has profoundly impacted the business environment, transforming traditional industries and creating new opportunities. Just some of the changes in the business environment due to the sharing economy are improved asset utilisation and efficiency, focus on access over ownership, development of new business models, as well as globalisation of services. Although these changes are mostly positive and the business model of the sharing economy is promising, this industry is not resilient to layoffs. This paper conducts a trend analysis of layoffs within the sharing mobility sector in the period 2020-2023, exploring the dynamics and implications of workforce reductions in this evolving sector. Secondary data available from the layoffs.fyi website will be used in the study. The conducted analysis will assess the magnitude and patterns of job losses and examine the broader impact on the shared mobility workforce. Research findings could contribute to a better understanding of the industry's employment landscape.

Key words | *layoffs, sharing economy, shared mobility, trend analysis*

Acknowledgement | This research was supported by the Science Fund of the Republic of Serbia, Grant no. 7523041, Setting foundation for capacity building of sharing community in Serbia - PANACEA.

Special session on Game theory

Miklós Pintér

Smart technologies and port operations: The role of service quality

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Abstract | Smart technologies increase efficiency in port operations. The enhancement depends on the quality of the offered services. In this paper, we formulate a game theoretical model to identify a port's optimal adoption strategy of smart technologies and analyze the impact of service quality on the port's pricing and adoption decisions. A utility-based model is developed to study the added value of smart technologies and its quality for port operations.

Key words | *smart technologies, quality, game theory, port operations*

Partial mixed extension and incomplete preferences

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Abstract | Games where the mixed extension does not exist is considered. We define the notion of partial mixed extension and a corresponding Nash equilibrium type notion. We also show that how partial mixed extension is related to games with incomplete preferences (Bade, 2005).

Key words | *non-coopertative games, mixed extension, incomplete preference*

Special session on Multicriteria decision making under SDG context

Helena Sofia Rodrigues, Ângela Silva
& Jorge Esparteiro Garcia

A simulation model for optimising material (re-)use in the wood-based construction sector

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Abstract | This research focuses on studying how different decision strategies in the construction industry affect the efficient use and environmental impact of building materials. Our proposed approach is a combination of discrete-event and agent-based simulation and aims to optimize material use and reuse in construction and demolition processes, supporting a circular economy in the construction sector. This is done through changes in decision-making process of the ecosystem, such as an emphasis on the Design for Deconstruction approach. The model covers the entire lifecycle of buildings and construction materials, estimates costs and benefits of their reuse. The framework includes a detailed financial and environmental cost-benefit analysis for various scenarios, evaluating the implications of different decisions regarding construction techniques, material storage, reuse, selling, or disposal. The simulation is designed to be

scalable and modular, allowing for the incorporation of additional factors and scenarios. This will be achieved through a complex multicriteria simulation model that considers costs of transportation, technical issues of recovering materials and carbon storage.

Key words | *modelling, simulation, deconstruction, circularity, optimisation*

Acknowledgements | The research was supported by the BioLOG project: the authors are grateful for the support of National Center of Science (NCN) through grant DEC-2020/39/I/HS4/03533, the Slovenian Research and Innovation Agency (ARIS) through grant N1-0223 and the Austrian Science Fund (FWF) through grant I 5443-N. The authors also gratefully acknowledge the Slovenian Research and Innovation Agency (ARIS) and the Ministry of Economy, Tourism and Sport (METS) for the grant V4-2351 from the CRP 2023 programme. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101035805. The project GDI UP is co-financed by the Republic of Slovenia, the Ministry of Higher Education, Science and Innovation, and the European Union – NextGenerationEU.

Assessing sustainable development goals in the Alto Minho region through multi-criteria methods

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Abstract | The Sustainable Development Goals (SDGs) are a universal call to action to end poverty, protect the planet, and ensure peace and prosperity by 2030. Evaluating the Alto Minho Region - Portugal, in alignment with these goals requires the analysis of a diverse set of indicators that assess progress across social, economic, and environmental dimensions. To conduct a comprehensive evaluation, this research study uses TOPSIS technique to determine the best alternative among a set of options based on their similarity to the ideal solution. The method involves benchmarking alternatives against a reference set, thereby facilitating a compromise solution that integrates all facets of sustainability.

The main goal of this research is to apply these indicators to the Alto Minho region using multi-criteria models. This approach aims to monitor the region's progress towards sustainability, identifying areas requiring improvement, and suggest local policies with global sustainability frameworks to ensure balanced and inclusive development.

Key words | *sustainable development goals, TOPSIS, Alto Minho, multi-criteria analysis*

Logistics Performance Index in EU – a two-stage methodological framework

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Abstract | The Logistics Performance Index (LPI) is a comprehensive measure, that provides a numerical score for each country. The efficiency of logistics, as measured by the LPI, is closely linked to the United Nations' Sustainable Development Goals (SDGs), which aim to promote a more sustainable and equitable future. High logistics performance directly contributes to several SDGs, such as SDG 9, SDG 11 and SDG 13. This study aims to contribute to a deeper understanding of the intricacies of logistics performance within Europe, with the overarching goal of fostering informed decision-making and driving continuous improvement in the region's logistics landscape. Based on

LPI indicators of 2023, the EU countries are ranked using CRITIC (CRiteria Importance Through Intercriteria Correlation) and MARCOS (Measurement of Alternatives and Ranking according to COmpromise Solution) methods. Additionally, a cluster analysis is made, identifying patterns and trends, such as groups of countries with similar strengths or weaknesses in logistics infrastructure or performance.

Key words | *Logistics Performance Index, multicriteria decision making, CRITIC, MARCOS*

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Evaluating Logistics Performance in EU countries: A hybrid approach with human and economic factors

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Abstract | The Logistics Performance Index (LPI) is a critical tool for assessing and comparing the efficiency of logistics and supply chain operations across countries. The interrelationship between the LPI, the Human Capital Index (HCI), Gross Domestic Product (GDP) and the European Chamber (EC) underscores the vital role of a skilled and healthy workforce in ensuring efficient logistics operations. Each of these indices and organizations plays a crucial role in advancing the SDGs. The LPI improves logistics and infrastructure, the HCI enhances human potential and workforce quality, GDP reflects economic capacity to invest in sustainable development, and the EC drives policy and

business practices that support the SDGs. Together, they contribute to creating a sustainable, inclusive, and prosperous future. The main objective of this study is to elucidate the connectivity among these indices and demonstrate the significance of human and social factors in economic activities. To achieve this, a hybrid approach was employed, incorporating the Analytic Hierarchy Process and Linear Regression to analyse the performance of European countries.

Key words | *Logistics Performance Index, Human Capital Index, Analytic hierarchy process, linear regression*

Acknowledgement | This work is supported by The Center for Research and Development in Mathematics and Applications (CIDMA) through the Portuguese Foundation for Science and Technology (FCT - Fundação para a Ciência e a Tecnologia). references UIDB/04106/2020 and UIDP/04106/2020 (Rodrigues). ADiT-Lab (Rodrigues and Silva) and Algoritmi (UIDB/00319/2020). This research is part of Bruna Barros logistics master thesis.

A memetic NSGA-III for green flexible production scheduling with real-time energy costs and emissions

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Abstract | The use of renewable energies strengthens decarbonization strategies. To integrate volatile renewable sources, energy systems require grid expansion, storage capabilities, or flexible consumption. This study focuses on industries adjusting production to real-time energy markets, offering flexible consumption to the grid. Flexible production considers not only traditional goals like minimizing production time, but also minimizing energy costs and emissions, thereby enhancing the sustainability of businesses. However, existing research focuses on single goals, neglects the combination of makespan, energy costs, and emissions, or assumes constant or periodic tariffs instead of a dynamic energy market. We present a novel memetic NSGA-III to minimize makespan, energy cost, and emissions, integrating real energy market data, and allowing manufacturers to adapt consumption to current grid conditions. Evaluating it with benchmark instances from literature and real energy market data, we explore the trade-offs between objectives, showcasing potential savings in energy costs and emissions on estimated Pareto fronts.

