

Book of Abstracts 17th International Conference on Operational Research

KOI 2018

Zadar, Croatia 26–28 September, 2018

CROORS

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RESEARCH SOCIETY



University of Zagreb
Faculty of Economics & Business



MINISTRY OF SCIENCE AND EDUCATION
OF THE REPUBLIC OF CROATIA

Editors

Josip Arnerić — Anita Čeh Časni

I m p r e s s u m

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17TH INTERNATIONAL CONFERENCE ON OPERATIONAL RESEARCH
KOI 2018, 26-28 September, Zadar, Croatia

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P r e f a c e

Abstracts of plenary lectures and contributed talks, presented at the 17th International Conference on Operational Research KOI 2018, are included in this book. The International Conference on Operational Research (KOI) is the major event organized by the Croatian Operational Research Society (CROORS) since 1991. In the period from 1991 to 1996 it was organized annually 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 researchers 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, Zagreb and Osijek. The conference KOI 2018, organized by Croatian Operational Research Society in collaboration with Faculty of Economics and Business, University of Zagreb, was held in Zadar, at Falkensteiner Club Funimation Borik**** from September 26 to September 28, 2018. The conference KOI 2018 brings together various topics grouped into the following sessions:

- Plenary Session
- Special Session on Data Envelopment Analysis
- OR Theory and Applications
- Mathematical Programming
- Multicriteria Decision Making
- Quantitative Methods in Banking and Finance
- Statistics and Econometrics
- Machine Learning and Data Mining

Plenary lectures are given by eminent international experts:

- Andrija Mihoci, Department of Economic Statistics and Econometrics, Brandenburg University of Technology, Germany
- Mirjana Kljajić Borštnar, Faculty of Organizational Sciences, University of Maribor, Slovenia
- Ali Emrouznejad, Aston Business School, Aston University, UK
- Kenneth Sörensen, Department of Engineering Management, University of Antwerpen, Belgium
- Vincent Charles, Buckingham Business School, UK

In addition to plenary lectures there are 86 contributed talks, with 4 talks devoted to the 40th anniversary of DEA. The total of 116 registered authors and co-authors participate the conference from 17 different countries: Belgium, Chile, Croatia, Czech Republic, France, Germany, Hungary, Iran, Macedonia, Nigeria, Poland, Romania, Slovakia, Slovenia, Spain, Turkey and UK.

Also, the Workshop on Data Science and Machine Learning is organized during the conference KOI 2018 with the guest lecturer Vincent Charles, Buckingham Business School, University of Buckingham, UK.

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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2012 - Dr.rer.pol. Statistics and Econometrics, Humboldt-Universität zu Berlin

2008 - M.Sc. Economics and Management, Humboldt-Universität zu Berlin

2007 - Diplom Accounting and Statistics, University of Zagreb

Professional experience

2017 - present | Vertretungsprofessor und Lehrstuhlinhaber für allgemeine Betriebswirtschaftslehre, insbesondere empirische Unternehmensforschung und Transformation, Brandenburgische Technische Universität, Cottbus-Senftenberg

2017 - present | Gastdozent für Wirtschaftsmathematik Hochschule für Wirtschaft und Recht, Berlin

2015 - 2017 | Gastprofessor und Lehrstuhlinhaber für Wirtschaftsstatistik und Ökonometrie, Brandenburgische Technische Universität, Cottbus-Senftenberg

2014 - 2016 | Gastdozent für Wirtschaftsmathematik und Statistik Technische Hochschule [FH] Wildau

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2013 - present | Visiting Lecturer for Quantitative and Qualitative Analyse and for Auditing German University in Cairo, Berlin

2008 - 2003 | Research Associate for Statistics at C.A.S.E. - Center for Applied Statistics and Economics and Sonderforschungsbereich 649: „Ökonomisches

Risiko“, Lecturer at the Berlin Doctoral Program in Economics and Management Science (BDPEMS), Humboldt-Universität zu Berlin
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Additional info

Research Topics | financial econometrics, analysis of limit order book markets, statistics of financial markets, high-frequency finance, empirical pricing Kernels and financial markets

Collaboration | Humboldt-Universität zu Berlin, Technische Universität Dresden, University of Rijeka, University of Zagreb, Singapore Management University, Griffith University, Wrocław University of Technology, Universität Wien

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Education

2006 - PhD University of Maribor, Management Information Systems

2003 - M. Sc. University of Maribor, Faculty of Organizational Sciences, Decision Support Systems

1998 - Bachelor Degree University of Maribor, Faculty of Organizational Sciences, Organizational Informatics

Professional experience

2017 - present | Associate Professor

2008 - 2016 | Vice Dean for Research, Head of Institute of Organization and Management

