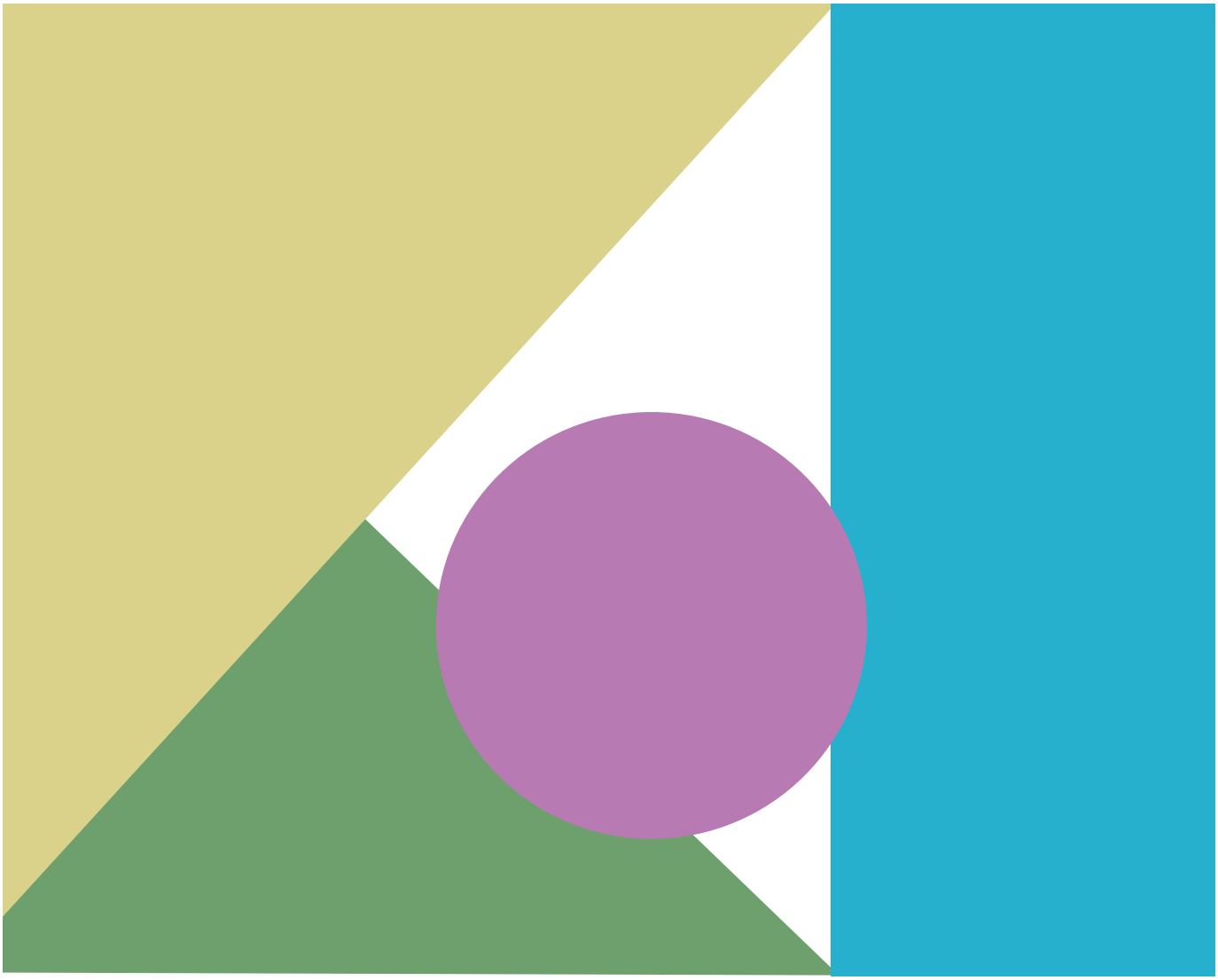

Book of Abstracts

Editors: Tea Mijač & Tea Šestanović

KOI 2022

19th International Conference on Operational Research

September 28-30, 2022 Šibenik, Croatia

CRORS
CROATIAN OPERATIONAL
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I m p r e s s u m

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19th International Conference on Operational Research
KOI 2022, 28-30 September, Šibenik, Croatia

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P r e f a c e

Abstracts of plenary lectures and contributed talks, presented at the 19th International Conference on Operational Research KOI 2022, 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 2022, organized by Croatian Operational Research Society in collaboration with Faculty of Economics, Business and Tourism, University of Split, is held in Šibenik, Croatia, from September 28 to September 30, 2022. The conference KOI 2022 brings together various topics grouped into the following sessions:

Plenary Sessions

Special Sessions on:

- Applied Graphs Theory and Discrete Optimization
- Challenges of Alternative Investments
- Computational Mathematical Optimization
- Decision Intelligence Analytics in the Financial Sectors
- Ensuring a Green and Sustainable Future through Smart Cities
- Game Theory

- Novel Applications of OR
- OR in Forestry
- Real-World Applications of Machine Learning
- Smart Cities development and trends: Cases and research opportunities
- Tackling the Issues Encompassing Composite Indicators
- Value Co-creation and Competitive Advantage of Smart Tourism

Regular Sessions on:

- Mathematical Programming
- Multicriteria Decision Making
- Optimization in Human Environment
- Quantitative Methods in Banking and Finance
- Applied Statistics and Econometrics
- Machine Learning and Data Mining

Plenary lectures are given by eminent international experts:

- Marc Sevaux, Université Bretagne Sud (Lorient, France)
- Yurii Nesterov, Department of Mathematical Engineering from the Louvain School of Engineering, Center for Operations Research and Econometrics
- Ozren Despić, Aston Business School, Operations & Information Management, Aston University, UK

In addition to plenary lectures there are 103 contributed talks. The total of 116 registered authors and co-authors participate the conference from 24 different countries: Austria, Belgium, Bosnia and Herzegovina, Chile, Croatia, Czech Republic, Hungary, India, Iran, Israel, Lichtenstein, Netherlands, North Macedonia, Poland, Portugal, Romania, Slovakia, Slovenia, Serbia, Spain, Sweden, Turkey, UK and US. Also, the Workshop on How AI sees the world around us is organized during the conference KOI 2022 with the guest lecturer Goran Zaharija, University of Split, Faculty of Science. The conference has an international Program Committee and is held in english language. After the conference, full papers will be blindly reviewed by two independent reviewers and accepted ones will be published in the Croatian Operational Research Journal CRORR (indexed in WoS ESCI, SCOPUS and other important scientific databases).

Editors

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Plenary Speakers

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Education

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Education

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Profesional experience

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2003 - present | Lecturer, Aston Business School, Birmingham

Additional info

My main research focus is on developing mathematical models for their use in efficiency measurement and decision making. Investigating their theoretical properties and applicability in different contexts is one aspect of that research while the other one, equally important, is in the direction of making these models simpler and easier to understand by practitioners. The following further narrows down the main areas of interest: Data Envelopment Analysis and Performance Measurement, Composite Indicators and Aggregation Operators, Multi-criteria and Soft Decision Analysis, Machine Learning and Optimisation

Plenary Lectures

Metaheuristics, glorious past, controversial present and bright future?

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Abstract | The lecture will focus on metaheuristics and will present a general view of these methods used to solve combinatorial optimization problems over the ages. The talk will present a vision of what has been a glorious past (the golden age) of metaheuristics. Over the last 20-30 years, they have been successfully used to solve various optimization problems. Many different techniques such as Simulated Annealing, Tabu Search, Variable Neighborhood Search, GRASP, Genetic Algorithms, Memetic Algorithms and others have shown their efficiency and superiority on many problems. A more recent trend in metaheuristics publications has seen the appearance of too many nature-inspired metaheuristics. All these methods are "polluting" the domain and for most of them do not bring anything from a scientific point of view. The talk will quickly explain why we have reached this situation. The lecture will end with the presentation of recent and future works at the crossroad of metaheuristics and machine learning that should bring a bright future to the metaheuristic community.

Key words | *metaheuristics*, *combinatorial optimization*

Primal subgradient methods with predefined stepsizes

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Abstract | In this talk, we suggest a new framework for analyzing primal subgradient methods for nonsmooth convex optimization problems. We show that the classical step-size rules, based on normalization of subgradient, or on the knowledge of optimal value of the objective function, need corrections when they are applied to optimization problems with constraints. Their proper modifications allow a significant acceleration of these schemes when the objective function has favorable properties (smoothness, strong convexity). We show how the new methods can be used for solving optimization problems with functional constraints with possibility to approximate the optimal Lagrange multipliers.

Key words | *primal subgradient method*, *nonsmooth convex optimization*, *step-size rules*

Composite indicators, Geometric Data Envelopment Analysis, and the case of Dubai Government Excellence Model

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Abstract | Composite indicators (CIs) summarise complex and multi-dimensional issues through a single score for each unit of assessment. They are used by many organisations, governments, and international regulatory bodies in the effort to understand and measure relative progress of different entities. CIs are recognised as a useful tool in policy analysis, but their construction and interpretation are often difficult and controversial. In the effort to improve their constructions process and to enhance their wider acceptance in practice, various methods were proposed, one of which is the popular "Benefit of the Doubt" approach based on data envelopment analysis (DEA). In this paper we derive a new method for constructing composite indicators, which is based on the Geometric Data Envelopment Analysis. The method is similar to the "Benefit of the Doubt" approach but due to a different nature of the geometric aggregation, it carries some significant differences relevant to the practice and to the theory of composite indicators. The properties of the two DEAbased CIs and their differences are discussed first. After the overview of their properties and differences, we present the case study based on the Dubai Government Excellence Model. We will take a closer look at their Website Excellence Model (WEM) composite indicator, which is constructed to assess and compare relative performances of all the Dubai Government departments. Our main objective within that context will be improving their methodology and their processes from a number of different perspectives, such as: usability of the results, fairness, equity, credibility, robustness, and reliability of the composite indicator created. The two DEA-based CIs will turn out to be prime candidates to achieve the desired results. But which one has more to offer?

Key words | *Composite indicators*, *Data envelopment analysis (DEA)*, *Benefit of the Doubt (BoD)*, *Geometric DEA*, *Dubai Government Excellence Model*

Special Session on Applied Graphs Theory and Discrete Optimization

Janez Žerovnik

On heuristics for parallel graph colouring

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Abstract | We introduce new variants of the parallel randomised heuristical algorithm for solving the NP-hard graph colouring problem. The original sequential algorithm due to Petford and Welsh is based on the antivoter model of Donnely and Welsh, which mimics the behaviour of a physical process based on a multi-particle system of statistical mechanics. While the original simulations of the parallel algorithm were run only for 3-colorings, we simulate the new variant of the algorithm also for higher coloring using a massively parallel machine. It is well known that the performance of these type of heuristics highly depends on the parameter, sometimes called the temperature of the system. We test the hypothesis that the algorithm can be improved by considering local temperatures of system and stretch this idea to assign a temperature to each vertex of the graph individually.

Key words | *graph colouring*, *randomised heuristics*, *parallel algorithm*

On double Roman domination

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Abstract | Double Roman domination of graphs is a discrete optimization problem motivated by a number of applications of Roman domination in present time and in history. In the 4th century, the Roman Empire began to lose its power and the Emperor Constantine was faced with a problem of how to defend the Empire with limited resources. Each of its regions should be secured by an army stationed there and a region having no army can be protected by an army sent from a neighboring region. While the problem is still of interest in military operations research, it also has applications in cases where a time-critical service is to be provided with some backup, i.e. positioning of fire stations, first aid stations. In this case, usually it is desired to have k emergency teams to be available in case of concurrent multiple accidents or a major undesired event. One of the natural generalizations is double Roman domination, where in the district two emergency teams are expected to be quickly available in case of multiple emergency calls. In the talk, we will survey the results on the double Roman domination as well as represent some our recent studies of double Roman domination of some graph families.

Key words | *graph theory*, *domination*, *double Roman domination*

Strengthening of the semidefinite relaxation for graph coloring problem

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Abstract | Let $G = (V, E)$ be a graph with $|V| = n$. The chromatic number $\chi(G)$ is the smallest t such that vertices of G can be partitioned into t stable sets. Let $S = (s_1, \ldots, s_k)$ be a matrix where each column s_i represents a stable set vector and where the corresponding stable sets partition vertices into k sets. The $n \times n$ matrix $X = SS^T$ is called coloring matrix. Now let $I \subseteq V$ be a subset of vertices of G. We denote by G_I the subgraph that is induced by the set of vertices I, and by $X_I = (X_{i,j})_{i,j \in I}$ the submatrix of X which is indexed by I. In our work we consider subgraphs G_I with $I = \{1, \ldots, k+1\}$ such that vertices $\{1, \ldots, \mathrm{k}\}$ form a clique C, and vertex $k+1$ is not adjacent to all vertices in C, and we show that the inequality $\sum_{i \in C} X_{i,k+1} \leq 1$ holds for any coloring matrix X_I. Furthermore, we introduce respective inequalities into the semidefinite relaxation and show that the Lovász theta number can be strengthened. Finally, we compare our bounds with relaxations given by Szegedy and Meurdesoif and present computational results.

Key words | *Chromatic number*, *Lovász theta number*, *semidefinite relaxation*

Rainbow domination of Petersen graphs

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Abstract | We obtain new results on rainbow domination numbers of generalized Petersen graphs P(ck, k). For some infinite families, exact values are established, and in all other cases lower and upper bounds with small gaps are given. We also consider singleton rainbow domination, where the sets assigned have cardinality at most one, and provide analogous results for this special case of rainbow domination.

Key words | *graph theory*, *domination*, *optimization*

Measurement of importance of edges in transport networks with a designed service system

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Abstract | Let the service system in a transport network be given. This service system (e.g., emergency, health care or supply system) can be represented by weighted p-center or p-median problem. An importance of the edge according to the designed service system can be determined as a function of elongation of its travel time. In our contribution, we study several possible methods of measuring the impact of such elongation on designed service systems. We consider various probability distributions of travel time elongation and the probability of collapse of the individual edge. These methods are tested on real networks that represent self-governing regions of our country.