Key words | *green flexible job shop scheduling, memetic NSGA-III, OR in energy, sustainable production*

Developing digital, green and entrepreneurial competences: A focus on tools and programs using MCDM

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Abstract | Advancing green and digital transition is a key topic on Europe's agenda, aligned with the UN's SDG goals. In this context, this research investigates existing support tools and programs for upskilling digital, green, and entrepreneurial (DGE) competences. The data collection process resulted in the identification of 90 tools/programs, each differing in their contributions to DGE competences, and other varying features. The goal of the research was to select the best support tools and programs available within the project partner group (11 partners from 9 countries). An expert focus group assisted in defining the tool selection criteria and their grading, highlighting the importance of learning outcomes recognition and the development of multiple DGE competence areas. After the grading process, alternative assessments were analyzed using the PROMETHEE method, resulting in a ranking of the 15 most useful DGE tools/programs. These tools, having demonstrated their effectiveness and success in similar projects addressing SDG 4 and SDG 9, will be further promoted to relevant stakeholders and prioritized in capacity-building actions.

Key words | *digital skills, entrepreneurial skills, green skills, PROMETHEE*

Acknowledgement | This research has been supported by Interreg Central Europe project CE0100048 "Capacity2Transform"

Efficiency analysis of flood protection systems of municipalities in the Republic of Serbia

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Abstract | The subject of this paper is the risk assessment of floods, where the occurrence of floods can be influenced by a whole series of factors or their combination. The consequences that floods cause are lack of drinking water, epidemics, technical and technological accidents. The aim of this paper is the application of two methods combined: Data Envelopment Analysis - DEA and Ordinal Priority Approach - OPA in terms of flood defense efficiency. Combining these methods, the results provide a more realistic picture of the real significance of the criteria in relation to which the units are compared and in relation to the values of the assigned weight coefficients, and it is possible to compare the results of these two methods. Public documents of the municipalities of the Republic of Serbia are used for the analysis and the DEA method makes it possible to identify which municipalities are most exposed to the negative impact of floods, and especially which of the protected areas are most at risk. An additional ranking of efficient municipalities is undertaken, using the OPA method, which should assess which efficient municipalities have the best flood protection system.

Key words | *risk assessment, natural disasters and other accidents, DEA method, OPA method*

Special session on OR in forestry

Sattar Ezzati & Lidija Zadnik Stirn

A critical look at the use of MCDSS for the management of natural resources (especially forests)

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Abstract | The management of natural resources (farmland, forests, water, etc.) is subject to a long-term, sustainable, and resilient paradigm and the provision of multiple goods and ecosystem services (ES) to achieve a balance between economic, environmental, and social objectives. As DSS based on OR methods can improve the management of natural resources (e.g. forestry), several studies have been conducted to develop participatory multi-criteria models to support decision-making in resource management. A brief overview of the published DSS is given. Using the example of forestry in Slovenia, a newly developed MCDSS based on DEA and group AHP is presented. The study area was divided into analytical units. The units were categorized according to the efficiency of ES provision in terms of DEA. By selecting actors, forest management strategies and criteria, the decision problem could be organized in a hierarchical structure. The weighting of the criteria and strategies was determined using the fuzzy group AHP, considering multi-criteria and participatory problems under uncertainty and ambiguity. In the conclusions, the advantages, difficulties, and limitations of introducing DSS are discussed.

Key words | *natural resources, forestry, management, MCDSS, DEA, AHP*

Special session on Smart tourism: Unlocking potential with metaverse and blockchain technologies

P. Mary Jeyanthi

The use of virtual reality in the tourism industry in Slovenia

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Abstract | In recent years, the use of different modern technologies in the tourism has become an inevitable necessity. Among these, virtual reality (VR) has the potential to significantly transform the tourism industry, enabling interactive experiences and extending the destination space around the globe. Focusing on the adoption and impact of VR in Slovenian tourism using a mixed-method approach, including tourists survey and interviews with different tourism stakeholders, this research explores perceptions and experiences with VR from both, tourists and tourism services providers. Results showed that while tourism services providers are generally more receptive and some have begun integrating VR into their services, consumers display significant skepticism and unfamiliarity with this technology, questioning its necessity in their tourism experiences. Furthermore, the results emphasize the need for greater awareness and integration of VR in tourism to realize its full potential. Even though research took place in specific market, it offers valuable insights into adoption of VR in tourism industry.

Key words | *tourism industry, technology adoption, virtual reality*

Special session on Sustainability reporting, auditing and finance in operational research

Jelena Poljašević

Green driving: How much energy can we save through behavioral change?

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Abstract | Since the 1st Industrial Revolution, fossil fuels have been the most important source of energy worldwide. Among other usages, they are a primary source of transport and are thus responsible for a large share of greenhouse gas emissions. Fuel consumption is influenced by the mass, size, and shape of the vehicle, which are related to the vehicle's drag and aerodynamics properties, and the speed at which the vehicle is driven. In addition to those, the key factor influencing fuel consumption is speed. Drivers have a direct influence on that and hence on fuel consumption. The most important factor for economical and fuel-efficient driving is the driving behavior itself, as this is the way to achieve the greatest savings in fuel consumption. Reducing vehicle speed shows promise for reducing fuel consumption as it exponentially reduces air resistance. In this study, we used Monte Carlo simulations to investigate the impact of different parameters on the average fuel consumption of a car, taking into account the driving resistance. We investigate optimal speeds and other parameters that reduce fuel consumption and thus contribute to better energy efficiency.

Key words | *fuel consumption, green transition, Monte Carlo simulations*

Psychologically optimal KPI achievement policy

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Abstract | Workforce performance measurement is a key aspect of modern HRM management. It is based on setting KPIs and OKRs of employees that are usually linked to predetermined milestones. While they may seem easily achievable while distant, it is not clear how approaching of milestones affects employee's time utilization. Building on a task-based time allocation model by Bokal and Steinbacher, we propose an approach to achieving planned KPIs, where we want to complete assignments in surplus, so we have reserve for the days when we don't have time to do assigned tasks, thus aiming to achieve psychologically optimal experience of flow. Due to sensibility of real life experiments, we implement a simulated Monte Carlo experiment following the aforementioned task-based time allocation model. These experiments show stable improvement of simulated emotional state of workers applying the proposed policy, compared to regular KPI achievement policy.

Key words | *KPI, OKR, Monte Carlo simulations, emotional states*

Regular session on Applied statistics and econometrics

Factors of individual cryptocurrency investing: evidence from Croatia

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Abstract | This paper aims to detect disparities between those who accept cryptocurrencies with the purpose of investing and the opposite ones. Based on 216 questionnaire responses, out of which 110 were cryptocurrency investors and the rest were without such investing experience, we depicted a profile of a typical cryptocurrency investor in Croatia. Backward stepwise logistic regression was used to analyze the data. Explanatory variables consisted of investors' socio-demographic attributes, financial literacy and risk propensity. When socio-demographic variables were a model input, gender and level of computer literacy explained disparities between cryptocurrency investors and non-investors. Extending the basic socio-demographic model with an individual's risk propensity and financial literacy, which was composed of financial knowledge, financial attitude and financial behavior, improved profiling of cryptocurrency investors, while increasing prediction accuracy and model fitting as well. Altogether, cryptocurrency investors are usually risk-tolerant men with a higher computer and financial literacy than cryptocurrency non-investors.

Key words | *alternative investments, cryptocurrency, questionnaire, logistic regression*

Controlling for endogeneity in the impact of institutional quality on the environment

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Abstract | This paper investigates the impact of institutional quality on environmental quality, as measured by carbon emissions, within a multivariate framework across European Union countries from 1996 to 2022. Institutional quality, being a latent variable represented by a composite index, is prone to measurement error and simultaneity bias, potentially leading to endogeneity issues. To address this, the study employs a fixed effects two-stage least squares. The findings reveal that the impact, while positive and more pronounced compared to results obtained using alternative methods robust to heteroscedasticity, autocorrelation, and cross-sectional dependence, remains statistically insignificant.