2006 - 2008 | University of Maribor, Faculty of Organizational Sciences, Assistant Professor

2002 - 2006 | University of Maribor, Faculty of Organizational Sciences, junior researcher

1998 - 2001 | Small Business Development Center

Additional info

Mirjana Kljajić Borštnar received her PhD in Management Information Systems from the University of Maribor. She is an Associate Professor at the Faculty of Organizational Sciences, University of Maribor and is a member of Laboratory for Decision Processes and Knowledge-Based Systems. Her research work covers decision support systems, multi-criteria decision-making, system dynamics, data

mining, and organizational learning. She is the author and co-author of several scientific articles published in recognized international journals and conferences, including Expert Systems with Applications, Industrial Management and Data Systems, Group Decision and Negotiation and System Dynamics Review. She is member of System Dynamics Society, EURO, Slovensko društvo informatika. As a program committee member she serves at several conferences, like Bled eConference, Symposium of Operations Research, Symorg, ICT, IFIP DSS, and reviewer in many scientific journals. She is also a representative of academia in the program committee of Smart cities and communities, for HPC & Big Data.

Ali Emrouznejad



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1994 - 1998 | PhD, Warwick Business School

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Ali Emrouznejad is a Professor and Chair in Business Analytics at Aston Business School, UK. His areas of research interest include performance measurement and management, efficiency and productivity analysis as well as data mining and big data. Dr Emrouznejad is Editor of (1) Annals of Operations Research, (2) Associate Editor of RAIOR-Operations Research, (3) Associate Editor of Socio-Economic Planning Sciences, (4) Associate Editor of IMA journal of Management Mathematics, and (5) Senior Editor of Data Envelopment Analysis journal. He is also Guest Editor to several journals including European Journal of Operational Research, Journal of Operational Research Society, Journal of Medical Systems and International Journal of Energy Management Sector. He is also member of editorial boards other scientific journals. He has published over 120 articles in top ranked journals, he is also author / editor of several books including (1) “Applied Operational Research with SAS” (CRC Taylor & Francis), (2) “Big Data Optimization” (Springer), (3) “Performance Measurement with Fuzzy Data Envelopment Analysis” (Springer), (4) “Managing Service Productivity” (Springer), (5) “Fuzzy Analytics Hierarchy Process” (CRC Taylor & Francis) and (6) “Handbook of Research on Strategic Performance Management and Measurement” (IGI Global). For further details please visit <http://www.emrouznejad.com/>.

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1997 - Commercial Engineer, University of Antwerp

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2008 - present | Professor at University of Antwerp

2005 - 2008 | FWO fellow, Faculty of Engineering, KULeuven

2003 - 2005 | Postdoctoral Researcher at University of Antwerp

1997 - 2003 | Research/Teaching assistant at University of Antwerp

Additional info

Kenneth Sörensen is Professor of the Faculty of Applied Economics of the University of Antwerp. Within this Faculty he founded the ANT/OR research group. Kenneth Sörensen has published a large number of articles in international refereed journals and has presented his work at numerous scientific conferences. He is considered one of the world's leading experts in the field of metaheuristics. His main research interest lies in the application of advanced (metaheuristic) optimization methods and in the development and study of optimization methods. He is the founder and current coordinator of the EURO working group EU/ME - the metaheuristics community, the largest online platform for researchers in metaheuristics worldwide. He currently holds the position of Vice President 2 of EURO - The Association of European Operational Research Societies. He is also co-editor of the Journal of Heuristics, the International Transactions in Operational Research and 4OR - the Quarterly Journal of the French, Italian, and Belgian OR Societies.

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Education

2009 - Post Doc Research Fellow

2005 - PhD in Operational Research

Professional experience

1998 - | Academic and Consultant

Additional info

Vincent Charles is the Director of Research and a Professor of Management Science at Buckingham Business School, University of Buckingham. He is also a postdoctoral research fellow from National University of Singapore. He is an Honorary Professor at Maastricht School of Management, Netherlands; an Affiliated Distinguished Research Professor at CENTRUM GBS, PUCP, Peru; a Fellow of the Pan-Pacific Business Association, USA; a Council Member of the Global Urban Competitiveness Project, USA; a Higher Education Teaching and Learning Association Liaison to Peru, HETL USA; and a WiDS Ambassador, WiDS Buckingham (in collaboration with Stanford University, USA). He is a certified Six Sigma Master Black Belt, also holds executive certificates from Harvard Business School, MIT Sloan School of Management, and IE Business School. He has 20 years of academic and consultancy experience in the field of applied quantitative analytics (big data). He has published over 120 research works. He has developed the 4³ Architecture for Service Innovation. His area of focus includes productivity, quality, efficiency, effectiveness, competitiveness, innovation, service science and design thinking.