Key words | *Weighted p-median and p-center*, *transportation performance*

Acknowledgement | The research of the author is supported by the Slovak Research and Development Agency under the Contract no. APVV-19-0441 and by the research grants VEGA 1/0216/21 "Designing of emergency systems with conflicting criteria using tools of artificial intelligence", and VEGA 1/0077/22 "Innovative prediction methods for optimization of public service systems".

Solving SDP relaxations of Max-Cut problem with large number of hypermetric inequalities

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Abstract | We present a computational study of SDP-based bounds for Max-Cut that use a subset of hypermetric inequalities as cutting planes to strengthen the basic relaxation. Solving these relaxations is a computational challenge because of the potentially large number of violated constraints. To overcome this difficulties we describe heuristic separation algorithm for hypermetric inequalities and propose to use the augmented Lagrangian method as the bounding routine. Computational experiments show that the resulting relaxations yield a very tight bounds for the Max-Cut.

Key words | *semidefinite programming*, *max-cut problem*, *cutting-plane method*

Special Session on Challenges of Alternative Investments

Zdravka Aljinović & Blanka Škrabić Perić

Behavioural aspects of Bitcoin trading volume

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Abstract | The aim of this paper is to investigate the behavioral aspects of Bitcoin trading volume. We use consumer confidence and economic policy uncertainty as behavioral indicators and investigate its influence on Bitcoin for 22 world economies in the period between April 2013 and February 2022 differentiating between the period before and after the Covid disease outbreak. Assuming heterogeneity and cross-sectional dependence between cross-sections we employ Dumitrescu and Hurlin's heterogeneous Granger-causality test. The results indicate that uncertainty has a significant influence on Bitcoin trading volume while consumer confidence has a significant effect only in the period when the Covid pandemic was ongoing. Results are robust to different versions of Granger-causality tests.

Key words | *Bitcoin*, *heterogeneous Granger causality*, *economic policy uncertainty*, *consumer confidence index*

Acknowledgement | IP-2019-04-7816, HRZZ-IP-2018-01-4189

The role of institutions on Bitcoin trade: cross-country analysis

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Abstract | This paper investigates the role of institutions on investor's selection of Bitcoin exchange servers to trade on. Although the prices of Bitcoin do not vary greatly on different exchanges, the volume traded on these exchanges does differ significantly. We try to investigate these differences and confirm if countries' institutional quality influences Bitcoin trading volume. This assumption is based on the previous theoretical assumptions of Bitcoin being connected with fraudulent activities and money laundering. Assuming heterogeneity between countries where exchange servers are located, we employed Pooled Mean Estimator. Additionally, the benefit of this estimator is that it provides both short and long-run coefficients. Results indicate that corruption in a country attracts while internal and external conflicts repel investors to trade Bitcoin in a particular country. Furthermore, from control variables, VIX index positively influences Bitcoin trading volume while local stock market trade is negatively connected.

Key words | *Bitcoin*, *Pooled Mean Group estimator*, *Institutions*

Acknowledgement | IP-2019-04-7816

Method for portfolio performance comparing based on MCDM

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Abstract | Comparing portfolio performance is complicated due to the fact that each model is dominant in its own risk space. Since there is no single dominant measure of performance, the research problem is how to fit multiple different measures into one performance appraisal model that will allow the ranking of portfolios. In this regard, the purpose of this study was to develop a new comprehensive method for comparing portfolio performance based on multiple-criteria decision-making (MCDM). MCDM model includes several dimensions of performance measures: return measures, risk measures, stability measures, predictive power measures and other measures, are considered. The model has been tested based on weekly returns data for a sample of 57 stocks that are components of the STOXX Europe 600 index for the period 2000-2020. The results indicate that there is no identical ranking if we use MCDM and simple ranking or any measure individually. Sensitivity analysis suggests that the simultaneous engagement of different performance measures and the investor's attitude towards the importance of these measures are notably important in the portfolio efficacy estimation process.

Key words | *multiple-criteria decision-making*, *portfolio performance*, *optimization*, *portfolio evaluation*

Analysis of the influence of behavioural factors on the investment decision in the financial market

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Abstract | Investors in financial markets are often not rational as economic theory proposes. Instead, they tend to fall under the influence of their own behavioural biases when making an investment decision. This research observes the influence of different behavioural factors on the tendency of investors to make long-term investment decisions. Data was collected through a survey questionnaire and the final sample includes 310 investors in the Croatian financial market. Partial least squares structural equation modelling (PLS-SEM), as a suitable causal-predictive technique, was used to test the hypotheses. Five factors were used as independent variables, namely heuristics, prospect theory, herding, emotions and market factors, whereas the investment decision was used as a dependent variable. The results show that prospect theory, emotions and market factors positively affect the investment decision, while herding bias has a negative effect. Heuristics have not shown a significant effect on investment decisions. These results can help investors to understand their behaviour in order to change it and behave in a way that will lead them to better and long-term investment decisions.

Key words: *behavioural factors*, *financial market*, *investment decision*, *PLS-SEM*

Machine learning classification algorithms for predicting cryptocurrency price direction

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Abstract | Machine learning algorithms are most powerful tools used for cryptocurrency price forecasting. In addition to researching the predictive capabilities of regression models in forecasting cryptocurrency prices, it is useful to investigate the predictive capabilities of classification algorithms in predicting the direction of cryptocurrency prices. Predicting even just cryptocurrency price direction, with sufficient accuracy, might be of significant interest to an investor in the decision-making process. The aim of this paper is to gain insight into the predictive power of three widely used classification algorithms: Logistic Regression, Support Vector Machine and Gaussian naive Bayes classifiers. The analysis of paper is based on price historical data as well as on appropriate technical indicators. The results show how well the classification algorithms gain knowledge from price shocks in the past and applied it to predict cryptocurrency price changes in the financially unstable future.

Key words | *machine learning*, *cryptocurrency*, *classification algorithms*, *price direction*

Acknowledgement | The Croatian Science Foundation (CSF) under Grant [IP-2019-04 - 7816] supports this work.

Identification of a neural network model for cryptocurrency forecasting

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Abstract | Neural networks (NNs) are well established and widely used in time series forecasting due to their frequent dominance over other linear and nonlinear models including machine learning methods. Thus, this paper does not question their appropriateness in forecasting cryptocurrency's prices; it rather compares most commonly used NNs, i.e. feedforward neural networks (FNNs), long short-term memory (LSTM) and convolutional neural networks (CNNs). This paper contributes to the existing literature of neural networks by defining the appropriate NN structure comparable through different NN architectures, which yields the optimal NN model for cryptocurrency's price forecasting. Moreover, by incorporating turbulent events such as COVID and war periods, this paper emerges as a stress test for NNs. Finally, inputs are carefully selected, mostly covering macroeconomic and market variables that have already been used as well as Twitter-based Uncertainty Indices whose importance in cryptocurrency forecasting is tested.

Key words | *cryptocurrencies*, *machine learning*, *neural networks*, *Twitter-based Uncertainty Indices*

Acknowledgement | This work is supported by the Croatian Science Foundation (CSF) under Grant [IP-2019-04-7816].

What influence the prices of alternative cryptocurrencies?

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Abstract | This paper aims to investigate factors driving cryptocurrency prices, more precisely, the determinants of altcoins. Thus, we form a panel data model that includes cross (top 10 altcoins) and time (daily data from 1 January 2017 till 30 June 2022) sections where altcoin price is the dependent variable. Altcoin price determinants (independent variables) included in the model are: Bitcoin price, supply, trading volume, market capitalization, mining difficulty, number of calendar days from the cryptocurrency's inception, price volatility, and cryptocurrency attractiveness. Taking into account the fact that we have daily data, thus large T while the number of included altcoins is relatively small, resulting in short N, our panel data model will be estimated using LSDVc. Finally, this paper contributes to recent empirical research in a few elements: a) the analysis is performed on the set of most important altcoins; b) it comprises the most recent available data c) it uses a new method, panel data analysis (LSDVc estimator); d) our findings have significant implications for investors as well as consumers of the cryptocurrency altcoins.

Key words | *altcoin*, *cryptocurrency*, *panel data*

Acknowledgement | This work is supported by the Croatian Science Foundation (CSF) under Grant [IP-2019-04-7816].

Special Session on Computational Mathematical Optimization

Tibor Illés
& Petra Renáta Rigó

On the closed-form solution of the monopolist's long-run profit maximization problem

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Abstract | This paper analyses the monopolist's long-run profit maximization problem in the case of the linear demand and Cobb-Douglas production functions with two inputs from an economic perspective. Whenever the problem has a unique solution, its closed-form defines well the profit function for the given demand function. The closed-form solution of the problem is conditioned by returns to scale. The problem has a unique solution for the decreasing returns to scale in which closed-form cannot be found generally. In contrast, for the constant returns to scale, the closed-form of the unique solution arises straightforwardly. However, in the case of the increasing returns to scale, we have three subcases: no solutions, unique solution, and two different solutions. We derive necessary and sufficient conditions for the unique solution and its closed-form when returns to scale are increasing. The problem is enriched with economic interpretations and numerical illustrations.

Key words | *monopoly*, *long-run profit maximization*, *Cobb-Douglas technology*, *linear demand function*

Human resource planning according to the new categorization of functional capabilities of the LTC users

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Abstract | The new Long-term Care Act (ZDOsk) in Slovenia also envisages a new way of categorizing long-term care (LTC) users according to their functional capabilities. This also raises the question of standards and norms of care according to the new categorization, which leads to forecasting the necessary human resources through demographic projections of the population of individual functional regions. The article will present some guidelines for categorization and through this and through the required projections of the number of caregivers in a category of care to anticipate the target number of required providers on the horizon by 2060. The additional question is how to include in the costs of human resources the travel time due to the dispersion of villages. Optimization of the service implementation structure will be performed based on the linear goal programming model. We will present the needs on the thematic map of Slovenia by individual regions at the NUTS 3 level. We will draw attention to the need to design appropriate educational programs and consider the appropriate number of vacancies in educational programs for these human resources in Slovenia.

Key words | *Optimization of services*, *long-term care*, *multistate transitions*, *human resources*

Acknowledgement | The authors acknowledge the financial support from the Slovenian Research Agency for the research projects J5-1784 Creating Social Value with Age-Friendly Housing Stock Management in Lifetime Neighbourhoods and L7-3188 Hierarchical Design and Financing of the Social Infrastructure of Smart Silver Villages.

Combinatorial optimization for efficient and trustful blockchain

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Abstract | BlockChain (BC) is a specially designed distributed public data structure, maintained without any third party of absolute trust by the so-called consensus protocol. Besides the financial applications, BC can be utilized in different domains (digital identity, voting, IoT, insurance, healthcare, etc.). BC consists of a list of blocks containing data (referred to as "committed transactions") that are allowed to be added simultaneously. The main issues in maintaining BC are security, privacy, consistency, and reducing the consumption of electrical energy. We aim to contribute toward overcoming these issues by applying Artificial Intelligence (AI) tools. First we optimize usage of resources by developing a new consensus protocol, named Proof-of-Useful-Work (PoUW), based on combinatorial optimization (CO) that enables miners to be doubly rewarded: for creating blocks and solving submitted CO instances. The second contribution aims to improve security in BC by examining the anonymity level of the participants, having in mind that the corresponding transactions are usually publicly available. This task reduces to classification/clustering of transactions according to some criteria.

Key words | *distributed databases*, *consensus protocols*, *metaheuristics*, *artificial intelligence*

Acknowledgement | This is joint work with Dragan Urošević, Tatjana Jakšić-Krüger, Luka Matijević, Đorđe Jovanović, Milan Todorović and Dušan Ramljak within AI4TrustBC project funded by Science fund of Republic of Serbia.

A family of Ai-Zhang type interior point algorithms for linear complementarity problems

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Abstract | We investigate a family of long-step interior point algorithms for sufficient linear complementarity problems. Our aim is to combine two results from the interior point literature. The first one is the first long-step interior point algorithm with exactly the same complexity as the best short-step algorithms. It was proposed by Ai and Zhang in 2005 for monotone linear complementarity problems. We use a similar wide neighbourhood of the central path and we also split the search direction into two parts to use different step lengths for them. The other used idea is the algebraical equivalent transformation technique introduced by Darvay in 2003. This procedure is determined by a strictly increasing, continuously differentiable function. Using different functions we get the same central path but different search directions. In this talk, we will present results about applying the algebraical equivalent transformation technique defined by functions on the Ai-Zhang type long-step algorithm. We give sufficient conditions for the transformation function to keep the best complexity result of this long-step interior point algorithm. Anita Varga will present the related numerical results.

Key words | *interior point algorithm*, *linear complementarity problem*, *algebraic equivalent transformation*

Is the ground truth clustering the optimum clustering?

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Abstract | The data clustering problem is one of the most studied problems in the area of unsupervised learning. In this paper, we focus on specific formulation of the clustering problem as a mathematical optimization problem in binary variables, which are subject to linear constraints, and with the objective function, which represents the within-the-cluster similarity. We study the exact formulations underlying the well-known k-median and k-means problems and solve them with exact solvers like Gurobi or SOS-SDP solver from Piccialli et al., by using the Slovenian national supercomputer VEGA. We solved these models for a benchmark dataset where the clustering ground truth is known, for the number of clusters k that is around the true k. We evaluated the optimum clustering with a list of external measures (by using the ground truth clustering) and the internal measures, and compare the results with results of some other heuristic clustering algorithms. Our results show that the criteria to detect the true number of clusters do not yield the optimum number of clustering. Likewise, the ground truth clustering provided by the data-provider, is not the same as the optimum clustering computed.

Key words | *data clustering problem*, *mixed integer programming*

Superiorization of perturbation resilient algorithms:An antipodal method to constrained optimization

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Abstract | In many mathematical formulations of significant real-world technological or physical problems, the objective function is exogenous to the modeling process which defines the constraints. In such cases, the faith of the modeler in the usefulness of an objective function for the application at hand is limited and it is probably not worthwhile to invest much resources in trying to reach an exact constrained minimum point. This advocates using the superiorization method for practical applications. In doing so the amount of computational efforts invested alternatingly between performing perturbations and applying the Basic Algorithm's algorithmic operator can, and needs to, be carefully controlled in order to allow both activities to properly influence the outcome. The superiorization methodology can be thought of, in some cases, as lying between feasibility-seeking and constrained minimization. It is not quite trying to solve the full-fledged constrained minimization problem; rather, the task is to find a feasible point which is superior (with respect to a target function value) to one returned by a feasibility-seeking only algorithm.