Key words | *institutions, carbon emissions, endogeneity, FE-2SLS*

Acknowledgements | This work is supported by the Croatian Science Foundation under Grant IP-2020-02-1018.

Discretionary fiscal reaction in the euro area during the energy crisis

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Abstract | This paper examines the impact of the inflationary shock on discretionary fiscal responses in the euro area during the energy crisis of 2022 and 2023. The HICP inflation forecast error for 2022-2023 is utilized to assess the extent to which the negative effects of inflation were mitigated by fiscal policymakers. Panel models with fixed effects and the generalized method of moments were used, and it was demonstrated that the structural deficit as a percentage of potential GDP responded positively to inflation surprises in the euro area, demonstrating strong robustness. When debt sustainability is accounted for, the effects are somewhat weaker. Additionally, the real government spending forecast error affects the structural deficit, indicating that efforts to shield economic entities from the inflationary shock were unanticipated.

Key words | *inflationary shock, discretionary fiscal policy, energy crisis, generalized method of moments*

Estimating the drivers of life expectancy in EU: Dynamic panel data analysis

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Abstract | After the outbreak of COVID-19, life expectancy has become the focus of scientific and professional papers. The previous research connected life expectancy with macroeconomic conditions, environment, the lifestyle of the population, or health system specifics. This paper summarizes previous research findings and proposes a life expectancy model with all four mentioned groups of variables. The proposed model of life expectancy determinants is estimated using dynamic panel data for 27 EU countries from 2010 to 2021. For each group, we use several indicators. The results indicate the importance of all four groups of variables and justify all considered groups of variables necessary for modeling life expectancy. Most of the indicators have expected signs and are statistically significant. More preciously, GDP, drinking water, and private health expenditure have positive signs, while unemployment, alcohol, cigarette, consumption, and government health expenditure have negative signs. CO2 emission, education and government expenditure for health have unexpected sign and are statistically significant.

Key words | *life expectancy , dynamic panel data, lifestyle of the population, macroeconomic*

Spatial analysis of life expectancy determinants

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Abstract | Life expectancy is one of the fundamental indicators for measuring population health, and it has been shown to play an important role in economic development. Literature shows that life expectancy is influenced by a wide range of factors, including healthcare quality and socio-economic conditions. While some more recent studies prove life expectancy to be spatially autocorrelated between regions or countries examined, in most literature this is neglected. The aim of this paper is to investigate in more detail the determinants of life expectancy and to employ spatial autocorrelation analysis and spatial regression to recognize the spatial characteristics of life expectancy. Instead of the traditional regression techniques, spatial approach accounts for the spatial autocorrelation among countries, thereby enhancing the accuracy of our results. To capture a broader picture, we expand the set of examined determinants of life expectancy and segregate between different groups of indicators such as environmental, lifestyle, health system quality and macroeconomic indicators.

Key words | *life expectancy, spatial analysis*

Tourism-induced economic resilience in EU regions

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Abstract | In regional studies, resilience has become a prominent concept since the 2008 global financial crisis and gained further attention following the economic shocks induced by COVID-19. Research highlights diverse factors influencing regional economic resilience, including economic development, human capital, governance, and innovation. Recently, research has shed light on tourism's role in regional resilience. The COVID-19 pandemic underscored tourism's vulnerability to external shocks and the consequent risks for economies dependent on tourism. Nevertheless, the industry has demonstrated strong recovery potential, with EU tourism nearly returning to pre-pandemic levels by 2022. This study models regional economic resilience as the dependent variable, incorporating several tourism-related indicators from the EU Tourism Dashboard, such as tourist intensity and density, the share of domestic and international tourism, etc. We employ spatial regression models, beginning with SDEM estimations, using a data set covering 242 NUTS-2 regions. Initial results suggest that tourism influences economic resilience, but its impact varies depending on the specific phase and indicator considered.

Key words | *regional economic resilience, tourism, SDEM, NUTS-2 regions*

Z-score as measure of exposure: Analysis of pedestrian routes from home to school for children

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Abstract | Road traffic plays a vital role in modern development and culture, yet it also poses significant risks of human tragedy through accidents. Traffic accidents are a leading cause of death among youth, with children being particularly at risk. Studies indicate that intersections, pedestrian crossings, especially near schools and parks, are hazardous areas for children navigating traffic independently. Consequently, it is crucial to identify and rank dangerous areas. To this end, this study adopts the concept of exposure, proposing a new index and a more comprehensive method of exposure measurement. The index encompasses exposure measurement on the road network, pedestrian network, exposure due to technical features of pedestrian crossings, and routes and the number of children crossing. The index is measured by Z-score, and following the analysis, recommendations are provided for reducing exposure and increasing children's safety in traffic.

Key words | *exposure measures, Z-score, children in traffic, traffic safety*

Selection of the panel ARDL estimator: Case of the relationship between FDI, domestic savings and GDP

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Abstract | Numerous studies using the panel ARDL approach apply only the Pooled Mean Group (PMG) estimator instead of Mean Group (MG) and Dynamic Fixed Effect (DFE) estimators. The aim of the study is to test the appropriateness and differences of the three ARDL estimators in examining the relationship between the sectoral structure of FDI, domestic savings and GDP growth rate in a panel of 11 new EU Member States for the period 1995-2022. The paper uses three ARDL estimators and also finds that PMG is the most efficient estimator. The empirical analysis confirms the long-term, statistically significant impact of domestic savings on the GDP growth rate, although this impact is larger than in the case of FDI. The study has shown that foreign (FDI) and domestic savings are not substitutes and that the acceleration of economic growth should be based on models to stimulate domestic investment, income and savings. The study has also shown that it is necessary to adopt specific policy measures to attract FDI in high value-added sectors.

Key words | *ARDL model estimators, FDI, domestic savings, new EU member states*

Measuring similarity in consensus agreement between two binary classifier sets

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Abstract | Binary classification is a common task and numerous methods have been developed for binary classification problems. Many of these methods allow for different inputs that can be controlled by the researcher, such as different hyperparameter settings, the inclusion of different predictors, or different optimization criteria. When taking into account different inputs, one binary classification method applied to a fixed dataset will result in a set of binary vectors. We present an approach for calculating the similarity within such a set of vectors and between two such sets of vectors where we evaluate the similarity in consensus agreement. The within-set similarity is calculated by applying the k-adic version of the Jaccard coefficient and the simple matching coefficient, and we extend these coefficients to compare two sets of binary vectors. We derive the large sample variances of the coefficients and present some desirable properties of the coefficients. In addition, we present an application of such coefficients on a real-world dataset.

Key words | *similarity, binary sets, consensus agreement*

Exploring tax morale among university students: Determinants and policy recommendations

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Abstract | Tax morale refers to the intrinsic motivation of individuals to comply with tax obligations, which is essential for the effective functioning of any tax system. Understanding the factors that influence tax morale, especially among students, is crucial because they represent the future taxpayers of a country. The aim of the paper is to identify the key determinants of students' tax morale, whereby demographic factors, social norms, education, trust in state institutions and the perceived fairness of the tax system will be analyzed. Data will be collected using a structured questionnaire targeting university students from diverse academic disciplines and backgrounds. Structural equation modeling (SEM) approach will be used for data analysis. By providing empirical evidence on the factors that influence tax morale among students this study seeks to provide insights that can form educational strategies and policy interventions aimed at enhancing tax compliance in the long term.

Key words | *tax morale, determinants, university students, SEM approach*

Tourism and growth nexus in EU

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Abstract | International tourism, due to the lack of better alternatives, can become a government strategy for generating growth and employment. For such a growth strategy to be successful, countries need a liberal travel visa regime and a competitive passenger transport system. European integration has created such conditions. We show to what extent the tourism sector contributes to economic growth and how such a contribution depends on the country's economic growth level. Unlike studies using regression techniques, which focus on mean responses, we model the entire distribution of growth rates in a panel quantile regression framework. By estimating the conditional quantiles of the response variable given the values of the predictor variables, we overlook the effect at different levels of economic growth. This enables quantifying the asymmetric effect of tourism on the conditional distribution of growth rates and a clearer picture of this relationship. Research shows that countries facing relatively low growth rates can benefit more from tourism than countries with relatively high growth rates.