Plenary Lectures

Local Adaptive Multiplicative Error Models for High-Frequency Forecasts

ANDRIJA MIHOČI

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Abstract | A local adaptive multiplicative error model (MEM) accommodating time-varying parameters is proposed. MEM parameters are adaptively estimated based on a sequential testing procedure. A data-driven optimal length of local windows is selected, yielding adaptive forecasts at each point in time. Analysing 1-minute cumulative trading volumes of five large NASDAQ stocks in 2008, we show that local windows of approximately 3 to 4 hours are reasonable to capture parameter variations while balancing modelling bias and estimation (in)efficiency. In forecasting, the proposed adaptive approach significantly outperforms a MEM where local estimation windows are fixed on an ad hoc basis.

Key words | *high-frequency, MEM, local window selection*

Supporting Organizational Learning by Machine Learning Models Explanations

MIRJANA KLJAJIĆ BORŠTNAR

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Abstract | Machine learning models are still scarcely used in business decision-making processes. The reasons are in complexity of the problem and weak methodological knowledge of the business users. While research mainly focuses on the technical aspects, organizational aspects are neglected. In our research we set out to develop a framework for integration of top performing machine learning (ML) models, coupled with uniform explanations, into decision-making process. Machine learning model explanations provide sufficient feedback information to support the decision-making process, which builds a foundation for organizational learning. Using action design research approach, which combines design science research (building of the IT artefact) with action research (collaboration with practitioners/users) we address both the comprehensibility of the top performing black-box machine learning models and organizational aspects by including users during the development, evaluation and implementation. The proposed framework is applied to a complex decision-making process: business to business (B2B) sales forecasting process, which can be modelled as a classification problem. Results suggest that the provided ML model explanations efficiently support business decision makers, reduce forecasting error for new sales opportunities, and facilitate discussion about the context of opportunities for the sales team.

Key words | *business to business, machine learning, action design approach*

Data Envelopment Analysis: Static vs Dynamic

ALI EMROUZNEJAD

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Abstract | In this talk we first introduce standard definition of Data Envelopment Analysis (DEA) and further discuss the network DEA models. We further propose a DEA based method for assessing the comparative efficiencies of units operating production processes where input output levels are inter-temporally dependent. One cause of inter-temporal dependence between input and output levels is capital stock which influences output levels over many production periods. Such units cannot be assessed by traditional or static DEA which assumes inputoutput correspondences are contemporaneous in the sense that the output levels observed in a time period are the product solely of the input levels observed during that same period.

Key words | *network DEA, inter-temporal dependence, efficiency comparison*

VRPXL: Solving Extra Large Vehicle Routing Problems

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Abstract | We take a fresh look at the development of vehicle routing algorithms. First, we use data mining to gain knowledge on what distinguishes good solutions from “not-so-good” solutions. We then build an algorithm that is entirely based on a small set of well-chosen, complementary, and efficiently implemented local search operators and apply that knowledge to make them work effectively. Finally, the efficiency of the algorithm is improved by heavy heuristic pruning. The result is an algorithm that is both very fast and very effective, and can be scaled to solve instances that are orders of magnitude larger than those considered “large” in the literature.

Key words | *vehicle routing algorithms, data mining, heuristic pruning*

Regional Competitiveness in View of Management Science

VINCENT CHARLES

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Abstract | Regional competitiveness can be defined as the ability of a region to manage the totality of its resources and competencies to offer an attractive and sustainable environment for firms and increase the prosperity of its people. Over the past decades, enhancing competitiveness has become a popular target in economic policy-making and this is partly due to the fact that generally, the concept of competitiveness is linked to productivity, having a positive effect on long-term economic growth. But in order to enhance competitiveness, it must first be measured. This plenary talk focuses on the foundations of regional competitiveness and proposes a novel way to construct a regional competitiveness index through Management Science techniques. Further, it proposes the scaling of its performance over a period of time so as to facilitate the process of benchmarking. The proposed model also incorporates the value judgements of the decision-makers so as to realistically derive a regional competitiveness index, considering not only the five pillars of competitiveness (that is, economy, firms, government, infrastructure, and people), but also the knowledge of the decision-makers.

Key words | *regional competitiveness, envelopment-based analysis*

Special Session on Data Envelopment Analysis

**A Survey and Analysis of Scholarly Literature in DEA
Published by Croatian Researchers: 1978 - 2018**

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Abstract | After its introduction in 1978, Data Envelopment Analysis (DEA) has instantly been recognized as a useful methodology for measuring the relative efficiency of Decision Making Units (DMUs), which use the same multiple inputs and produce the same multiple outputs. Since then, the popularity of DEA has been constantly growing and consequently, a significant number of bibliographical items was published in this area, reporting on both theoretical and empirical results. There are several surveys on the relevant DEA bibliography made by international authors. The aim of this paper is to present the bibliographic survey of the DEA literature in the Croatian science, written or co-authored by the Croatian scientists in the period from 1978 to June 2018. We consider six main categories of publications and especially point out publications written in Croatian. Our paper includes the statistics on the authors, the type and the number of publications in DEA throughout the years as well as the analysis of their keywords, subjects and research area. Finally, we discuss the overall contribution of Croatian scientists to DEA in theory and application, as well as some future research opportunities.