Key words | *Superiorization*, *constrained optimization*, *perturbations*, *feasibility-seeking*

Acknowledgement | This is part of joint works with Professors Yair Censor (University of Haifa) and Karl-Heinz Küfer (Fraunhofer ITWM, Kaiserslautern, Germany)

Toward closing the gap between iteration bounds of long- and short-step kernel- based IPMs

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Abstract | An Interior-Point method (IPM) can be a long–step method or a short-step method. The first one takes long steps toward the solution while the second one takes short steps along the search direction. Long-step methods are more efficient in practice, however, their theoretical complexity is worse than the theoretical complexity of short-step methods. This discrepancy is known as "irony of IPMs". It has sparked a lot of research to design long-step methods whose theoretical complexity is of the same order of magnitude as the complexity of short-step methods. In this talk we consider a kernel-based IPM where the search direction and step size are determined using a special function that is called a kernel-function. The reason for considering kernel-based IPM is that it leads to improved iteration bound for long–step methods. We have analyzed a new kernel function and showed that the long-step method based on this kernel function has an iteration bound that is of the same order of magnitude as the iteration bound of the short–step method.

Key words | *Interior-point methods*, *kernel functions*, *short- and long-step methods*, *iteration bounds*

Free functions preserving certain partial orders of operators

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Abstract | Recently free analysis has been a very active topic of study in operator and function theory. In particular free functions that preserve partial orders of operators have been studied by a number of authors, in connection to Loewner's theorem and interpolation problems on the polydisk. Also operator concave free functions naturally get into the picture as we study the positive definite order preserving free functions. We will go through recent results in the field, and we will cover some recent works on analytic lifts and extension of operator monotone and concave functions to the matrix convex hull of their domains. This is related to some conjectures in the field, for instance McCarthy's conjecture that we can address now. If time permits, we will cover another recent joint work with M. Ga'al solving Blecher's problem on characterizing real positive definite order preserving functions.

Key words | *positive operators*, *partial order*, *Loewner order*, *multivariate interpolation*

New interior-point algorithms for solving symmetric cone horizontal linear complementarity problems

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Abstract | The optimality conditions of several optimization problems can be formulated as horizontal linear complementarity problems over Cartesian product of symmetric cones. We introduce a new class of search directions for interior-point algorithms solving these types of problems. We generalize the interior-point algorithms proposed recently by Illés et al. to symmetric cone horizontal linear complementarity problems. We also prove that the introduced algorithms have the same complexity bound as the best-known interior-point algorithms for solving these problems.

Key words | *symmetric cones*, *horizontal linear complementarity problems*, *interior-point algorithms*

Implementation of interior-point methods for solving sufficient linear complementarity problems

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Abstract | In this presentation we show the theoretical and practical results regarding different types of new interior-point algorithms for solving sufficient linear complementarity problems. In all the cases we use the algebraic equivalent transformation technique to determine the new search directions. To show the practical efficiency of our new algorithms, we also compare them to classical versions of the interior-point algorithms that use different search directions.

Key words | *interior-point algorithms*, *sufficient linear complementarity problems*, *algebraic equivalent transformation*

A whole new class of AET functions for determining search directions for interior-point algorithms

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Abstract | We propose new interior-point algorithms (IPAs) to solve sufficient linear complementarity problems (SU LCPs). To define the search directions, we apply the algebraic equivalent transformation (AET) technique. We introduce a whole new class of AET functions, which differs from the classes used in the literature to determine search directions. We provide example for AET function from our new class, which does not belong to the class of concave functions proposed by Haddou et al. Furthermore, the kernel function belonging to this AET function is neither eligible, nor self-regular kernel function. We give a unified proof in which we show that the IPAs using any member of this new class of AET functions have polynomial iteration complexity in the size of the problem, bit length of the data and in a special parameter of the matrix, called handicap. As a special case, we obtained a whole class of new IPAs for linear programming and linearly constrained convex quadratic programming problem, as well.

Key words | *sufficient linear complementarity problems*, *interior-point algorithms*, *new class of search directions*

Predictor-corrector interior-point algorithm acting in a wide neighborhood of the central path

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Abstract | We present a new predictor-corrector interior-point algorithm for solving sufficient linear complementarity problems. We use the algebraically equivalent transformation technique to define a new class of wide neighbourhoods. In a special case we prove that the introduced algorithm has the same complexity as the best-known interior-point algorithms for solving these types of problems.

Key words | *interior-point algorithm*, *predictor-corrector*, *linear complementarity problem*, *wide neighborhood*

Robust optimization for the berth allocation and quay crane scheduling problem under uncertainty

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Abstract | We consider an integrated berth allocation and quay crane scheduling problem where the arrival times of the vessels may be affected by uncertainty. The problem is modelled as a two-stage robust mixed-integer program where the berth allocation decisions are taken before the exact arrival times are known, and the crane assignment and scheduling operations are adjusted to the arrival times. To solve the robust two-stage model, we follow a decomposition algorithm that decomposes the problem into a master problem and a separation problem. Several new improvement strategies - general enough to be used when solving different optimization problems - are proposed to enhance the algorithm. The computational results show clear benefits of studying this problem under uncertainty as well as the efficiency of the proposed improvement strategies.

Key words | *Berth Allocation*, *Robust optimization*, *Uncertainty*

Special Session on Decision Intelligence Analytics in the Financial Sectors

Violeta Cvetkoska & P. Mary Jeyanthi

Managerial ability of Indian private sector banks

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Abstract | The aim of this paper is to estimate the managerial ability of Indian private sector banks in the period from 2014-15 to 2020-21. The estimation of managerial ability in the present context is based on the work of Demerijian, Lev, and McVay (2012), involving a three-stage approach. In the first stage, the relative efficiencies of the in-sample banks are calculated in terms of their observed ability to generate revenues relative to the quantity and mix of resources deployed. In the second stage, the impact of several contextual variables on efficiency is estimated in terms of regression analysis. In the final stage, a measure of managerial ability is derived as the residual of the regression. Further, the study seeks to validate the measure of ability by finding out the linkage between managerial ability measures and other measures of bank performance. The findings are given and analyzed with the intention of assisting state bodies and bank management in making better decisions for the successful operation of those financial institutions.

Key words | *bank performance*, *managerial ability*, *private sector banks*

The impact of COVID-19 on bank efficiency in the Western Balkan: A Window DEA approach

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Abstract | The aim of this article is to assess and compare the relative efficiencies of commercial banks in each of the six developing countries in the Western Balkan (N. Macedonia, Serbia, Montenegro, Bosnia & Herzegovina, Kosovo and Albania) by implementing the leading nonparametric methodology Data Envelopment Analysis for the period 2016 - 2020 and to assess the impact of the COVID-19 pandemics on the efficiencies of their banking systems. The window DEA model has been implemented with interest expenses and non-interest expenses as inputs and interest revenue and non-interest revenue as outputs. The results indicate that the average efficiencies of the six Western Balkan banking systems differ and Kosovo's banking system has noted the highest average efficiency in the whole observed period, whereas the B&H noted lowest average efficiency. The obtained results indicate that the COVID-19 pandemic decreased the relative efficiencies of the banking sectors in all of the six observed Western Balkan countries, with an exception of Kosovo. This is the first empirical study that includes a glimpse of the first COVID-19 impact on banking systems in the developing countries of the Western Balkan.

Key words | *banking industry*, *window data envelopment analysis*, *COVID-19*, *Western Balkan*

Capital requirements, risk-taking and deposit price: dynamic panel analysis for Croatia

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Abstract | This paper investigates the influence of bank capital regulation on their portfolio risk and deposit financing costs, assuming that the regulatory burden of capital requirements might trigger adverse effects for the asset riskiness, regardless of potentially beneficial effects for the deposit price reduction. The data for the Croatian banking sector in the 2011-2019 time span served as an input for the dynamic panel analysis. Results confirm that banks with a higher capital ratios have lower deposit financing costs, but tend to involve into risky investments in order to reimburse their shareholders for requesting extra funds. In addition, bank size, previous credit risk materialization, and higher economic growth diminish asset riskiness exposure, while bank profitability corresponds with the risk-taking behavior. Deposit price is shaped by the interbank market conditions, return on equity and portfolio risk, with only portfolio risk having a negative impact. Altogether, there is a solid evidence that the capital requirements regulation significantly alter bank business indicators. However, remarks about its counterproductive effects require more convincing evidence.

Key words | *capital requirements*, *banking regulation*, *risk-taking*, *dynamic panel analysis*

Special Session on Ensuring a Green and Sustainable Future through Smart Cities

Anton Manfreda & Zafer Yilmaz

Charging of electric vehicles in smart cities

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Abstract | Climate change is the biggest challenge of our generation. Modern mobility in smart cities is one of the areas addressing these challenges, as the transport sector is one of the largest emitters of GHG. The modern concept of smart cities, among other things, deals with the intertwining of technology and smart mobility. Electrification of transport, or electromobility, currently appears to be the only viable solution to meet future emissions targets. The large increase in electricity consumption due to the high concentration of EVs in cities can cause problems with the supply of electricity. This problem addresses the new concept of smart charging of EVs. In the future, there will be a variety of painful behaviours that will put different loads on the electricity grid. The diffusion of a new technology depends on technical aspects and the acceptance of this technology by users. Our study focuses on possible ways to persuade EVs users into actions that will benefit the electricity grid. This study based on a bibliometric study presents different forms of charging EVs and their impact on the electric grid in cities.

Key words | *electric vehicles*, *smart cities*, *smart charging*

An integrated methodology for the dedicated bus line network design problem

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Abstract | The public transport system has an essential role in the sustainability of the urban environment. By providing a network of rapid services, accessibility functions can be improved and, consequently, the efficiency of public transport. The paper focuses on the problem of the integrated rapid transit system network design. The aim is to develop a model for designing dedicated bus lanes (DBL) in areas with low accessibility provided by existing public transport grade-separated (i.e. subways and light rails). The DBLs seek to enhance the connections to subway and light rail lines, increasing the overall dimension and performance of the rapid transit network. The novelty of the analysed methodology consists of the integrated approach of the public transport network. The DBLs are established in function of the existing road infrastructure, location of existing bus stops and potential passenger volumes. Some relevant criteria (e.g., cost and future utilisation) are applied to solve the problem. Applications of the model provide an insight into the relative importance of different cost components.

Key words | *urban public transportation*, *rapid transit systems*, *network design*, *dedicated bus line*, *optimization*

Acknowledgement | This research has been supported by the Erasmus+ Programme of the European Union, through the Erasmus+ KA203 Strategic Partnerships for higher education, Project no. 2020-1-TR01-KA203-094242, "Energy Usage and Green Public Transportation in Future Smart Cities: An Innovative Teaching Program for Students, Stakeholders and Entrepreneurs".

A Multi-Objective Model for the Green Vehicle Routing Problem: a comparison of conventional and electric vehicles

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Abstract | Environmentally friendly approaches are rising in business operations in all levels of the supply chain. Due to growing environmental concerns about pollution, conventional vehicles are replaced with less harmful alternatives. The green vehicle routing problem (GVRP) is a variation of the vehicle routing problem (VRP) in which routes are driven by vehicles that use alternative fuels. Electric vehicles have become one of the most preferred alternative fuel vehicle in logistics solutions. However, there are disadvantages of electric vehicles owing to their limited range and long charging times. Since charging stations for electric vehicles are not yet widespread. Therefore, the routes that is used by conventional and electric vehicles may differ. In this study, the environmental effects of the use of conventional vehicles and electric vehicles are investigated with the multi-objective vehicle routing problem. GVRP is modeled to minimize both distance and fuel consumption using Mixed Integer Linear Programming for comparing conventional and electric vehicle. Restrictions arising from electric vehicles are taken into consideration.

Key words | *vehicle routing problem*, *green vehicle routing problem*, *multi-objective optimization*, *electric vehicles*

Smart cities, environment and governance

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Abstract | Establishing smart cities combined with the environmental problems creates the need for proper environmental governance. This study reviews existing smart city environmental governance approaches. Strengths and weaknesses are examined by comparing cases for alternative cities. Literature conceptualizes 4 types of smart city governance. In the first type, government is considered to be the promotor of the smart city. Green deck project in Hong Kong is analyzed. In the second model, governance is supported by data and sensor linked technologies & proper use of big data. In this case government transformation and restructuring is minimal and real time data sharing and IoT technologies are used vastly to make sense of cities and solve its environmental problems. Spain and Bristol & Manchester in UK are examined as examples for this model. In the third model, government transformation and restructuring is high. Cities are encouraged to use electronic governance tools. "Virtual Singapore" is analyzed for this case. In the final model, main aim is to create innovation hubs that come up with solutions for environmental and social problems. Amsterdam Smart City is examined as an example.

Key words | *governance*, *smart cities*, *esg*

Smart cities for a green future

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Abstract | With the rapid rate of urbanization and more than half of the world's population currently living in urban environments, cities are starting to face various challenges linked to mobility, living, environment, citizens, government, etc. Smart cities provide helpful solutions with the goal to run efficiently, intelligently, and sustainably, by integrating new technologies. Nevertheless, the mere implementation of them is not sufficient to bring benefits to society. To achieve a greater quality of life for citizens, social and environmental resources should be at the "hearth" of all activities. To better understand how the diffusion of IT can promote a sustainable future, preliminary research was done with a survey of 2937 people. Further on, a review of the previous use of behavioral change theories, with a focus on the previously established Fogg behavior model and trans theoretical model of behavior change, was conducted. The research also identified the appropriate methods that already exist to change individuals' behavior towards a sustainable future. Finally, a survey on adoption of smart city initiatives and individuals' sustainable behaviors was done.