Key words | *economic growth, tourism-led growth, panel quantile regression*

Estimating the elasticity of input substitution across the world

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Abstract | The paper uses panel data to estimate the elasticities of input substitution values for various economies worldwide. In order to investigate the relationship between the growth, development and openness of the economies and the elasticity of the inputs, the study offers the implementation of estimates on data that correspond to countries and periods with different values of economic growth, economic development and country openness. Econometric specifications arising from the first-order conditions of a firm maximizing profit are used. A frequency filter modifies time series to filter out the cyclic influences. The estimated values of the elasticity of the inputs are usually less than 1, confirming the current empirical results questioning the relevance of the production function of the Cobb-Douglas type. The analysis has shown a link between the values of the input substitution elasticity and economic growth, economic development and the degree of openness, confirming current theoretical research.

Key words | *panel data, economic growth, economic development, country openness, elasticity of input substitution*

Acknowledgements | The Grant Agency of Slovak Republic - VEGA, supports this paper by grant no. 1/0052/24, "Estimation of Key Structural Parameters of Current Macroeconomic Models". Cultural and Educational Grant Agency of the Ministry of Education, Research, Development and Youth of the Slovak Republic - KEGA - supports this paper with grant no. 026EU-4/2024, "Building an interactive book called Quantitative Economic Analysis".

Parameter estimation of Gaussian mixture models from projections

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Abstract | Gaussian mixture models are widely used and applicable in various classification and reconstruction problems. When applied to positron emission tomography (PET) image reconstruction, in addition to the latent membership variable, another missing data problem appears. The measurements consist of pairs of gamma rays emitted from a radioactive substance in opposite directions, which are then detected as lines in a plane (2D) or tubes in space (3D). Traditional reconstruction methods estimate radiation intensities locally, pixel-wise or voxel-wise, while we assume that the objects of interest emit radiation according to a Gaussian mixture model. Therefore, the parameters of the mixture need to be estimated from the recorded lines, which do not contain complete information about the original radiation sources. In this work we adapt the classical EM (expectation-maximization) algorithm to this type of data. The proposed unbiased estimation method is efficient on synthetic data even from relatively small samples and is shown to be resistant to small amounts of noise. This is part of joint work with Damir Seršić and Tomislav Matulić at the Faculty of Electrical Engineering and Computing.

Key words | *Gaussian mixture models, missing data, EM algorithm, positron emission tomography*

Acknowledgements | This research was supported by the Croatian Science Foundation under project IP-2019-04-6703.

On electoral volatility in electoral systems

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Abstract | One of the features of electoral systems is a change of choice made by the electoral body in time. Electoral volatility refers to the outcome between successive elections and can indicate if there is a big change with respect to party positions. We look at a simple measure for electoral volatility (electoral fluctuation (EF)) that represents an average change of votes between two consecutive elections at time t and t+1. By taking into account a relative change of votes between successive elections, we can modify the EF indicator. We examine both the EF indicator and the modified EF indicator in the empirical cases of elections in several countries.

Key words | *electoral systems, electoral volatility, electoral fluctuation indicator*

Estimation of the response curves in media communication

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Abstract | Estimating response curves is crucial for understanding the return on investments in media activities. This task is challenging due to the numerous variables involved, such as media channels, seasonality, pricing strategies, and distribution, influencing key business metrics like sales or transactions. These variables also exhibit lagged effects and non-linear behavior. However, once estimated, these response curves enable the determination of optimal investment levels and inflection points where ROI is maximized. This contribution introduces a complex algorithm that nests non-linear estimation into a variable selection using genetic algorithms to estimate both short-term and long-term response curves. The algorithm is demonstrated through a case study using daily data from 2019 to the end of 2022 for a clothing company in the CEE region. This approach allows for precise optimization of media investments, enhancing brand awareness or maximizing ROI.

Key words | *response curve estimation, variable selection, marketing investment efficiency, algorithmic media optimization*

Acknowledgements | This research was supported by the Internal Grant Agency of the Prague University of Economics and Business under grant F4/22/2023.

Assessing the effect of fiscal decentralization on environmental sustainability in EU countries

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Abstract | Over the past half century, global energy consumption, including all energy-related emissions, has risen sharply. Therefore, the EU has taken various policy initiatives to promote energy efficiency, renewable energy and a green environment. In order to meet the environmental challenges, fiscal decentralization needs to be extended in a more efficient way. The purpose of this research is to investigate the relationship between fiscal decentralisation and renewable energy in minimising environmental degradation in old and new EU countries between 2004 and 2022. A quantile regression analysis was used to get empirical results which demonstrate considerable differences between old and new EU countries. The overall findings support the asymmetric effect of fiscal decentralisation on environmental sustainability, but only in the new EU members. The results of this study show that devolution of powers to local governments and increasing use of renewable energy can improve the environmental sustainability of the new EU countries. In both groups of countries, GDP is the main cause of large CO2 emissions, while renewable energy consumption reduces pollution.

Key words | *fiscal decentralization, environmental sustainability, EU countries, quantile regression*

Does Eurozone equity ETF outperform or underperform its benchmark index in terms of tracking error?

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Abstract | The current research focuses on the largest and the most liquid Eurozone equity iShares Euro Stoxx 50 ETF, with fundamental objective in finding explanatory factors of tracking error during crisis periods. Added value of the research comprises of employing Markov regime switching model because the influence of explanatory factors of tracking error may deviate over time depending if bearish or bullish regime of the market, which usually coincide with non-crisis and crisis periods. Empirical findings indicate that increase in volatility led to a stronger decrease of tracking error during periods of market stress than in bullish regime, while negative impact of illiquidity on tracking error is similar for both regimes. Unlike single regime model, a Markov switching exhibits negative relationship between the net flows and tracking error as expected. The effect of premium/discount seems to be both positive and negative, although positive, but weaker, influence was found during bearish regime which can be explained by herding behavior of investors or higher trading costs in periods of market stress.

Key words | *ETF tracking error, Eurozone equity market, crisis, Markov switching regression*

ECB transmission mechanism efficiency: A DCC-MGARCH and wavelet coherence anaylsis

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Abstract | Following the revival of the global economy, energy crisis and an inflation, the ECB moves away from long-term non-conventional monetary policy and starts quantitative tightening. Its most important lever, with an impact on the real and financial sectors, is the increase in the ECB's key interest rates. This paper, however analyses whether the credit risk of bank financial intermediaries can influence the effectiveness of the monetary policy transmission mechanism, where the effects are transmitted to the real economy through Euribor - Overnight Index Swap (OIS) spread. The study is based on daily data from the period from 01.01.2018 to 30.06.2023. Due to an inherent heteroscedasticity in the variables of interest, which should be modelled appropriately, the dynamic conditional correlation (DCC) multivariate generalised autoregressive conditional heteroscedasticity (MGARCH) model is used in this paper along with wavelet coherence analysis (WCA). DCC-MGARCH can well portray the time-varying characteristics of variables of interest, while WCA has significant advantage in reflecting the correlation details and lead-lag relationship between the variables.

Key words | *Euribor – OIS spread, transmission mechanism, DCC-MGARCH, wavelet coherence analysis*

Regular session on Behavioral operational research

The impact of biases and emotions on CEO decisions in cyber risk management

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Abstract | In a digitalized business environment, cyber risks represent a significant threat to the operations of organizations, potentially jeopardizing their success and reputation. The role of CEOs is critical in initiating changes that lead to the management of cyber risks on an organizational level. However, managerial decisions regarding cyber risks are not solely based on objective facts. This research, grounded in Protection Motivation Theory (PMT) and enriched with insights from behavioral economics, explores the understanding of CEOs' intentions toward managing cyber risks. The empirical study is based on responses from CEOs of companies in Croatia, and the PLS-SEM technique was used to evaluate the model. The study highlights how optimism bias, recency bias, and emotions like fear and regret play an important role in shaping CEOs' decisions about managing cyber risks. Results reinforce the argument for expanding traditional Protection Motivation Theory to include elements of behavioral economics.