Key words | *smart city*, *sustainability*, *digitalization*

Big data analytics in smart cities research: insights from bibliometric analysis

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Abstract | Green and sustainable smart cities depend in part on how well smart city organizations can share and analyze data. The ability to share key information in real time is critical to the development of the smart city infrastructure applications. Hence, much attention has been paid to big data analytics methods and tools for smart cities development. However, the literature does not provide the current state of research in the tackled field. Therefore, our study aims to highlight the current knowledge structure of big data analytics in smart cities studies by applying a bibliometric approach. This study first provides an explanation of big data analytics in the context of smart cities and justifies the application of the bibliometric approach. Then, by applying a co-occurrence analysis, it identifies the main terms that co-occur in the papers on this topic indexed in the WoS databases between 2016 and 2021. The relations among these terms are identified using a tool for creating bibliometric networks. The identified clusters are explained in detail offering theoretical grounds for a better understanding of the current state in big data analytics in the smart cities research agenda.

Key words | *big data analytics*, *smart cities*, *bibliometrics*, *co-occurrence analysis*

A walking friendly environment - how to measure it?

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Abstract | Within the smart city paradigm, one of the main aims of urban planners and policymakers is to reduce the environmental footprint of urban growth by managing urban mobility in a citizen-friendly way. Facilitating and encouraging citizens to walk rather than drive to a destination is a way to make the modern form of urban mobility greener and safer; hence, creating and increasing the better quality of urban life. Evidence of the benefits of walking and walkable urban forms has appeared in different strands of literature, suggesting its multidisciplinary nature. The quality of the walking environment is an important means to spur walking in cities. The relevant literature points to different attributes that define the quality of the walking environment, covering both objective and subjective features. While physical features of walkability are important, they alone do not capture people's overall perceptions of the street environment. Given that walking is a multidisciplinary activity, measuring it requires a multidisciplinary approach. Over the past decade, many tools for measuring walkability have emerged, referring to physical and/or subjective aspects of walkability.

Key words | *walkability*, *pedestrian planning*, *transportation*, *metrics*, *level of service*

Special Session on Game Theory

Tamás Solymosi

Uncertainty in operations research games

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Abstract | Operations research games (also called combinatorial optimisation games) are cooperative games associated with various operations research problems. The cooperating players typically try to minimise total joint costs. The main task is then to distribute such costs between individual players in a fair or stable way. The functions assigning such distributions to games are called solution concepts. We usually compare them by their structural and computational properties (e.g., nonemptiness, largeness, the existence of an efficient algorithm yielding a distribution, nice axiomatisation). We shall focus on the following question: How does uncertainty influence such properties? What happens when we generalise such games to the interval, incomplete, or restricted games? We shall mainly focus on the case of minimum colouring games and minimum cost spanning tree (MCST) games.

Key words | *operations research games*, *cooperative game theory*, *solution concepts*, *uncertainty*

Acknowledgement | The author was supported by GAČR P403-22-11117S and GAUK 341721.

Approximation of the core of incomplete cooperative games

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Abstract | The main goal of the model of cooperative games is to determine in a rational way each player's payoff based on the worth of cooperation between different subsets of players. The main disadvantage of this approach is due to the huge number of such values (exponential in the number of players). The model of incomplete cooperative games deals with these problems by setting values of certain coalitions to be unknown. Based on the partial information, the goal remains the same - to determine each player's payoff. In our research, we focus on one of the most studied payoff distributions – the core. We study different approximations of the core based on information given by an incomplete game. Two approximations are given by approximating the core itself, others by approximating the so called core catchers – payoff distributions generalising the core. Comparison between the approximations is provided. Classes of cooperative games connected to core catchers are also studied. Specifically, we study the set of possible extensions of an incomplete game into a complete one with non-empty core catchers. These correspond to semibalanced and quasibalanced extensions."

Key words | *cooperative games*, *incomplete cooperative games*, *the core*, *balanced games*

Acknowledgement | The author was supported by the Charles University Grant Agency (GAUK 341721).

Computing balanced solutions for large international kidney exchange schemes

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Abstract | To overcome incompatibilities, kidney patients swap their donors. In international kidney exchange programs (IKEPs), countries merge their national patient-donor pools. We consider a credit system where in each round there is an initial transplant allocation, adjusted by a credit function yielding a target allocation. The aim is to find a solution in the patient-donor compatibility graph that approaches the target allocation as much as possible, to ensure stability of the international pool. We use max matchings that lexicographically minimize the country deviations from the target allocation. We first give a poly-time algorithm for computing such matchings, then perform a computational study for a large number of countries. For the initial allocations we use two easy-to-compute solutions and two classical concepts: the Shapley value and the nucleolus. These are hard to compute, but by using state-of-the-art methods they are within reach for IKEPs of up to fifteen countries. Our results show that using lexicographically minimal maximum matchings instead of ones that only minimize the largest deviation from the target allocation may make an IKEP up to 52% more balanced.

Key words | *kidney exchanges*, *matching game*, *compensation scheme*, *computer simulation*

Applying the Selten-Szidarovszky technique to Cournot oligopolies with a log-concave price functions

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Abstract | We critically review the proofs in the literature for equilibrium uniqueness for Cournot oligopolies with log-concave price functions. In particular this is based on a proof appearing in Economics Bulletin 34(2), 1229-1234 (2014) using the Selten-Szidarovszky technique. We provide a new proof, with all fine details. In doing so we use the opportunity for discussing various issues that one has to pay attention to when dealing with this technique.

Key words | *Selten-Szidarovszky technique*, *log-concavity*, *Cournot oligopoly*, *equilibrium uniqueness*

The disruption nucleolus of bankruptcy games

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Abstract | The bankruptcy problem (also known as the claims problem) models the fundamental question of how to share a scarce resource. In their seminal paper, Aumann and Maschler (JET, 1985) proved that the 2000 year old Talmud divisions coincide with the nucleolus allocations of the related cooperative games. Despite of the dozens of bankruptcy allocation rules, if any specific rule is mentioned in legislative procedures it is surely the proportional rule (divide the estate in proportion to the claims). It is, however, not a cooperative game theoretic division rule. Curiel, Maschler and Tijs (ZOR, 1987) proposed the so-called adjusted proportional rule and proved that it has several appealing properties. In the talk we show that the adjusted proportional allocation of a claims problem coincides with the disruption nucleolus allocation of the related bankruptcy game. It follows that the adjusted proportional allocations are (in a lexicographic sense) the most resistant against the propensity of agents and even of coalitions of agents to disrupt a proposed division of the estate among the claimants.

Key words | *claims problem*, *adjusted proportional rule*, *bankruptcy game*, *disruption nucleolus*

Acknowledgement | Supported by research grant NKFI K-119930

Special Session on Novel Applications of OR

Kolos Csaba Ágoston
& Marianna E.-Nagy

Bid matching based clearing of two-sided multiunit auctions

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Abstract | Motivated by the simplified model of day-ahead electricity markets, we consider two-sided multiunit auctions, where participants submit divisible or indivisible price-quantity type demand or supply bids. While day-ahead electricity markets are typically cleared using the concept of market clearing price (MCP), we propose an iterative bid matching algorithm to determine the set of accepted bids, while considering supply-demand balance constraints for each market period. We demonstrate the characteristic differences of the two clearing approaches via simple examples, and using simulations, we compare the results obtained via the proposed method with results obtained via the conventional MCP-based method.

Key words | *mechanism design*, *day-ahead electricity markets*, *multiunit auctions*, *matching*

Acknowledgement | This work is been supported by the Hungarian Academy of Sciences through Momentum Programme LP2021-2 and by Grant 137608 of the Hungarian National Research, Development and Innovation Office

A lexicographically optimal completion for pairwise comparison matrices with missing entries

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Abstract | It is an attractive approach to complete a partially filled pairwise comparison matrix such that an inconsistency index of the corresponding complete matrix is optimised as a function of the missing entries. Inspired by the popular Koczkodaj inconsistency index and a solution concept of cooperative game theory called the nucleolus, this paper proposes a lexicographically optimal completion for sets of pairwise comparisons with missing entries. In particular, the inconsistency of the most inconsistent triad is reduced first, followed by the inconsistency of the second most inconsistent triad, and so on. The necessary and sufficient condition for uniqueness is proved to be a simple graph-theoretic notion, that is, the undirected graph, where the edges represent the known elements, should be connected. The suggested technique is compared to the completion method that minimises the inconsistency index proposed by Saaty via Monte Carlo experiments.

Key words | *incomplete pairwise comparisons*, *lexicographic optimisation*, *LP modeling*

College admissions with ties and common quotas: Integer programming approach

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Abstract | Admission to universities is organised in a centralised scheme in Hungary. In this paper we investigate two major specialities of this application: ties and common quotas. A tie occur when some students have the same score at a programme. If not enough seats are available for the last tied group of applicants at a programme then there are three reasonable policies used in practice. Even though student-optimal stable matchings can be computed efficiently for each of the above three cases, we developed (mixed) integer programming (IP) formulations for solving these problems, and compared the solutions obtained by the three policies for a real instance of the Hungarian application from 2008. In the case of Hungary common quotas arise from the faculty quotas imposed on their programmes and from the national quotas set for state-financed students in each subject. The overlapping structure of common quotas makes the computational problem of finding a stable solution NP-hard, even for strict rankings. In the case of ties and common quotas we propose two reasonable stable solution concepts for the Hungarian and Chilean policies. We developed (mixed) IP formulations for solving these.

Key words | *assignment*, *stable matching*, *college admission*, *integer programming*

Influence monitoring and network flows

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Abstract | The study of diffusion processes on networks plays an important role in fields such as epidomology, social science, business and economics. Related discrete optimization problem was introduced by Kempe, Kleinberg & Tardos, as determining k nodes starting from which the maximum expected value of influenced nodes are produced by a given diffusion process. They proved that the above influence maximization problem is NP-hard, but the greedy heuristic provides a guaranteed approximation ratio. Recently Hajdu & Kresz introduced the influence monitoring problem which, instead of targeting most influential nodes in outbreak, identify those vertices through which the highest expected number of vertices are accessible in "infection chains". We present a stochastic programming based network flow formulation of the influence monitoring problem and show that it can provide an approximation with an arbitrary small gap. Methodology efficiency is demonstrated through test cases.

Key words | *influence maximization*, *diffusion processes*, *network flows*

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Special Session on OR in Forestry

Lidija Zadnik Stirn

A multi-objective model for optimizing wood distribution and processing

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Abstract | Wood is a renewable material source with a variety of different uses. If managed properly, wooden products are capable of storing carbon over their lifetime, which makes them a perfect sustainable option over their alternative non-wooden counterparts. Moreover, most wooden products, as well as residual resources from their manufacturing processes, can be utilized and reused for alternative streams, or ultimately for the production of energy. This, together with its cascading utilization possibilities makes wood a perfect material for a circular economy. A mixed-integer linear programming model is introduced for the optimal distribution of available roundwood into various product streams. This allocation takes arising demands and production capacities into account, while also considering the further distribution of residual materials (e.g. sawdust, chips, cutoffs) created during the conversion process of the allocated primary resource. Economic and environmental objectives are both examined during the optimization process. The efficiency of the approach will be presented on available statistical data of various wood product groups and resource availabilities.

Key words | *material flow*, *roundwood*, *circular economy*

Acknowledgement | The authors gratefully acknowledge the European Commission for funding the InnoRenew CoE project (Grant Agreement #739574) under the Horizon2020 Widespread-Teaming program, and the Republic of Slovenia (Investment funding of the Republic of Slovenia and the European Union of the European Regional Development Fund). They are also grateful for the support of the Slovenian National Research Agency (ARRS) through grants N1-0223 and V4-2124. Balázs Dávid is supported in part by the University of Primorska postdoc grant No. 2991-5/2021.

Participatory decision-making in a multi-criteria fuzzy model for evaluating forest strategies

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Abstract | Forests provide a wide variety of ecosystem services (ES) and present an important renewable natural resource in economic, social and above all ecological environments. Sustainable forest management (SFM) requires balance of demands and supply of ES. Thus, SFM is subjected to several decision-makers (stakeholders) covering interests of different groups, and to natural capacities and threats. As such, SFM reveals a multicriteria, participatory problem under uncertainty, subjectivity, and ambiguity. A broad range of methods have been proposed to solve this problem, most usually a group fuzzy AHP. Here we propose a different approach. We organize the problem in a hierarchical structure by selection of stakeholders, identifying the criteria for their importance in the decision process, the SFM strategies and criteria for their evaluation. Weights of stakeholders, SFM strategies and their criteria are determined by interactive α-level cuts fuzzy method combined by Dempster-Schafer evidence theory that enables to manage uncertain and missing information. Proposed model will be tested on forest bioenergy production and use problem (case of Slovenia).

Key words | *sustainable forest management*, *participatory decision-making*, *risk*, *group multi-criteria methods*, *fuzzy analysis*, *missing information*

Acknowledgement | The authors are members of the Slovenian Research Agency, research core No. P4-0059 (with no financial support).

Spatial optimization for reducing wind exposure of forest stands at the property level

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Abstract | Storms represent one of the most important disturbances in Sweden. The risk of storm damage to the forest might be influenced by climate change in the future if the soil frost period length is shortened by global warming. In this study, we present a new mathematical model to minimize forest exposure at the property level during a long planning horizon. The model minimizes the height difference between neighboring spruce stands in the forest property based on a user defined parameter, i.e. a user defined parameter was used to indicate the minimum height difference needed between two neighbor stands to consider a forest edge as vulnerable and therefore minimize it by the model. Forest exposure was only minimized for spruce stands due to their higher sensitivity to storm damages compared to other species. We investigated the trade-off between the net present value from wood production and the length of vulnerable forest edges in the property. The results show that small declines on the net present value can reduce largely the length of vulnerable edges in the property. In conclusion, the presented model could be applied to similar planning problems where forest edges are relevant.