Key words | *cyber risk management, protection motivation theory, cognitive biases, emotions*

Say what? Attitudes about immigration among student population in Croatia

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Abstract | A spectre is haunting Europe — the spectre of extreme right-wing populism. At its origin lies hate speech and, often, crimes against migrants who come from outside Europe. Political economy literature points out to, on average, net positive effects that migrants bring to the economy, but the balance on the political market is more worrisome. For a small open economy, overly depended on tourism, that "successfully" lost more than 1 million of its inhabitants in the last 30 years; the question of successful integration of migrants represents a first order condition of public policy. Thus the research question set in this paper is how to change attitudes in Croatian society about immigrants? Our pioneering approach is based on the experiment within survey method and it is tested on a sample of 1500 business and economic students from five university centres in Croatia (Osijek, Pula, Rijeka, Split and Zagreb). Results indicate that there is a small, but statistically significant, effect for the treated groups vis-a-vis their attitudes on the effect that migrants have on the labour market, social security system, overall safety and the economic development of Croatia.

Key words | *imigration, experiment, survey analysis, students*

Research approaches and software in discrete event simulation (DES) studies - a systematic review

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Abstract | In this systematic literature review (SLR), we comprehensively examined the evolution of Discrete Event Simulation (DES) from time period of 1968 to 2024. This review synthesizes findings from key studies published, highlighting significant advancements in DES by analyzing publication trends, study types, application areas, and the types of software employed. Our search strategy targeted 14 journals focused on simulations and operational research, all ranked as Q1 or Q2. We formulated a search query to run on the Web of Science and Scopus databases, and after removing duplicates, 192 journal articles remained for further screening and analysis, in line with the Prisma methodology. By identifying current trends and gaps in the literature, this paper provides a comprehensive overview of the latest developments in DES and suggests directions for future research to enhance its effectiveness and broaden its applicability in operational research and related fields.

Key words | *operational research, Discrete Event Simulation, SLR*

The presence of product placement in the film industry

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Abstract | The subject of the paper research is film as a means of communication with an emphasis on covert advertising and communication manipulation. Starting from the previous findings and conducted research, paper investigates the extent to which the marketing method of product placement is used, and how much products and services are actually represented in 20th and 21st century films. ie the frequency of product placement in movie. Due to ethical implications, this research is conducted in relation to the topic of socially responsible behavior, ie whether the promotional messages within the films indicate the problems of society such as racism, the position of women, etc. The research indicated that out of the 10 most watched films of all time, 7 of them contain hidden ads. Also, in 5 out of 10 analyzed films there is at least one frame that contains a promotional message related to the consumption of tobacco products. Product placement is becoming increasingly popular globally, and if applied well, a film can serve as a truly powerful promotional tool used to convey a message to an audience, whether it is a commercial message or a particular idea that may be of value to society.

Key words | *film industry, advertising, product placement*

Impact of financial literacy on investments in traditional, alternative assets, and cryptocurrencies

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Abstract | The study was conducted through a survey in 2023, comprising a sample of 445 respondents from the Croatian financial market. The analysis reveals that higher levels of financial literacy lead to broader portfolio diversification, including traditional and alternative assets as well as cryptocurrencies. Differences in investor behavior were uncovered through structural equation modeling, which showed various investment strategies depending on the level of objective and subjective financial literacy. The results indicate that respondents with higher objective financial literacy tend to invest in cryptocurrencies directly and by diversifying their traditional portfolios with alternative assets and cryptocurrencies, without a preference for alternative assets on their own. Conversely, respondents with higher subjective financial literacy prefer direct investments in traditional and alternative assets but not in cryptocurrencies, considering the latter as significant investments only within diversified portfolios.

Key words | *financial literacy, portfolio diversification, cryptocurrencies, investment strategies*

Acknowledgements | This work is fully supported by the Croatian Science Foundation (CSF) under the project "Challenges of Alternative Investments" [IP-2019-04-7816].

The influence of personality traits and behavioral factors in the investment decision-making process

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Abstract | This research aims to explore the importance of the personality traits and behavioral characteristics in the investment decision-making process of individual investors. The survey analysis was conducted. The final sample includes 310 investors in the Croatian financial market. Partial least squares structural equation modeling (PLS-SEM) was used. The results show that investors' personality characteristics, stability and plasticity are exogenous constructs. Stability positively affects investors' emotions, overconfidence heuristic, loss aversion and investment decisions. Plasticity influences their overconfidence and loss aversion. Heuristic, emotions and loss aversion positively influence long-term investment decisions. These decisions have a positive impact on the investment performance satisfaction, which positively affects intentions to start or continue investing. This research can help to all financial market participants because it provided a unique comprehensive model of the effect of the personality traits and different behavioral factors on investment decision-making process and extended the understanding of investor decision making.

Key words | *behavioral factors, personality, investment intention, PLS-SEM*

CB-SEM vs PLS-SEM comparison in estimating the predictors of investment intention

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Abstract | This paper compares different SEM approaches in estimating the predictors of investment intention. CB-SEM and PLS-SEM techniques were compared in the estimation of the model according to the theory of planned behavior (TPB). Moreover, PLSc was taken into consideration in the methods comparison. In order to make conclusions about which factors affect stock investment intention, TPB model with attitude towards behavior, perceived behavioral control and subjective norm as independent variables was estimated with three different approaches. The factors in the model were measured with survey indicators on a sample of 200 Croatian residents. The results mostly show matching conclusions about the investment intention predictors, with a small difference in PLS-SEM. Furthermore, factor loadings are higher according to PLS-SEM, as well as the indicators of convergent validity and reliability. On the other hand, CB-SEM shows stronger structural paths than PLS-SEM. PLSc results are closer to those of CB-SEM. While CB-SEM shows better model fit, PLS-SEM shows high predictive power. This research further provides explanations of the differences and guidelines on when to use which approach.

Key words | *CB-SEM, investment intention, PLS-SEM, structural equation modeling*

Regular session on Machine learning and data mining

Application of pointer networks for inferring (near) optimal guards in Art Gallery problem

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Abstract | The Art Gallery problem is a well-known combinatorial optimization problem in computational geometry that seeks to minimize the number of guards required to ensure visibility within a simple polygon. Specifically, the goal is to identify a minimal set of points (guards) within the polygon such that every internal point remains visible to at least one guard. This visibility criterion is established by line segments connecting each point to a guard, all contained within the polygon. In our study, we focus on the variant where guards are selected from the set of polygon vertices. However, finding the optimal guard configuration is NP-hard, necessitating the use of approximation algorithms. To address this problem, we propose a novel approach leveraging deep learning techniques. Specifically, we employ pointer networks, a specialized type of neural network designed for subset selection based on specific criteria. Our empirical findings demonstrate that our approach achieves near-optimal guard counts for Art Gallery instances consistent with the model's training data sizes.

Key words | *combinatorial optimization, Art Gallery problem, pointer networks, polygon guarding*

Multiple spheres detection problem with application in earthquake depths analysis

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Abstract | We introduce a modified version of the well-known k-means algorithm designed to solve the problem of detecting multiple spheres. This algorithm will be applied to a given dataset originating from several spheres in the area. The algorithm gives very good results assuming we have a good initial approximation. For this purpose, we will first apply several iterations of the DIRECT global optimization algorithm to the given dataset. We provide illustrative examples for both non-intersecting and intersecting spheres and demonstrate a real-world application in the analysis of earthquake depths.

Key words | *clustering, k-means, multiple spheres detection, global optimization*

Using machine learning to predict delayed discharge from hospitals

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Abstract | The increasing demand for healthcare services poses significant challenges in effectively managing patient flow, particularly concerning patients classified as Alternative Level of Care (ALC). These patients, although no longer in need of acute care, often encounter obstacles to discharge, resulting in hospital overcrowding and compromised health outcomes. Using administrative health data from Canadian hospitals, this study develops machine-learning models to identify potential ALC patients. Our findings show the efficacy of the eXtreme Gradient Boosting algorithm in accurately predicting potential ALC patients. To understand how the predictions are made, an explainable AI approach was used to identify the most important features that impact machine learning outcomes. We developed an easy-to-follow guideline for hospital staff to identify ALC patients proactively. Hospitals can use such decision-making tools to optimize resource allocation, enhance operational efficiency, and ultimately improve patient care outcomes.

Key words | *delayed discharge, machine learning, explainable AI, healthcare*

Marker gene methods for cell discrimination in single-cell RNA-seq data

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Abstract | Single-cell RNA-seq (scRNA-seq) produces a plethora of data from which one can derive information about gene expression levels for individual cells. In order to efficiently classify cells based on the tissues they originated from, it is crucial to identify and select informative genes to preserve the differences occurring between distinct cell types while excluding as much redundant information as possible. Finding such a subset is a computationally challenging combinatorial optimization problem in scRNA-seq data analysis. Several state-of-the-art methods tackle this issue in different ways. The aim of this paper is to evaluate state-of-the-art marker gene selection methods, comparing their classification accuracy, running time, and memory consumption using real-world datasets. Additionally, we will modify one of the methods under consideration, scGeneFit, allowing it to achieve higher accuracy while having significantly lower running times. We will compare it to the original implementation and the remaining state-of-the-art methods.

Key words | *scRNA-seq, gene expression, marker genes, cell-type discrimination*

Regular session on Mathematical programming

Genetic algorithm for the electric bus charging stations location design problem

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Abstract | In the contribution we present a mathematical model and propose a solution method for solving the electric bus charging station's location design problem. Goal of the problem solving is to minimise cost related with building of charging stations and to cover all tours by electric buses. Operation of electric buses in the public transport have some limitations such as lower driving range in comparing with diesel buses and longer charging times. We formulate a location-scheduling mathematical model, where the set of possible charging station locations can be formed by the set of all terminal stations and depots in the network. Tours of all vehicles are known and will be unchanged. To solve the problem, we can use various exact or metaheuristic methods. In this contribution we propose a solving method based on the Genetic Algorithm metaheuristic. Using the proposed method, we realised extensive numerical experiments on the test data sets created from real operational data provided by the municipal transport operator in the city of Žilina.

Key words | *electric buses, charging stations, genetic algorithm, location-scheduling problem*

Acknowledgements | This work was supported by the research grant VEGA 1/0654/22 Cost-effective design of combined charging infrastructure and efficient operation of electric vehicles in public transport in sustainable cities and regions.

Charger location with electric bus scheduling problem

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Abstract | We are dealing with the issue of the usage of electric buses in the public transport system. To achieve an effective system the optimization of schedules as well as the charging infrastructure is in place. Therefore we address the combined problem of electric bus scheduling and the charging infrastructure location problem. In our case, we have developed a mixed integer linear mathematical model to describe the combined problem. In order to test the mathematical model and its possible usage in real-life solutions we performed several numerical experiments using an IP solver on the datasets generated from real-life data provided by a public transport system provider in the city of Žilina, Slovakia. The mathematical model proved to be applicable for smaller instances of the problem.

Key words | *electric buses, scheduling problem, charger location, mathematical modelling*

Acknowledgements | This work was supported by the research grant VEGA 1/0654/22 "Cost-effective design of combined charging infrastructure and efficient operation of electric vehicles in public transport in sustainable cities and regions".

Sub-optimizing routes in MS Excel: An approach of solving the TSP and VRP

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Abstract | This paper introduces an approach for solving Traveling Salesman Problem (TSP) and Vehicle Routing Problem (VRP) for a heterogeneous fleet of vehicles in MS Excel. MS Excel, along with its optimization solver add-in application with implemented evolutionary algorithm, was selected as the platform for development of the procedure. The evolutionary algorithm enables MS Excel to identify sub-optimal routes of the considered problems within a short timeframe. The second part of the paper presents two examples that illustrate the application of the proposed procedure for a TSP with 23 locations, and a VRP with 26 locations. All locations are situated in Prague, the capital city of the Czech Republic, and its vicinity. The results prove the effectiveness of the algorithm in optimizing route planning for urban environments, highlighting its practicality in real-world scenarios.

Key words | *traveling salesman problem, vehicle routing problem, MS Excel solver, heterogeneous fleet*

Acknowledgements | Prague University of Economics, Faculty of Informatics and Statistics, project no. F4/10/2024

Integer programming formulation for single source multiple depot pipeline scheduling problem

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Abstract | In this paper, an integer programming formulation is proposed to determine both sequence and batch sizes of gasoline products for pumping operations at source and timings and quantities of dropped products for delivery operations at depots in a single source multiple depots Indian pipeline. The objective of the proposed model is to reduce the sum of pipeline and depot inventory costs, back order costs and interface costs. The Batch tracing constraints ensure that material from accessible batches is delivered at the depots during the pumping of new batches. Furthermore, a new set of variables and constraints ensure that the products are delivered to the customers before the committed due dates respecting the installed pump capacities. Relevant data such as depots' daily demands, initial stocks at both depot and pumping station, pipeline fill was collected from the Indian pipeline to test the efficacy of the proposed formulation. The mathematical model was implemented in CPLEX with C++. Results suggest that the proposed formulation can result in significant savings in the supply chain cost for the firm for a short length pipeline compared to manual approach.

Key words | *mathematical optimization, integer programming, application in gasoline industry*

Regular session on Multicriteria decision making

Assessment of companies' readiness to use Open data – towards a multiple-criteria model development

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Abstract | Open data (OD) refers to data published in open standard formats, available to use and reuse for non-commercial and commercial purposes. OD promotes transparency and participation and is one of the vital elements of data economy. The OD progress is measured by indexes (i.e. Open Data Maturity Report, OURdata index), but little is known about the use of OD in companies. To measure readiness of the companies to use OD we aim to develop a multi-criteria assessment model using DEX methodology. We present criteria identification, categorization and ranking (assigning importance) in this paper. We conducted a facilitated brainstorming session with 16 domain experts and AI as the 17th expert, using brainstorming software. The experts contributed ideas, reflecting the question: »Provide criteria and indicators for determining the readiness of companies to use OD«. In total 260 ideas were generated, categorized and ranked into 11 categories by experts. Evidence suggest that group supported brainstorming with additional application of AI can yield many ideas in a short time and experts' reflection on the importance of the ideas can overcome the subjective judgement of a model developer.

Key words | *open data, readiness, companies, multi-criteria decision modeling, DEX*

Acknowledgements | This research was supported by the Slovenian Research Agency: P5-0018 - Decision Support Systems in Digital Business, and Slovenian Research Agency and Ministry of Digital Transformation of Republic of Slovenia: V5-2356 - Open Data Maturity Assessment and Encouragement in Slovenian Enterprises: Methodology Development and Web-Based Solution.

Deriving citation performance of ORMS journals by DEA models

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Abstract | Citation impact of scientific journals is measured by traditional metrics such as impact factor, article influence score, journal citation indicator, and others. While the impact factor is based on the total number of citations and does not reflect the quality of journals cited, the article influence score considers the past importance of the citing journals. This paper aims the analyse the possibility of measuring the performance of journals by data envelopment analysis (DEA) models. We applied traditional radial and SBM DEA models with weight restrictions where the outputs of the models are the citation counts from Q1 to Q4 categories and other journals according to the impact factor. This basic model is extended by considering the impact factor of the journals from the previous year as one of the inputs of the model. The results of the study are illustrated in the set of 80 journals from the Web of Science category Operational Research and Management Science (ORMS). The dataset for the study was obtained from the Journal Citation Reports in the period from 2017 until 2022.

Key words | *data envelopment analysis, citation impact, ranking, performance*

Acknowledgements | The research is supported by the Internal Grant Agency of the Faculty of Informatics and Statistics, Prague University of Economics, project F4/10/2024.