Key words | *Forest planning*, *Storm damage*, *Decision support system*

Decision making model to consider risks in forest management using FSI WINGS

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Abstract | Traditionally, forests were used for timber production. However, social expectations and climate have changed significantly in recent decades. We construct a multi-criteria model, whose objective is to select the most appropriate scenario for forest management. Three forest functions (production, social and ecological) are selected as main criteria. The sub-criteria represent risks in forest management. Sub-criteria of production function are illegal logging, timber price and natural disasters. Sub-criteria of social function are social security, recreation, owner's activity, forest pollution. Sub-criteria of ecological function are climate change, insects, non-native species and biodiversity loss. Forest management scenarios present the alternatives. Decision makers evaluate all criteria and sub-criteria using linguistic terms. The importance of each criteria and sub-criteria is evaluated using the Finite Sum of WINGS Influences (FSI WINGS) method, the new concept of Weighted Influence Non-linear Gauge System (WINGS). Instead of an infinite sum, the FSI WINGS method uses a finite sum of influences. Alternatives are evaluated using one of the multi-criteria decision making methods.

Key words | *forest management*, *risks*, *multi-criteria decision making*, *FSI WINGS*

Special Session on Smart Cities development and trends: Cases and research opportunities

Maja Ćukušić

Future of urban development: anticipatory governance

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Abstract | In order to deal with ongoing and future changes that are difficult to predict, it is important to establish agile city policy and governance. Anticipatory governance seeks to understand and shape the changes that are expected in the future by incorporating knowledge about the future into policies and decision-making.The research discusses the design of anticipatory governance systems that should employ foresight in order to see the future in terms of the results, or governments that can anticipate and adapt to changes.The research discusses how citizens' involvement can be crucial in helping cities develop a knowledge base about changes that are happening, so that they can be more aware of them and better prepared to deal with them. Some participatory foresight methods (digital and non-digital) are discussed that could be used to help cities launch foresight activities.The aforementioned is important for urban (or smart city) development.

Key words | *anticipatory governance*, *urban development*, *foresight*

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IOT platforms in smart cities: evidence from Croatia and Slovenia

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Abstract | When implementing the Internet of Things (IoT) platforms in smart cities, it is critical to select the appropriate platforms that meet relevant criteria. This research, therefore, identifies and presents relevant criteria for selecting an IoT platform. The survey with experts is conducted in Croatia and Slovenia, and both end-users and vendors have evaluated the importance of the proposed criteria. These two sources form the database for the empirical comparison of the two neighboring countries of Southeastern Europe. The results of comparison indicate the existence of several evaluation differences between end-users and vendors and between vendors in Croatia and Slovenia which are discussed in the study.

Key words | *IoT*, *smart cities*

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Citizens attitudes towards smart city's elements

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Abstract | The role of citizen in smart cities has advanced from the role of the observer to the collaborator in city processes who actively participate by involving innovative thinking. The research in Slovenia and Croatia suggest that their citizens are keen on the development of smart cities and believe that the new technologies can improve their personal and work life. Their main point of concern are security and privacy issues regarding the data collected by technologies. However, they see a great potential of smart cities for solving environmental issues and are willing to change their behaviour towards a more sustainable. Slovenes and Croats are quite similar in their perceptions and attitudes towards digitalization, sustainability, and smart cities.

Key words | *smart cities*, *attitudes*

Special Session on Real-World Applications of Machine Learning

Saša Mladenović
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Network based predictive modelling

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Abstract | Real-world networks can be classified into several categories based on the nature of the represented entities. Depending on the given area we can talk about information networks, technological networks, biological networks, etc., and then we did not even talk about the subgroups of these network types. Almost every aspect of our life can be represented as a network of real-world entities. It is clear to see that understanding the basic rules that are forming such networks can help us to understand and predict the behavior of real systems. The temporal dimension and interactions between different entities in such networks play a critical role in forming the structural patterns and properties of the connections among the nodes. We introduce a new technique that can learn and understand the basic rules of temporal networks and predict the future lifecycle of real-world network entities. Citation networks are one of the most famous examples of information networks. We introduce a use-case

of our method, predicting the citation count of papers using the temporal dimension of a citation network. We also compare our solution with existing methods.

Key words | *temporal networks*, *predictive modelling*, *citation networks*

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Challenge of real-life dataset: modeling the university student dropout

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Abstract | We contribute to educational data mining by trying to predict permanent dropout of students at the Faculty of Economics, University of Banja Luka, Bosnia and Herzegovina, using data at the end of the first semester and finding the main characteristics that influence dropout. The imbalanced university dataset with mostly categorical features from the school year 2007/08 to 2018/19 includes 5 057 students, with a significant proportion of missing data and missing variables. We experimented with datasets before and after feature reduction. Feature selection is based on Pearson and Phi correlation coefficients. Dropouts are students who did not accomplish their degree within 6 years of study. After data preprocessing, we implemented Histogram Gradient Boosting Classifier and neural network and Shapley Additive exPlanations in Python to show how the model decides" who to eliminate. We experimented with a 2-3-4 layer neural network using stochastic gradient descent adaptive estimation (adam), backpropagated, feedforward neural network. Activation function for hidden layers is ReLu, while Sigmoid function is used for output layer. The models are trained with imbalanced and balanced datasets.

Key words | *machine learning*, *imbalanced data*, *missing data*, *prediction*

Application of machine learning for estimating live vegetation moisture content with optical sensor

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Abstract | Measurement or estimation of live vegetation moisture content is an important task for vegetation health and biodiversity preservation, and especially in forest fire management. Live fuel moisture content (LFMC) is an important variable for predicting fire danger. Traditionally the LFMC is measured by field sampling and laboratory measurement. This procedure is expensive and inappropriate. There is demand for new approaches to LFMC estimation with invasive methods. In this paper we investigated the potential of LFMC estimation by measuring plant leaf absorption of light. We performed an experiment with three plants in different moisture conditions and measured the leaf absorption in 18 spectral bands ranging from 410 nm to 940 nm using an optical sensor. True moisture content was determined using halogen moisture analyzer. We used machine learning algorithms to train a model for determining the moisture content measured with the moisture analyzer from

18 bands absorption measured by an optical sensor. The best results were achieved for decision tree regression and multi layer perceptron.

Key words | *eOptical sensor*, *Internet of Things*, *Remote sensing*, *Regression model*, *Live Fuel Moisture*

Late vs. early churn prediction and determinants

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Abstract | Identifying churners became a core strategy to survive for businesses in various industries. This process implies selecting relevant features and building the churn prediction model, which is highly dependent on the churn definition statement and associated churn window size. Short churn window size is related to early churn prediction modeling, while late churn allows for long churn window size. Too short windows might mislabel customers as churned, leading to a high false-positive rate of a churn, while too long windows may result in irreversible loss of customers. The duration of the churn window size may vary depending on different business goals. The main goal of this work is to examine the dependency of churn prediction models on the churn window size. We focus on comparing prediction performance and feature importance with respect to churn window size. The proposed methodology starts with a fixed set of features related to customer behavior data, which is followed by building separate churn prediction models for different churn window sizes. The predictive performance of churn prediction models and feature importance are assessed depending on the churn window size.

Key words | *churn prediction*, *late churn*, *early churn*, *churn determinants*

Real-world object detection with YOLOv5

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Abstract | Today, the amount of data around us growing rapidly and there is an opportunity to utilize it. Visual data is generated by cameras in surveillance, homes, shopping centers, cars, etc. Advances in computing power have allowed us to work with deep neural networks where we can process images with rich feature extraction. One-shot detectors process the whole image at once and one of them is YOLO. YOLOv5 is the fifth version of the YOLO algorithm which provides fast and accurate, real-time object detection from small (fast) to large (accurate) neural network models. Transfer learning, training from scratch, multi-GPU training, and hyperparameter evolution are important concepts in object detection problems, and the YOLOv5 framework includes all of those concepts. Upgrading object detection to object tracking can be easily achieved with DeepSort algorithms. Object tracking reduces the speed of inference but provides us with a lot of possibilities such as counting objects, speed estimation, direction tracking, etc.

Key words | *real-world data*, *object detection*, *yolov5*

Multi-label classification of energy efficiency of public buildings based on random forest and CART

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Abstract | Non-residential buildings deserve attention when it comes to energy consumption, which should be indicated as an energy class in the energy certificate in Croatia. In this paper, data on 509 public buildings with energy certificates were extracted from the Energy Management Information System. These data included 46 features on meteorological, construction, geospatial and occupational characteristics of the buildings. The objective of this study was to develop and compare a random forest model (RF) and a classification and regression tree model (CART) to classify public buildings into energy classes and to determine the key predictors of each model. These methods were selected for their effectiveness in multiple label classification problems. Both methods used different parameters and hyperparameters to obtain a model with the highest classification accuracy. In this work, the CART method outperformed the random forest method with a classification accuracy of 95.05%. The most important variables in both models were construction characteristics of the building. This study could be useful for policy makers in the field of energy efficiency and energy retrofit.

Key words | *random forest*, *classification and regression trees*, *multi–label classification*, *energy efficiency*

Opportunities of agent-based modelling in the digital environment

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Abstract | This paper aims to apply agent-based modelling to the objective database on the case study of a Croatian company (via the webshop). By analysing sales data, it was observed that 81 % of registered customers made one order, leading to a relatively small proportion of returning customers. However, in the observed period, 5% of users registered but did not make purchases. The literature indicated the need for practical research in digital environments. An agent-based model was built upon available databases (Google Analytics, Meta Business and WooCommerce sales report). By analysing the behaviour of returning customers, we tried to propose a way of influencing the behaviour of potential customers. After proposing a model, data points were identified, and the advantages and disadvantages of using this approach were acknowledged and listed. The output of this case study showed that to generate suggestions, it would be necessary to connect all databases with the help of a unique ID. Additionally, the paper proposes a user model with given points needed for the successful use of this method in a digital environment.

Key words | *agent-based*, *AI*, *data points*, *digital environment*

Special Session on Tackling the Issues Encompassing Composite Indicators: Theory and Applications of OR and Statistical Methods

Milica Maričić
& Veljko Jeremić

Fine tuning the weights in Global Innovation Index: application of multivariate statistical methods

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Abstract | Throughout the years, the Global Innovation Index (GII) has established itself as the leading proxy for measuring countries' innovativeness. With several papers raising questions about the methodological framework of GII, the issue of the equal-weight approach employed for the creation of GII is often deemed as an important methodological setback for the index. The objective of the paper is to present alternative ways of determining the weighting scheme of GII by employing the multivariate I-distance method. Besides the possibility to move away from expert and/or equal weight to a data-driven weighting scheme, the proposed approach enables the insights to decision-makers into possible ways of improvement for the country's GII performance. The paper will outline the potential future directions of improvement of the GII and map of strengths and weaknesses of the West Balkan region.

Key words | *Global Innovation Index*, *I-distance method*, *weighting scheme*, *composite indicators*

Time series analysis of composite indicators: The case of Human Development Index (HDI)

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Abstract | Composite indicators are metrics created by aggregation of individual weighted indicators that measure different aspects of the observed multidimensional problem. The Human Development Index (HDI), first published in 1990, is one of the first composite indicators to gain international recognition. Having in mind the availability of data the aim of this paper is to apply the model of time series in the analysis of HDI index of the Western Balkans. The introductory part of the paper will review the importance of forming and evaluating composite indicators in the field of human development, as well as the application of time series analysis and predictions in the field of composite indicators. The second part will be dedicated to presenting the HDI methodology. The third part will consider the theoretical framework of time series analysis. In the fourth part, the procedure of time series analysis will be explained in detail and the obtained results will be presented. HDI time series from 1990 to 2019 for Serbia, Croatia, Bosnia and Herzegovina and Slovenia will be analyzed. In the last part, a conclusion will be presented, as well as the directions of future research.

Key words | *composite indicator*, *time series analysis*, *human development index*, *ARIMA methodology*

Analysis of machine learning algorithms for specific datasets using composite index

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Abstract | Many machine learning algorithms (MLAs) can be applied to analyze the datasets. The MLAs applied to the datasets with specific characteristics (meta-feature values) should be evaluated concerning different measures that refer to MLA´s model quality. Those measures are related to the accuracy, confusion matrix, mean squared error, reliability and/or training time. In practice, for a specific dataset, the MLAs applications results with respect to quality measures present a multi-criteria decision-making (MCDM) problem. This paper presents the analysis of a given MCDM problem using the composite index approach. The composite index approach is a base for the simple additive weighting method (SAW) and analytic hierarchy process (AHP). By applying the SAW or AHP, we can decide on the optimal MLA for the observed dataset. Further, it is needed to investigate if the optimal MLA is also optimal for other datasets with the same meta-features.

Key words | *composite index*, *multi-criteria decision-making*, *machine learning*, *meta-features*

Acknowledgement | This work has been fully supported by Croatian Science Foundation under the project UIP-2020-02-6312.

Redesigning the composite index of sharing economy: issues and perspectives

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Abstract | The sharing economy has significantly influenced changes in consumer behaviour and attitudes. As a consequence, it altered business models and transactions with a vast number of organizations around the globe accommodating their business operations and algorithms according to the uprising demand for sharing economy services. Furthermore, many countries, regions and/or cities whose economic prosperity depends on the tourism industry are forced to adhere to such global trends strategically and on time. An objective of this study is to propose the usage of composite index methodology in the evaluation of the availability of countries'/cities' sharing economy services. The evaluated LATAM Sharing Economy Index 2021 evaluates and ranks the 44 biggest cities in Latin America. The index consists of a few main indicators describing the overall level of availability of crucial sharing economy services such as flat-sharing, e-scooters, car-sharing applications, gym sharing, and ride-hailing services. The paper will shed additional light on the methodological challenges when building composite indexes for sharing economy.

Key words | *sharing economy*, *composite index*, *multivariate statistics*, *methodological issues*

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 Value Co-creation and Competitive Advantage of Smart Tourism

Daniela Garbin Praničević

Do smart tourism technology effects really matter in Covid and post Covid 19 era?

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Abstract | The research objective is focused on exploring the effects of smart tourism from the perspective of tourism industry recovery. The first part of the paper will present an overview of the state of tourism and its growth in the period before the pandemic globally, as well as the situation during and after the Covid-19 pandemic. As research methodology, the systematic analysis of relevant studies will be provided. The search will include scientific articles from Wos and Scopus databases that contain the keywords 'smart tourism', 'Covid 19' and 'post Covid 19 recovery'. In discussion part, the research will answer the questions such as: does the application of smart tourism technologies really affect the recovery of tourism as an industry in pandemics and post-pandemics? In line with that, systematic analysis will be additionally reconsidered as valuable analytical method with potential to contribute decision-making in smart tourism as well.

Key words | *smart toursim*, *Covid and post Covid 19 - recovery*, *systematic literature review*, *decision making process*

Determinants of regional economic resilience in Croatian NUTS 3 regions

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Abstract | Since the global financial crisis in 2008, there has been a substantial and ongoing discussion about regional economic resilience in economic geography and regional studies. However, the discussion highlighted how difficult it is to define, quantify, and assess regional economic resilience. This paper investigates which factors enhance Croatian regions' regional economic resilience. The dynamic panel data model is formed to estimate the effects of various independent variables on regional economic resilience in 21 Croatian NUTS 3 regions for a period of eleven years (2009-2019). The results of our model confirmed the expected positive impacts of regional development level, human capital, population density, tourism demand, trade openness, innovation, and sectoral specialization in construction. In contrast, regional specialization in services and quality of governance on the national level negatively impacted regional resilience. Since this study is one of the exceptional attempts to investigate regional economic resilience in Croatian NUTS 3 regions, empirical findings provide useful information for policymakers looking to increase regional resilience.

Key words | *regional economic resilience*

Importance of RevPar indicators in the business of 5 * luxury hotels in the city of Split

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Abstract | In a dynamic tourism market, the analysis of indicators is essential in order to successfully manage the hotel business. In order to operate more efficiently, the most important indicator is RevPar in the hotel industry. In particular, RevPar has a strategic role in business decision-making, business control and the indicator shows how well the hotel is operating well or still doing badly. The aim of this paper is to calculate the average RevPar for luxury 5 * hotels in the city of Split. For the city of Split, luxury hotels are the key to develop in the process of providing luxury services. Hotels as generators of economic drivers, employment and other positive aspects for a tourist destination, it is extremely important to know RevPar 5 * hotels in order to direct their business towards maximizing income. With the maximization of income hotels can adequately plan their future business with further investments in the development of luxury hospitality.The research methodology is based on descriptive statistics.

Key words | *RevPar*, *hotel performance*, *luxury hotel business*, *revenue*

System dynamics model for waste management in tourism-orineted remote areas

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Abstract | Tourism-oriented remote areas in Croatia, such as islands, face many challenges. First of all, all Croatian islands are zed by a low local permanent population but a high number of tourist visits, with a high increase in the number of visits in recent years. This is especially highlighted from May to September. This specificity of tourism-oriented remote areas pointed out the need for better waste management. This paper aims to validate the previously developed system dynamics model for waste management in tourism-oriented smart cities and examine the differences in waste generation among observed areas. Data on waste generation and management has been collected for four Croatian islands (Hvar, Mljet, Lastovo, and Vis). Simulation scenarios proved that Croatian islands, characterized by geographic isolation and a tourism-driven economy, stand as a significant obstacle to achieving sustainability in terms of waste management. Results confirmed the importance of understanding the complexity of the waste management system in remote areas, providing new insights and support for policymakers regarding waste management.

Key words | *system dynamics*, *waste management*, *tourism-oriented remote areas*, *islands*, *Croatia*

Applied Statistics and Econometrics

Time series analysis of microclimate data in pedunculate oak forests

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Abstract | Each specific type of forest ecosystem has its own specific microclimate that depends on the macroclimate of the wider area, relief as well as the structural elements of the forest stand. Since the microclimate affects certain ecological and biological processes in the forest ecosystem, its study is a big part of research on forest biodiversity and its relationship to climate. Data on air and soil temperature, relative air humidity and soil moisture were collected over a longer period of time, with great frequency, at multiple forest stands near Vinkovci. This type of data poses a challenge with its size, multidimensionality with highly correlated variables, and different types of seasonality, but also provides a great opportunity for new insight. Given the complexity of the data, simple models generally do not perform well, and computationally complex state-of-the-art models are required. In this paper, the authors evaluate different time series models for the pedunculate oak forest microclimate data and attempt to provide statistical methodology for microclimate comparison between different plots.

Key words | *time series analysis*, *SARIMA*, *microclimate*

Recovery process optimization using survival regression

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Abstract | The goal of this paper is to propose, empirically test and compare different logistic and survival analysis techniques in order to optimize the debt collection process. This process uses various actions, such as phone calls, mails, visits, or legal steps to recover past due loans. We focus on the soft collection part, where the question is whether and when to call a past-due debtor with regards to the expected financial return of such an action. We propose to use the survival analysis technique, in which the phone call can be compared to a medical treatment, and repayment to the recovery of a patient. We show on a real banking dataset that, unlike ordinary logistic regression, this model provides the expected results and can be efficiently used to optimize the soft collection process.

Key words | *decision support systems*,*credit risk modeling*, *survival analysis*, *scoring*, *debt recovery*

Acknowledgement | This research has been supported by the Czech Science Foundation Grant 22-19617S and by the VSE institutional grant IP 100040.

Intensity and the size of price jumps

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Abstract | Despite the fundamental assumption of price continuity in the financial asset pricing models, following a certain stochastic process with a continuous state space and continuous time, in practice prices are observed at discrete time intervals. However, technological advances and the increased availability of high-frequency data, observed at very short intervals, for example every minute or second, have made it possible to use more complete information to estimation of the continuous part of the price process which is commonly joined to Brownian motion. In doing so, the process of price jumps is described by Poisson's stochastic process with discrete state space but continuous time. Joining the price jump process to the stochastic price process significantly changes the traditional understanding of the financial asset pricing and has serious consequences for financial risk management and recent literature offers empirical evidence for this. In order to be able to identify price jumps, using high-frequency data, various methods have been developed that are primarily based on comparing estimators of realized variance of returns that are robust and those that are not robust to jumps.

Key words | *price jumps*, *high-frequency data*, *realized variance*, *Poisson stochastic process*

The immediate impact of the Covid-19 pandemics on the global economy

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Abstract | The paper identifies the main economic shocks associated with the outbreak of the COVID-19 pandemic during the second quarter of 2020. The practical part measures the global economy's response to the pandemic outbreak in the period under review using the deviations of key variables from the log-quadratic trend in the US and EU economies. The theoretical part uses a simple two-period real-business-cycle model to verify the effects of the shocks. The model coefficients are calibrated using other studies and corresponding data. The changes in the total productivity factor, labor supply, and demand are calibrated so that the theoretical economic response corresponds to the practical. The pandemic outbreak was mainly associated with a sectoral shock. According to the theoretical model prediction, the decline in economic activity also caused a downfall in total factor productivity. The calibration also supposes that the shock persistencies are very high. In the given period, agents expected an even more significant economic deterioration in a future period.

Key words | *two-period real-business-cycle model*, *COVID-19*, *calibration*, *global economy*

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Economic complexity and income inequality in EU countries

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Abstract | This paper studies the relationship between economic complexity and income inequality. To assess the relationship, panel data methodology for the period from 1995 to 2020 is employed in the paper. Additionally, to control for the level of economic activity and the education level, GDP per capita and average years of schooling are included as well. The findings of the paper point to the conclusion that the increase in economic complexity leads to a decrease in income inequality. However, the results of the performed analysis also indicate that there are substantial differences between the 'old' EU member states and a group of 'new' EU member states that joined the EU in three enlargement waves in the 21st century.

Key words | *income inequality*, *economic complexity*, *EU*, *panel*

Multivariate analysis of the post-transition OECD countries in the context of inequality measures

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Abstract | The aim of this paper is to classify the post-transition OECD countries according to the Gini coefficient for income inequality, the S80/S20 ratio, income share of the bottom 40% of the population, educational attainment – tertiary education, and labor force participation rate using factor and cluster analyses. Factor analysis resulted in two extracted factors, and factor scores were calculated. Hierarchical and non-hierarchical cluster analysis was performed on factor scores to classify eight post-transition OECD countries and three candidate countries. The dendrogram obtained by the hierarchical Ward's method showed solutions with three or four clusters are acceptable. Non-hierarchical k-means method for the three-cluster solution clustered Croatia with Bulgaria and Romania. These three countries are OECD candidate countries. In the four-cluster solution, Croatia and Romania remained together, Bulgaria clustered into a separate cluster, while the composition of the other clusters remained the same. Our findings confirm that the three candidate countries remain behind because of historical reasons and non-implementation of structural reforms.

Key words | *cluster analysis*, *factor analysis*, *inequality measures*, *OECD countries*

It's the labour marker, stupid! Pension system reform on a household income level

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Abstract | Croatia's economy is characterised with deficits on many levels. Lack of structural reforms is the most likely root of its sub-optimal performance in the last 30 years. Labour market shortages combined with inadequate pension system reforms are one of many examples in that case. The general aim of this paper is to combine these two fields – pension system reforms and participation of workers in third age in the labour market – to fill the gap in the existing research thus providing a scientific basis for implementing optimal public policies aimed at 60+ potential working force. Data obtained from survey analysis and focus groups, collected during SENIOR 2030 project, revealed their preference for establishing so called "pensioners service centre". This centre would act as a market place where supply and demand for currently-retired-potential-workers would meet. Along the focus groups, paper combines multiple data sources and presents distributional analysis based on given data. Furthermore, this paper aims to make the first calculation of incentivising pensioners' return to the work force by simulating standard student wage rates per hour on household incomes of retired people.

Key words | *pension system reform*, *labour market institutions*, *ageing*, *pension system*, *microsimulation*

Acknowledgement | This research was partly funded by the Croatian Science Foundation and European Social Fund (ESF) under the project SENIOR 2030. Opinions, findings, conclusions and recommendations are those of the authors and do not necessarily reflect the views of ESF.

The social value of social farming in the hierarchical structure of care networks

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Abstract | In Slovenia, as in other EU Member States, statistics show a steady decline in the number of farms. Small farms, in order to survive, are opting for entrepreneurial opportunities with complementary activities on the farm. In order to promote the multi-purpose character of agriculture and to preserve nature in rural areas, the possibilities of various entrepreneurial initiatives in the form of complementary activities of production and services on the farm must be constantly sought and analysed. One such service that is proving to be a good opportunity after the adoption of the Long-Term Care Act in Slovenia is social farming for the care of older adults. We examine the social value that such activity can bring to Slovenian coffers, from pension to health insurance to the future insurance fund for long-term care. We also show what this means for dispersed users in rural areas. Using data on rural dispersion of age cohorts and calculating the probability of needing care in each age group, we show how to organise a database and how to assess the impact of user dispersion on care costs and thus the social value of social farming in rural areas using the multistate transition model.

Key words | *optimal regionalization*, *functional region*, *long-term care*, *dispersed users*

Acknowledgement | The authors acknowledge the financial support from the Slovenian Research Agency from the research projects J5-1784 Creating Social Value with Age-Friendly Housing Stock Management in Lifetime Neighbourhoods and L7-3188 Hierarchical Design and Financing of the Social Infrastructure of Smart Silver Villages.

The external shock impact on the financial soundness indicators of financial institutions in Croatia

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Abstract | This research aims to determine the impact of dynamic and unstable macroeconomic, financial, political or social environment caused by unpredictable event(s) on financial soundness indicators of the most important traditional financial institutions in the Republic of Croatia - commercial banks and insurance companies. Additionally, the impact of regulatory changes on the financial institutions' preparedness and reaction to external shocks will also be accounted for. The empirical analysis is based on data for the period from 2005 to 2021 and performed separately for the banking sector and insurance companies. Dependent variables used in the model encompass financial soundness indicators in the field of profitability, efficiency, liquidity, risk exposure and capitalisation whereas chosen macroeconomic indicators represent changes in the macroeconomic, political, financial or social environment. The results revealed that the 2008 financial and economic crisis had a larger impact on the soundness of financial institutions than the unpredictable and somewhat stronger shock caused by the 2020 Covid-19 pandemic.

Key words | *financial soundness indicators*, *financial institutions*, *external shock(s)*, *Croatia*

Forest fires and public health in the province of Biobío, Chile

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Abstract | Forest fires generate a series of negative consequences for people's health and represent a growing public health problem, nationally and internationally. The main focus of this study was to investigate the effects of forest fires in the number of care for respiratory symptoms in public health centres. An empirical study was conducted in the province of Concepción (Biobío region) using forest fires data provided by the National Forestry Corporation (CONAF) and data on respiratory care provided by the Ministry of Health between 2010 y 2020. An ordinary least squares regression model was estimated to determine the effect of forest fires on the number of admission to respiratory care visits in public health centres. The results show that, on average, areas affected by forest fires have a higher number of respiratory care visits compared to unaffected areas. These results may be useful for the implementation of health public policies.

Key words | *Forest fires*, *public health*, *respiratory diseases*

Machine Learning and Data Mining

Detecting fraudulent websites: A machine learning approach

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Abstract | Identity theft and private data threats from phishing scams have gotten more sophisticated. The average individual has difficulty determining whether a link in an email or website is trustworthy. The research aims to use machine learning and deep neural networks to develop a model for identifying fraudulent phishing websites. Firstly, we gather and prepare the dataset, which consists of 5000 websites' unique resource locations (URLs), containing a collection of benign, safe, i.e. legitimate URLs, but also spam, phishing, malware and other URLs. Secondly, we extract features of the fraudulent websites (URLs), focusing on the following attributes: URL code, URL of the website, date when URL was applied as potentially fraudulent, verification of the URL as fraudulent, date when URL was confirmed as the fraudulent, status of the URL (online or offline), and target company. Thirdly, we use Phyton to apply several machine learning models (Decision Tree Classifier, Random Tree Classifier, Multilayer Perceptrons, Extreme Gradient Boosting, Autoencoder

Neural Network, and Support Vector Machines) and select the most accurate model (Extreme Gradient Boosting).

Key words | *Machine learning*, *Extreme Gradient Boosting*, *Phishing*, *URL*, *Python*, *Website*

Acknowledgements | This research has been fully funded by the PhisHRban project (KK.01.2.1.02.0267).