A fuzzy multi-criteria decision-making approach to an outpatient chemotherapy service

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Abstract | An outpatient chemotherapy service involves a complex care system consisting of a multi-step process, intricate procedures, and interdisciplinary caregivers. Bringing changes and improvements needs to be carefully considered and accepted by all stakeholders. In such a context, a group multi-criteria decision-making approach with the objective of helping an oncology department reorganise is proposed. As there is some ambiguity in the stakeholders' consensus on the improvement solutions, a fuzzy TOPSIS method compared to a fuzzy VIKOR method is used. The advantages of these approaches are that they do not require experts to be familiar with fuzzy set theory, allow for dealing with preferences and uncertainty, and are a useful tool for group decision-making in healthcare that incorporates both qualitative and quantitative criteria.

Key words | *multi-criteria decision-making, fuzzy sets, chemotherapy outpatient services, hospital management*

Development of a multi-method simulation model for migration flows on the Balkan route

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Abstract | The paper presents the development of a comprehensive simulation model to study migration flows on the Balkan route using agent-based modelling (ABM). By integrating diverse modelling methodologies and empirical data, the project seeks to advance the understanding of migration processes, considering both micro- and macro-sociological factors. The ABM approach will allow for the simulation of individual and group behaviours, providing insights into emergent phenomena within complex social systems. In the project, we will collaborate with international research institutions and stakeholders to gather data, validate theories, and propose strategies for managing migration flows under varying geopolitical conditions.

Key words | *Migration Flows, Agent-Based Modeling (ABM), Balkan Route, Social Simulation*

Acknowledgements | The research was supported by research project no. J5-4585 MIG@B | Modelling of international migrant flows in the Balkans, financed by the Public Agency for Scientific Research and Innovation Activity of the Republic of Slovenia.

Regular session on Mixed OR methods

Analyzing small and medium-sized enterprises' sustainability practices and customer perceived value

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Abstract | The research deals with aspects of sustainability and corporate social responsibility in SMEs in tourism. The research will look into customer perceived value of the sustainability practices. The goal is to look into certified tourism SMEs and their efforts to communicate their commitment to sustainability to customers. The research questions that will be answered will be how the tourism SMEs communicate their commitment to sustainability while being part of available sustainability certifications (with focus on accommodation in Croatia). Furthermore, the open questions are how do the customers perceive the value of sustainability practices and certification, and how can the positive perceived value of tourism SMEs that are certified influence customers' revisit intention. The methods used will be content analysis, interviews with management of SMEs in tourism and finally there will be experiment used to see how customers perceive sustainability while staying in a hotel or using a tourism service.

Key words | *sustainability, customer perceived value, sustainability certification, SMEs*

Goal programming of required resources in demographic changes

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Abstract | In spatial planning, a long-term housing programme is required, especially when it comes to finding the best possible solution with limited financial resources and taking into account the priorities of the goals in the social housing. In Europe, we are experiencing an ageing population and therefore rapid changes in the demographic structure. If we plan to meet demographic changes with a satisfactory housing supply, we must take into account both the dynamics of the decline in the number of young people in a given area and the increase in the number of older people, whose functional abilities are characteristically declining. We should also be aware of their existing housing standards and financial capabilities to ensure their adaptation to new needs. We show how the spatial data can be combined with the projection of age structures and the dynamics of housing needs when using the goal programming approach and how the financial possibilities of a region influence social housing policy. The case of Local Action Group (LAG) Haloze programming is presented. Such an approach could be used in any LAG or region if the appropriate spatial and demographic data is available.

Key words | *goal programming, age structure, housing, demographic projection*

Acknowledgements | The authors acknowledge the financial support from the Slovenian Research Agency from the research projects L7-3188 Hierarchical Design and Financing of the Social Infrastructure of Smart Silver Villages. Samo Drobne also acknowledges the financial support from the Slovenian Research Agency through the research core funding Earth Observation and Geoinformatics (P2-0406).

Comparison of Python metaheuristic packages

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Abstract | Metaheuristic approaches are utilized to find suboptimal solutions within a reasonable timeframe. This is crucial for NP-hard problems such as the traveling salesman problem, vehicle routing problem, and knapsack problem. However, identifying the appropriate software to execute such algorithms is not straightforward. This paper presents a comprehensive study aimed at identifying a suitable package in the programming language Python. Python is one of the most widely used programming languages worldwide and is employed daily in numerous companies. The sheer number of packages available can be over-whelming, making it challenging to select the right tool for a given problem. The objective of this paper is to locate and compare such packages, preselect suitable ones, and determine the best package or packages. The criteria for decisionmaking include firstly number of algorithms implemented, secondly flexibility, customization and tuning capabilities, thirdly performance and also quality of documentation, learning curve in relation to the knowledge of AI, maintenance, community support and overall health of the package.

Key words | *Python, metaheuristics, performance, test functions for optimization*

Acknowledgements | The research is supported by the Internal Grant Agency, Faculty of Informatics and Statistics, Prague University of Economics and Business – project no. F4/10/2024.

An application of input-output model to the assessment of CO2 emissions of Croatian economic sectors

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Abstract | The negative effects of pollution and the impacts of different productive sectors on the degradation of the environment have become important issues in the analysis of economic development. This study aims to estimate the overall carbon footprint of different economic sectors of the Croatian economy. Total CO2 emissions are decomposed by direct and indirect emissions of productive sectors and final demand by applying the input-output (IO) methodology. IO approach enables decomposition the total CO2 emissions of specific sectors into emissions related to production of final goods and services and the production of intermediate inputs delivered to other economic sectors. The highest level of direct emissions has been generated by sectors producing energy products and transportation. As the output of those sectors is required as intermediate inputs used by the other sectors, IO model redistributes emissions to other sectors delivering final products to domestic users and abroad. Besides transport and electricity, the highest level of total direct and indirect emissions in Croatia are found in the construction sector, production of non-metallic mineral products and food industry.

Key words | *CO2 emission, input-output model, productive sectors, Croatia*

Teaching profit maximization: can a non-calculus approach indeed help?

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Abstract | In microeconomics class, students encounter two fundamental mathematical programming problems: optimizing economic costs and profits. Traditionally, these are addressed using differential calculus, which can be daunting for first-year students new to the subject. This study explores an alternative approach, focusing on minimizing costs and maximizing profit using the weighted arithmetic-geometric mean inequality (WAG). WAG is straightforward and does not require prior formal knowledge. To assess its accessibility compared to calculus, both methods were presented to first-year economics students. Results showed that students found WAG easier for cost minimization but not for profit maximization. Although WAG is not superior to calculus, it generally serves as a useful complement and a control method.

Key words | *cost minimization, profit maximization, weighted AM-GM inequality, calculus*

Policy abuse and consumer online buying: Reactance theory perspective

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Abstract | Consumer online misbehaviour, such as policy abuse, is rising and thus causing significant economic and financial losses. We utilised reactance theory to explore the effects of demographic characteristics (age, gender, education) and conformity orientation on consumer online misbehaviour (product return, promotion and item not received abuse policies) and further impact of misbehaviour on online buying frequency. We used the convenience sampling method (online survey) and collected 244 responses (Croatian consumers) who bought and misbehaved online concerning policy abuse at least once last year. We analysed data using confirmatory factor analysis and regression analysis. The research results show that demographic characteristics are associated with consumer online misbehaviour to a different extent. Conformity orientation negatively influences product return and item not received policies abuse. In addition, only promotion policy abuse positively affects the frequency of online buying. This study contributes to psychological reactance theory by revealing the role of demographic characteristics and conformity orientation for reactance concerning online misbehaviour.

Key words | *consumer online buying policy abuse, demographic data, conformity orientation, reactance theory*

Exploring managerial accounting utilization in NGOs through structural equation modelling

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Abstract | This study examines the relationship between contingency factors, managerial accounting, and the level of community engagement - a proxy for organizational performance for non-profit organizations. An online questionnaire-based survey was conducted, which produced 416 valid responses (a response rate of 39.36%) from non-profit organizations operating in Croatia. The study employed structural equation modelling (SEM) to test the research hypotheses. The results show that contingency factors (organizational decentralization, manager's decision-making style and environmental uncertainty) were significantly associated with applying managerial accounting in non-profit organizations. Furthermore, using managerial accounting in non-profit organizations was significantly associated with non-profit organizations' community engagement. The results also indicate the indirect effect of managerial accounting in non-profit organizations between the contingency factors and the level of non-profit organizations' community engagement.