Learning representations for k-means clustering

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Abstract | A distance function and a feature space in which the data is represented are crucial to any clustering algorithm. Our distance function is Euclidean distance while the feature space in which the data is represented will be subject to the learning process. Our work will try to better understand recent advances in this field, in particular the Deep Embedded Clustering (DEC) algorithm. While the DEC algorithm proposes to transform the data with a non-linear learnable mapping to the latent feature space of much smaller dimensionality (thus avoiding various problems that arise in high-dimensional spaces, better known as the "curse of dimensionality" problems), we will try to understand whether a similar approach can be used as an alternative to standard kernel K-means approach (e.g. K-means with Gaussian kernel) that is designed to better identify non-linearly separable clusters by mapping the data to the latent feature space of higher dimensionality. All our results will be experimentally verified on different datasets.

Key words | *clustering*, *K-means*, *neural networks*

Going concern prediction: Do machine learning models beat traditional regression models?

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Abstract | The concept of going concern (GC) assumes that a firm will not terminate its' operations in the near term. When there is substantial doubt about a firm's ability to continue as a GC, an auditor should include an emphasis of the matter in the audit report. Failing to adequately recognize GC may have severe implications for auditors, such as lawsuits, reputation damages, loss of audit clients and audit fees. Therefore, it is important for auditors to form accurate expectations about a firm's GC uncertainty. However, making accurate predictions of rare events such as GC is quite challenging. When the number of events is low relative to the number of predictors, traditional methods such as logistic regression could produce overfitted risk models. A solution to this problem may be in the application of machine learning (ML) in variables selection that are well-suited for high-dimensional data, such as regularization methods. Regularization methods also tend to outperform traditional methods in prediction accuracy due to the bias-variance trade-off. The aim of this study is to compare the performance of traditional regression with ML based on

regularized regression approach using a large set of financial and non-financial data for firms listed on Croatian capital markets from 2009 to 2018. Also, we take special caution when evaluating the predictive models performance due to class-imbalanced problem.

Key words | *going concern*, *prediction*, *machine learning*, *rare events*

Finding the most representative Latent Dirichlet Allocation run for topic modelling

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Abstract | The number of research publications is growing exponentially making the extraction of meaningful information increasingly challenging. Natural language processing may provide a solution. Latent Dirichlet Allocation (LDA) is frequently used to detect topics in a corpus of documents. It relies on Monte Carlo methods for estimation, which introduces a replicability risk. Recently, an approach to stabilization of topic-term allocation was proposed and implemented in R LDAPrototype package. Stabilization is achieved by analysing the topic-term frequency matrices from a set of LDA replications and choosing the LDA replication that is the most representative for the set. Another approach might be to base the choice of the most representative LDA replication on the document-topic frequency matrices. The objective of this research is to compare the two approaches to stabilization of LDA results on a corpus of papers on learning analytics and educational data mining.

Key words | *learning analytics*, *topic modelling*, *Latent Dirichlet Allocation*, *stability of allocation*

Acknowledgement | This work has been fully supported by the Croatian Science Foundation under the project IP-2020-02-5071.

Metaheuristic Approaches to neural networks training

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Abstract | In recent years, machine learning, and in particular neural networks (NN) have received much attention due to their numerous real-world applications. NN training is an essential step in building a model that can make reliable predictions based on given data. The process of NN training aims to find the optimal values for its internal parameters so that the network performs well on test data according to a given metric. The most common way to train an NN is to successfully use an optimizer based on gradient descent (GD). At each epoch, the optimizer updates the parameters based on the given data. In this paper, we are interested in using metaheuristics to guide the entire training process. The main idea is to identify the promising regions of the search space and invoke a GD -based optimizer in these regions as a local search procedure. For this purpose, we applied metaheuristics such as Variable Neighborhood Search and the Memetic algorithm to the NN training process and measured their performance on publicly available classification datasets, using classification accuracy as an evaluation metric.

Key words | *Machine learning*, *Variable neighborhood search*, *Memetic algorithm*, *Optimization*

Acknowledgement | This work was partially funded by a bilateral project between the Republic of Serbia and the Republic of Croatia: "Application of Optimization Methods in Biomedicine", by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Agreement No. 451-03-9/2021-14/200029 and by the Science Fund of the Republic of Serbia, Grant "AI4TrustBC: Advanced Artificial Intelligence Techniques for Analysis and Design of System Components Based on Trustworthy BlockChain Technology". We would like to thank Tatjana Davidović and Slobodan Jelić for their contribution to this paper.

Ensembles for the Resource Constrained Project Scheduling Problem

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Abstract | The Resource Constrained Project Scheduling Problem (RCPSP) is a combinatorial optimization problem that attracts many researchers due to its complexity and its daily application. RCPSP belongs to the class of NP -hard problems, so heuristics are usually used to solve it. Priority rules are one of the methods commonly used in dynamic environments. These rules are simple and in combination with the schedule generation scheme can build a schedule very quickly. In the literature we can find more than one priority rule and each of them has some advantages and disadvantages compared to another. The question is whether we can somehow combine them to achieve even better results and overcome some of the disadvantages of each rule. To answer this question, we use ensembles, which are commonly used in machine learning. Priority rules, which can be found in the literature, are used for creating ensembles. Ensembles are created using three different methods - simple ensemble combination, bagging, and boosting. Ensemble members are combined using the sum and vote method to make a final decision.

Key words | *resource constrained project scheduling*, *ensemble*, *priority rules*, *machine learning*

Center based iterative method for clustering and multivariate outlier detection

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Abstract | In this investigation the center based iterative method is constructed by modifying the well known k-means algorithm. The modification is conducted by involving the fact that the Mahalanobis distance follows the chi-squared distribution. The proposed method is presented and examined on the Gaussian mixture model, where a local convergence properties and existence of a fixed point of the proposed method are determined.

Key words | *clustering*, *outlier detection*, *convergence*, *fixed point*

Mathematical Programming

General variable neighborhood search for the multiple traveling repairman problem with profits

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Abstract | There are set of n users (labeled by numbers between 1 and n) requiring some of kind of service and set of m (identical) repairmans (numbered by numbers between 1 and m).Each repairman starts from initial position (depot), visits and services users in some order. The time of servicing of each of users is equal to zero. For performed service, repairman obtains revenue which is equal to difference between initial profit proposed by user (p_i for user i) and time until this user is serviced. The problem consists in selecting a subset of all users (customers) to be served by some of these repairmans so that the total revenue received from the users (customers) is maximized. To address this problem, an general variable neighborhood search is proposed. The Main part of proposed method is variable neighborhood descent as local search. Proposed variable neighborhood search consists of exploring in total nine different neighborhoods. For representing solution an efficient structure (the Frenwick tree) is used in order to speedup neighborhoods exploring. The performance of the algorithm were compared with those of the leading reference algorithms on selected subset of 470 b.

Key words | *General variable neighborhood search*, *Multiple repairman problem*, *Heuristic*, *Combinatorial optimization*

Acknowlegdement | This work has been supported by the Serbian Ministry of Education, Science and Technological Development, Agreement No. 451-03-9/2021-14/200029 and by the Science Fund of Republic of Serbia, under the project "Advanced Artificial Intelligence Techniques for Analysis and Design of System Components Based on Trustworthy BlockChain Technology (AI4TrustBC)".

Properties of mathematical programming problems with absolute values

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Abstract | The presence of absolute values in modeling of real-life problems causes that the problems are hard to solve because the absolute values make the problem nonconvex and nonsmooth. Even the simple-formulated problem Ax+|x|=b is intractable since, e.g, the Set-Partitioning problem or the linear complementarity problem can easily be expressed in this form. In our presentation, we investigate linear programming problems involving absolute values in their formulations, so that they are no more expressible as standard linear programs. We analyse fundamental properties regarding the topology and the geometric shape of the solution set, including the conditions for convexity, connectedness and boundedness. We also address various complexity issues, showing that many basic questions are NP-hard to solve. From the algorithmic point of view, we discuss several lower and upper approximation methods. In particular, for a lower bound of the optimization problem (maximization formulation), we propose a local search heuristic. To compute upper bounds, three types of relaxations of the feasible set are utilized and compared.

Key words | *Linear programming*, *Nonsmooth optimization*, *Interval analysis*, *NP-hardness*

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Solving multi level multiobjective linear programming (ML_MOLP) problems with fuzzy parameters

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Abstract | Many business problems in complex decentralized organizations can be presented as ML_MOLP problem with fuzzy parameters. Different methodologies with different degrees of efficiency according to the criteria of analysts and decision makers have been proposed to solve such problems. This paper presents a methodology that uses some methods of multi-objective programming and multicriteria decision making to solve ML_MOLP problem with fuzzy parameters. The Iskander's method was used for defuzzification of the objective functions and constraints of the problem. The AHP method was used to determine the weights of the objective functions within and between the decision levels, while the fuzzy goal programming method was used to obtain the preferred non-dominated solution. The efficiency of the proposed methodology was tested on an example of the production planning in a complex decentralized company.

Key words | *multi-level programming*, *multi-objective linear programming*, *fuzzy parameters*, *linear goal programming*

Longitudinal analysis of economic activities' relative efficiency using the DEA approach

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Abstract | Measurement of economic activities' efficiency for purpose of this research is presented by the model that includes the set of one output and four relevant input variables. Return on assets represents the output variable that measures efficiency, while the input variables are total debt/EBITDA, EBITDA/employee, assets turnover and human capital efficiency that represents the segment of intellectual capital efficiency. Analysis of economic activities' efficiency is performed using the data envelopment analysis (DEA). The purpose of research is to present the possibilities of monitoring the relative efficiency of individual non-financial activities of economy using the DEA methodology. DEA is used for relative efficiency measurement and evaluation, benchmarking, target setting and identifying the best practice. In order to achieve the above-mentioned purpose, the objective of the research is to determine the relative efficiency of individual non-financial activities of economy in the period from 2002 to 2020 using data from the population of all non-financial entities in the Republic of Croatia.

Key words | *total debt to EBITDA*, *EBITDA per employee*, *assets turnover*, *human capital efficiency*

A review on 50 years in fractional programming

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Abstract | Fractional programming (FP) refers to a family of optimization problems whose objective function is a ratio of two functions. FP has been studied extensively in economics, management science, information theory, optic and graph theory, communication, and computer science, etc. This paper presents a bibliometric review of the FP-related publications over the past five decades in order to track research outputs and scholarly trends in the field. The reviews are conducted through the Science Citation Index Expanded (SCI-EXPANDED) database of the Web of Science Core Collection (Clarivate Analytics). Based on the bibliometric analysis of 1811 documents, various theme-related research indicators were described, such as the most prominent authors, the most commonly cited papers, journals, institutions, and countries. Three research directions emerged, including Electrical and Electronic Engineering, Telecommunications, and Applied Mathematics.

Key words | *fractional programming*, *literature review*, *bibliometric analysis*, *visualization*, *mapping network*

Multicriteria Decision Making

Inference and specification of multi-criteria decision models in the industry 5.0 processes

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Abstract | Industry 5.0 is a new emerging paradigm, in which the concepts of automation, big data and AI are complemented with human-centricity, cooperation between people and cobots, and decision-making based on human expertise. This research work introduces a novel methodology for the inference and specification of multi-criteria decision models that can be applied in business/production processes for industry 5.0. Objective holistic decisions are inferred automatically from big data on processes, IoT measurements, and use of products and services, as well as from ontologies on past decision-making models and patterns. In addition to applying data analytics, regression methods for the indirect derivation of preferential parameters from sets of correlated parameters or referential historical alternatives are used to obtain objective MCDM models. An aggregation-disaggregation approach is proposed to consolidate the inferred objective decisions and MCDM models with subjective judgments of human decision-makers, which allows for constructive learning. A case study is presented that pertains to the dynamic electricity energy supply market. AHP and utility models are thereby constructed.

Key words | *multi-criteria decision analysis*, *preference specification*, *regression models*, *data analytics for industry 5.0*

Internal or external project manager? A case study

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Abstract | An organization that employs internal and external project managers (PMs) faces the issue of which is the better. Internal PMs are usually employed for an extended period, with a monthly salary, while external PMs are hired for a fixed period and get a retainer. The paper proposes a model based on Data Envelopment Analysis (DEA), that objectively evaluates the relative performance of PMs according to their past performance. The model was applied in a case study with dozens of projects managed by dozes internal and external PMs. The case study results show that the average performance of internal PMs is statistically significantly higher than that of external PMs.

Key words | *Multi-criteria decision analysis (MCDA)*, *Data Envelopment Analysis (DEA)*, *Super Efficiency (SE)*

Customer segmentation and ranking via the Super Efficiency ranking method

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Abstract | Many organizations have their own method of segmentation and of customer evaluation to help them give the appropriate managerial attention to each segment and each customer. This paper proposes an improved objective method that allows segmentation and full ranking of customers. The proposed method is based on customer criteria with quantitative values that can be extracted from the organizational information system. Customer scores are calculated objectively by the Super Efficiency (SE), which is a ranking method via Data Envelopment Analysis (DEA). The relative location of each customer within that customer's segment (for example, Platinum, Gold, Silver, and Bronze), tracks changes that occur over time, and enables a full and precise ranking of the customers according to company-defined criteria. The applicability of the proposed method was successfully demonstrated in a real-world case study.

Key words | *Customer segmentation*, *Data Envelopment Analysis (DEA)*, *Multicriteria Decision Making.*

Supplier selection and order allocation considering rank reversal with reference points

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Abstract | Supplier selection and order allocation is an interface between supplier evaluation and inventory management. This management area can be considered as a two-stage decision making model, where the first decision level is to select some of the qualified suppliers and the next decision level is to order the quantity of products to be supplied by the selected suppliers. In the first decision stage, the paper presents a selection procedure using Data Envelopment Analysis (DEA) with the help of compromise programming. Since more than one efficient decision units are possible for DEA efficiencies, they cannot be ranked and DEA weights are not unique. Therefore, some common weight selection method is needed. The rank reversal problem is rarely investigated using data envelopment analysis. The paper attempts to estimate the change in the number of suppliers and in the supplier pool caused by the change in environment. At the second decision level, inventory costs are taking into account. However, there are often additional costs according to the traditional inventory costs of ordering and holding stock. Such costs may include the usual shortage costs, penalties and/or downtime costs.

Key words | *Data Envelopment Analysis*, *Supplier Evaluation*, *Order Allocation*, *Rank Reversal*

Elements of simulated annealing in Pareto front search

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Abstract | Determination of the Pareto front of location problem solutions represents one of the very complex and computational time demanding tasks, when solved by exact means of mathematical programming. This paper is motivated by possible application of the metaheuristic simulated annealing to the process of obtaining a close approximation of the Pareto front by a set of non-dominated solutions of the p-location problem. Contrary to the other approaches, the suggested method is based on minimization of non-dominated solution set area, which directly describes quality of the approximation. Elements of the simulated annealing method are used for random breaking some limits imposed on local characteristics of the improving process. The presented results of the numerical experiments give an insight to relations among the simulated annealing parameters and optimization process efficiency.

Key words | *discrete location problems*, *bi-criteria decision-making*, *Pareto front*, *simulated annealing*

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Multi-criterial analysis of policy measures in e-learning roadmap at Maldives National University

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Abstract | Policy measures are long-term activities that must be implemented and constantly upgraded to achieve strategic goals. This paper analyzed policy measures in the Maldives National University's e-learning roadmap using the analytic hierarchy process (AHP) and decision-making trial and evaluation laboratory (DEMATEL) for resource allocation purposes. In the policy measures' evaluation, there were more than 20 participants - persons with managerial functions at Maldives National University and persons at lectures and researchers' positions. By using the AHP, the participants evaluated the policy measures. The highest priority measures are related to the developing infrastructure and e-learning resources. Since this is the first cycle of e-learning implementation, the university does not have the infrastructure yet. On the other hand, using the DEMATEL, participants prioritized the measures that can have the highest impact on the whole system. Again, since the university is in the introduction phase of e-learning, it is not a surprise that participants evaluated policy measures related to advisory services and implementing research projects as the most-affecting measures.

Key words | *AHP*, *DEMATEL*, *resource allocation*, *decision making*

Hyperheuristics for determination of non-dominated set of public service system designs

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Abstract | A design of a public service system subjects to various objectives, which are usually in conflict. The most known pair of conflicting criteria is the system and fair criterion, where the system criterion expresses utility or disutility of an average system user and the criterion of fairness takes into account the access of the worst situated minority of the system users to service. A series of non-dominated system designs is important especially for the decision maker responsible form the final form of the system. In this contribution, we concentrated on study and construction of hyperheuristics assigned to the efficient determination of a non-dominated set of public service system designs, where the system and fair criteria are taken into account. The suggested hyperheuristic disposes with a list of subordinate heuristics with dynamically updated ranks depending on their previous success in improving quality of the non-dominated solution set. To explore properties of the employed subordinate heuristic, a series of numerical experiments with real-sized benchmarks has been performed and the obtained results are presented.

Key words | *public service systems*, *bi-objective optimization*, *Pareto front approximation*, *hyperheuristics*

Acknowledgement | This work was supported by the research grant VEGA 1/0216/21 "Design of emergency systems with conflicting criteria using artificial intelligence tools". This work was supported by the Slovak Research and Development Agency under the Contract no. APVV-19-0441.

Integrations of analytic hierarchy process and social network analysis

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Abstract | The analytic hierarchy process (AHP) is the most often used method for multi-criteria decision making (MCDM). Its application can be found in many fields. Usually, the decision-making context requires more than the application of AHP. In this paper, we discuss the integration of AHP with the method of social network analysis (SNA). The paper presents and demonstrates four types of AHP-SNA integrations. The first integration is the application of the SNA to track the evolution of some specialized scientific or professional journal or conference in the field of the AHP. The second integration is related to using the SNA to calculate the weights of participants in a group decision-making problem, which is analyzed using the AHP. The third integration is associated with the situation when some centrality measure from SNA is being used as a criterion in the decision-making problem analyzed using the AHP. The last integration analyzed in the paper is related to the developing new MCDM method, which enables modeling influenced (dependencies) among the criteria and is based on AHP and SNA.

Key words | *analytic hierarchy process*, *social network analysis*, *integrations*

Digital Economy and Society

Economic contribution and integration of Croatian ICT sectors

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Abstract | Despite numerous benefits of information and communication technology (ICT) in promoting economic growth and sustainable development of national economy, its significance is insufficiently researched, especially in the segment that quantifies contribution of ICT sectors to total economy and integration among ICT sectors. To emphasize the importance of the Croatian ICT sectors, in this paper model of sectors extraction is adapted to quantify the importance of ICT sectors in the open and closed input-output system for the period 2010-2020. The proposed model calculates contribution of ICT sectors in terms of output, gross value added and employment and monitors the interaction among ICT sectors related to cross-sectoral and intra-sectoral deliveries among ICT sectors. Results of the conducted analysis indicate that Croatian ICT manufacturing industries lag behind the ICT service industries. Relative integration measure differs for individual ICT sectors.

Key words | *input-output model*, *ICT sectors*, *integration measure*, *contribution*

Digital transformation of SMEs: Towards a comprehensive methodology for government support measures

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Abstract | Digital maturity of enterprises has been measured predominantly by surveys, which provide a general insight into the state of digital maturity of a population of enterprises. However, this type of research does not provide an assessment of the digital maturity of individual enterprises, nor of government support measures efficiency. To address this problem, we have designed and implemented a multi-criteria assessment model that enables assessment of an individual enterprise's digital maturity level, allow enterprises to better plan their future digital transformation and assess the efficiency of government support measures. We analyze the current and desired digital maturity level of 613 SMEs from Slovenia, assessed between December 2020 and April 2021. The results are coupled with the two major surveys (Statistical Office of the Republic of Slovenia and the Digital Innovation Hub Slovenia). The contribution of this study is to show the importance of combining different approaches to assessing digital maturity and will serve as the basis for developing a comprehensive methodology for assessing government support measures that are based on relevant data from complementary sources.

Key words | *digital transformation*, *digital maturity*, *assessment*, *methodology*, *SMEs*, *data sources*

Key words | This research was supported by the Slovenian Research Agency: Program No. P5-0018— Decision Support Systems in Digital Business and Digital Innovation Hub Slovenia.

Validation of the eFANgelism scale in Croatia

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Abstract | The purpose of this paper is to examine the factor structure of the eFANgelism scale in Croatia. Primary data were collected through a cross-sectional survey of a convenient sample among HNK Hajduk Split fans during January 2022. The scale was translated into Croatian and distributed through the Qualtrics Survey website to open and closed fan groups on social networks to answer a key research question: What is the underlying factor structure of the eFANgelism scale? The questionnaire was accessed by 462 respondents, and 370 of them completely filled in the questionnaire and were taken for further processing. Dwyer et al. (2015) established the scale and listed four dimensions of eFANgelism (advocate, advertise, antagonize, and assimilate) that were first empirically confirmed in a study by Park et al. (2021) in the Korean professional football league. The findings of this study present a 14-item two-factor scale among Croatian football fans. The results provided new insights into the validity of the original version of the eFANgelism scale. It is concluded that the Croatian adaptation of the eFANgelism scale is a useful instrument for segmenting the sports market.

Key words | *eFANgelism scale*, *sports market*, *football fans*, *Croatia*

South east European contribution to SDG-4 literature in the field of sustainability

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Abstract | In this paper, we analyze the South East European (SEE) literature on sustainability education, related to the United Nations' Sustainable Development Goal (SDG 4). Analysis is performed for the 2016-2021 period, to analyze the structure of the regional research in the field. SDG 4 is focused on inclusive and quality education, including lifelong learning and has been used globally as a benchmark of education policies, research and activities. However, the regional body of scientific research has not yet been previously analyzed by using the quantitative bibliometric approach to identify the clusters of regional SEE literature, or inform on the most productive and influential authors, institutions and publication outlets in the region. The bibliometric data are obtained from the Elsevier Scopus database, with most of the Scopus documents being previously mapped to the SDG-related research areas. Quantitative data analysis and visualization are conducted by using the Elsevier SciVal and Leiden University's VOSviewer science mapping software.

Key words | *Sustainability education*, *Quantitative bibliometrics analysis*, *Science mapping*, *South East Europe*

Acknowledgement | This research has been funded by Scientific Center of Excellence for School Effectiveness and Management. Access to SciVal for research purposes has been kindly provided by Elsevier BV.

Digital divide in e-government use: case of Europe

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Abstract | Citizens and businesses are increasingly using the internet to perform their daily tasks. In recent years, the use of e-government services has become popular because it allows information to be obtained at any time, as well as performing administrative tasks remotely. This research aims to examine the use of e-government services by citizens and to measure the development of e-government in European countries. The results of the cluster (hierarchical and K-means) and ANOVA analysis based on data from 2015 and 2020 indicate that there are improvements in the use of e-government services and that differences between countries are increasing. In addition, the results of clustering confirm the existence of four clusters. The groupings of countries were formed based on characteristics of the country's affiliation to northern/western or southern/eastern Europe and their affiliation and time of accession to the European Union as common features of newly formed groups. The research confirms the existence of differences between clusters in the development of e-government on the supply side, and the differences are statistically significant.

Key words | *e-government*, *cluster analysis*, *digital divide*

Acknowledgement | This work has been supported by the Croatian Science Foundation (grant number UIP-2017-05-7625).

Some quantitative indicators of a few features of electoral systems: a case study

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Abstract | Electoral systems can be analyzed by means of their many properties. We consider some quantitative indicators of a few technical features of electoral systems. With respect to the question of the effective number of parties in a political system, one can observe some known indicators (e.g., fractionalization of vote shares, the Laakso-Taagepera index, the Wildgen index). With regard to the question of government stability, one can look at the indicator which is called the expectation of government stability. We examine these indicators from the empirical point of view, i.e., in relation to the cases of elections in different countries.

Key words | *electoral systems*, *vote fractionalization*, *Laakso-Taagepera index*, *government stability indicator*

Workshop

How AI sees the world around us

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Abstract | Each individual perceives the world around them differently. Autonomous vehicles and robots operating in real-world environments are often cited as examples of advanced Artificial Intelligence systems. What makes such systems intelligent, and how do they perceive the world around them? Artificial intelligence is also present in devices that we use every day. Unlocking a laptop or cell phone by facial recognition is becoming a standard feature of all newer devices. How do computers see our faces and how do they recognize them? How do we distinguish and recognize the faces of our acquaintances? The goal of this workshop is to answer the previous questions (and hopefully more) and provide an introduction to the basic concepts of computer vision and Artificial Intelligence. We will discuss how computers create a model of the world around them and how they use this model to "think" and make decisions. This workshop also includes a practical example with an unplugged activity in which we will try to simulate the method of AI facial recognition system which should help us to better understand the underlying principles.

Key words | *AI*

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

The objective of the KOI conference is to bring together 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. Main intention of the conference is to exchange ideas and experiences through direct contacts with researches of common interest, particularly including young researchers in improving their scientific work. Main intention of the conference is to exchange ideas and experiences through direct contacts with researches of common interest, particularly including young researchers in improving their scientific work.

18 KOI conferences were successfully held so far in different cities of Croatia settled at the beautiful Adriatic seaside or in the continental part of Croatia, such as: Rovinj, Rab, Trogir, Pula, Split, Šibenik, Zadar, Zagreb and Osijek. From 1991-2008 the papers that were presented at the conference and positively reviewed, were published at the conference proceedinigs. From 2010 and further, the accepted papers are published in the **Croatian Operational Research Review (CRORR)** journal which is indexed in relevant databases. Book of Abstracts from the conference is also published and distributed at the conference.

Previously held KOI conferences

- KOI 2020 - 18th International Conference on Operational Research, September 23-25, 2020 in Šibenik, Croatia
- 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
- KOI 2010 - 13th International Conference of Operational Research, September 29-October 1, 2010 in Split, Croatia
- KOI 2008 - 12th International Conference of Operational Research, September 24-26, 2008 in Pula, Croatia
- KOI 2006 - 11th International Conference on Operational Research KOI 2006, September 27-29, 2006, Pula, Croatia
- KOI 2004 - 10th International Conference on Operational Research KOI 2004, September 22-24, 2004, Trogir, Croatia
- KOI 2002 - 9th International Conference on Operational Research KOI 2002, October 2-4, 2002, Trogir, Croatia
- KOI 2000 - 8th International Conference on Operational Research KOI 2000, Rovinj, Croatia
- KOI 1998 - 7th International Conference on Operational Research KOI 1998, September 30-October 2, 1998, Rovinj, Croatia
- KOI 1996 - 6th International Conference on Operational Research KOI 1996, Rovinj, Croatia
- KOI 1995 - 5th Conference on Operational Research KOI 1995, Rab, Croatia

- KOI 1994 - 4th Conference on Operational Research KOI 1994, Rab, Croatia
- KOI 1993 - 3rd Conference on Operational Research KOI 1993, Rovinj, Croatia
- KOI 1992 - 2nd Conference on Operational Research KOI 1992, Rovinj, Croatia
- KOI 1991 - 1st Conference on Operational Research KOI 1991, Zagreb, Croatia

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.

About CRORS

Croatian Operational Research Society (CRORS) was established in 1992 as the only scientific association in Croatia specialized in operational research. Today the Society has more than 140 members and its main mission is to promote Operational Research in Croatia and worldwide for the benefit of science and society. This mission is realized through several goals:

- to encourage collaboration of scientists and researchers in the area of operational research in Croatia and worldwide through seminars, conferences, lectures, and similar ways of collaboration,
- to organize the International Conference on Operational Research (KOI),
- to publish a scientific journal Croatian Operational Research Review (CRORR).

Since 1994, CRORS is a member of the The International Federation of Operational Research Societies (IFORS), an umbrella organization comprising the national Operations Research societies of over forty five countries from four geographical regions: Asia, Europe, North America and South America. CRORS is also a member of the Association of European Operational Research Societies (EURO) and actively participates in international promotion of operational research. It also publishes an electronic yearly magazine CRORS News (available at https://hdoi.hr/news/crors-news-magazine/). If you are a researcher, academic teacher, student or practitioner interested in developing and applying operations research methods, you are welcome to become a member of the CRORS.

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