Key words | *non-profit organizations, managerial accounting, contingency factors*

Workshop

Rajan Batta

Using operations research methods to guide UAV search in a disaster area

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Abstract | The first part of the workshop focuses on search path optimization for recording emerging targets. This portion of the work considers the situation where targets emerge according to a non-homogeneous space-time Poisson process during the mission. The only provided information is the time-dependent arrival rate function for each cell in the area. Two heuristics are proposed. The first heuristic is based on an approximation of the target recording problem as an orienteering problem with time windows (OPTW), in which the time window settings for each cell are associated with the type of target-emerging condition that it represents. These second heuristic is based on a tabu search method. To analyze the effectiveness of both heuristics, target arrivals are simulated across a suitable number of replications and summary statistics are obtained. Further, computational testing is conducted to study the impacts of three factors: sensor-capture radius, UAV speed, and UAV service time. The factorial analysis shows that sensor-capture radius and UAV service time affect performance significantly. Both heuristics deliver comparable solutions, with the tabu search method consuming less CPU time. In terms of managerial insights, what we find is that cell visitation priorities should be based on a combination of factors that includes its target-emerging conditions, distance from the start and endpoints, and available mission time.

The second part of the workshop focuses on a situation where sub-regions with targets present have already been identified. The goal is to develop a search and route plan for the UAV so as to maximize the total number of targets detected within a limited mission duration. First, a non-linear Mixed Integer Programming (MIP) model is applied to address the problem. To linearize the model, continuous search time variable is discretized such that it can only take a finite number of possible values. Therefore, the resulting Mixed Integer Linear

Programming (MILP) models an approximation of the original problem. Next, an exact solution approach is presented and a clustering heuristic is suggested to solve larger problem instances. To validate the proposed solution methods, extensive computational experiments are conducted. Furthermore, a real-world case study is presented within the humanitarian domain to demonstrate the effectiveness and relevance of the suggested approaches.

Key words | *mixed integer linear programming, UAV search, disaster area, orienteering problem with time windows, tabu search method*

Special methodological workshop for postgraduate students

Analysis of zombie companies characteristics in the CEE region

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Abstract | The issue of zombie companies has been studied through works from the Japanese crisis of the nineties of the last century, to the actualization of this topic after the Covid-19 pandemic. The largest number of papers studied the macroeconomic effects that zombie companies have on the entire economy of an individual country (Japan, Caballero et al., 2008; Italy, Schivardi et al., 2017; Austria, Beer et al., 2021; 7 EU countries, Storz et al., 2017; 34 European countries, Acharya et al., 2022; European OECD countries, 2018; Altman et al., 2023; states, Albuquerque and Iyer, 2023). A smaller number of papers studied the characteristics within the company itself that lead to the emergence of zombie companies (for 14 developed countries, Banerjee and Hofmann, 2022; for China, Bowman, 2022; for Poland, Nehrebecki, 2023). The subject of research in this paper will be the analysis of the characteristics of listed zombie companies with the aim of determining what are the characteristics of zombie companies compared to non-zombie listed companies in Central and Eastern Europe (hereafter CEE region).

Key words | *zombie, CEE, financial ratios*

What is the potential demand for artificial intelligence solutions for entrepreneurs in Croatia?

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Abstract | Artificial intelligence (AI) is in its pivotal moment to change the way in which businesses operate globally, offering unprecedented opportunities for growth and efficiency. Worldwide, firms are increasingly taking advantage of AI technologies to transform traditional businesses, start new businesses and enhance their business operations. (Soni et al., 2020). To gain the competitive edge in the today's Croatian market, there seems to be possibilities for entrepreneurs in Croatia to use AI solutions and enhance their productivity and efficiency, while putting human in the center of the business and focusing on strategic thinking and innovation. This research paper has the aim to discover gaps and challenges with AI solutions and focus on determining what is the potential demand for AI solutions in Croatia and what are the current perceptions, beliefs, and attitudes about the AI solutions of entrepreneurs of Croatia about the AI solutions. The qualitative research involving interviews of entrepreneurs and scientists, as well as the focus group of students entering the job market, will offer recommendations for start-up offering AI solutions in Croatia and entering Croatian market.

Key words | *artificial intelligence, entrepreneurship, market for AI, AI in Croatia, ChatGPT*

Assessment of bid-ask spread in the bond market with machine learning

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Abstract | The EU sovereign bond market is of great significance as it plays a crucial role in maintaining economic stability and financial infrastructure inside the European Union. Sovereign bonds are essential for governments as they provide a mechanism to secure funding for public expenditure, infrastructure development, and economic stimulus programs. A liquid and well-functioning market for sovereign bonds is crucial to protect financial stability. More precisely, the liquidity of sovereign bonds in the secondary market is vital as it ensures that these securities can be bought and sold with minimal price impact, reflecting the true market value and providing confidence to investors about the ease of entering and exiting positions. The natural measure of liquidity is the bid-ask spread. Accurately forecasting the bid-ask spread is essential for assessing the efficiency and functioning of the bond market. In light of recent regulatory changes and the ongoing electronification of the EU bond market, accurate daily forecasting of the bid-ask spread is especially advantageous. These changes aim to enhance transparency, reduce trading costs, and increase market efficiency. Moreover, for high-frequency traders and institutional investors accurately predicting bid and ask prices on an intraday basis is essential in order to execute large trades efficiently without significantly affecting market prices. Intraday forecasts can help identify short-term liquidity fluctuations and market anomalies, thereby improving trading strategies and liquidity management. The objective of this research paper is to develop and evaluate a variety of machine learning models that accurately forecast the daily and intraday liquidity of government bonds in the EU sovereign bond market. The research will employ a diverse array of input variables to investigate the extent to which they impact bond liquidity.

Key words | *sovereign bond market, bid-ask spread, machine learning models*

Round table

Bruno Ćorić

Economic disasters: frequency, determinants and effects

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Abstract | Many studies suggest that macro-finance models incorporating the risk of economic disasters can explain many financial phenomena. This literature is based on the historical data for a limited number of countries. Our research project constructs a global dataset on economic disasters after WWII. We also explore the recovery after economic disasters using historical and post-WWII data. Our results suggest that extreme economic crises are associated with huge and remarkably persistent loss. On average, output loss surges to above 26% in the first few years after the outbreak of a disaster and remains above 20% for as long as 20 years. It is only after more than 50 years that the loss is fully recovered. Finally, the rare disaster models usually consider economic disasters as large exogenous shocks. Our research project suggests that the frequency of economic disasters is partially endogenous and associated with the level of democracy, quality of institutions, and economic policy. The explanatory power of these variables appears sufficient to account for the difference between the number of economic disasters in old OECD and non-OECD countries after WWII.

Key words | *economic disasters, recovery, frequency*

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About KOI

The **International Conference on Operational Research (KOI)** is the major event organized by the Croatian Operational Research Society (CRORS) since 1991. In the period from 1991 - 1996 it was organized annualy, while from the 1996 nowards it is organized every two years.

Aims and scope

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- KOI 2018 - 17th International Conference on Operational Research, September 26-28, 2018 in Zadar, Croatia
- KOI 2016 - 16th International Conference on Operational Research, September 27-29, 2016 in Osijek, Croatia
- KOI 2014 - 15th International Conference on Operational Research, September 24-26, 2014 in Osijek, Croatia
- KOI 2012 - 14th International Conference of Operational Research, September 26-28, 2012 in Trogir, Croatia
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We are pleased to invite all academicians, practitioners and particularly young researchers, as well as students, interested in all branches of operational research, mathematical modelling and economic analysis to participate in the conference by presenting their papers and exchanging ideas in order to improve the quality of the scientific work in this area.

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