Key words | *DEA, efficiency, Croatian science, bibliography, survey*

Evaluating the Efficiency of Commercial Banks using DEA Window Analysis

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Abstract | The aim of the paper is to evaluate the relative efficiency of Macedonian commercial banks by using the DEA technique window analysis. Based on the profitability approach, two inputs and two outputs are selected for our research. The sample consists of 14 commercial banks in Macedonia and the observed period covers 11 years (2007-2017). According to the average efficiency score for the whole observed period, the most efficient bank belongs to the group of large banks, and also this group of banks show the highest efficiency. The Macedonian banking sector as a whole shows the highest efficiency in 2007 (84.04%), and the lowest efficiency in 2011 (65.25%). In the period from 2007 to 2011 a decline in the efficiency that is related to the global financial crisis is noted, from 2012 until 2016 the efficiency notes growth, and in 2017 compared to 2016 a small decline is noted (2.28%). Findings from this research are consistent with the factual situation in the Macedonian banking sector and they give valuable information to regulators, policy makers and bank management in the direction of further improvement of one of the most important indicators of success for financial institutions, the efficiency.

Key words | *DEA, window analysis, profitability, relative efficiency, banking sector*

The Analysis of the Contextual Variables Affecting the Fiscal Rules Efficiency in the European Union

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Abstract | Fiscal rules are among the cornerstones of macroeconomic policies in the European Union, both on the national and the supra-national level. The importance of enacting and conducting of the fiscal rules has become apparent after the expansion of public debts and budget deficits in the period of the global financial crisis. Besides the supra-national rules, governments impose the national fiscal rules in order to fulfil the convergence criteria regarding the public debt and budget deficit. Still, there is an open question on their influence on other economic parameters. This paper examines contextual variables that influenced the efficiency of implementing fiscal rules in 28 European Union countries. We observe the period of the last financial crisis and its aftermath when most of the countries introduced new or adjusted existing national fiscal rules, using the two-stage Data Envelopment Analysis. Therefore, the main goal of the paper is to study the impact of contextual variables on fiscal rules efficiency scores. In the first stage, we specify the DEA model to estimate the relative efficiency for each observed country in each year in the period from 2008

to 2016. After that, in the second stage, the efficiency scores are regressed on several contextual variables to observe the factors that explicate the variation in the DEA-efficiency.

Key words | *fiscal rules, efficiency, DEA, EU-28, contextual variables*

Ranking of DMUs using SBM Optimistic and Pessimistic DEA Models

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Abstract | The paper aims at the problem of ranking of efficient DMUs in DEA models. There were proposed various principles for this purposes by many researchers in the past. Super-efficiency models are one of the most popular tools for ranking of efficient DMUs. They are based on removing of the DMU under evaluation from the set of units and measuring a distance of this unit from the new efficient frontier. Andersen and Petersen radial model and Tone's super-efficiency SBM model are applied very often in various case studies but each of them has its advantages and disadvantages. The paper presents an original approach for ranking of (not only) efficient DMUs. The proposed SBM model uses goal programming methodology and minimizes either the sum of undesirable deviations or maximal undesirable deviation from the efficient frontier. Using this methodology the optimistic and pessimistic efficient frontier is constructed. The DMUs are ranked according to the measure that minimizes the distance from the optimistic efficient frontier and maximizes from the pessimistic frontier. The distance is measured using a metric with slack and surplus variables. The procedure generates a unique complete ranking of all DMUs. The results obtained by the presented procedure are compared with several super-efficiency models and other approaches for ranking DMUs. They are illustrated on a real data set - evaluation of 194 bank branches of one of the Czech commercial banks

Key words | *DEA, SBM models, efficiency, goal programming*

OR Theory and Application

Investigation of an Optimal Number of Clusters by the Adaptive EM Algorithm

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Abstract | This paper considers the investigation of an optimal number of clusters for datasets that are modeled as the Gaussian mixture. For that purpose, an adaptive method that is based on the modified Expectation Maximization (EM) algorithm is developed. The modification is conducted within the hidden variable of the standard EM algorithm. Assuming that data are multivariate normally distributed where each component of Gaussian mixture corresponds to one cluster, the modification is provided by utilizing the fact that the Mahalanobis distance of samples follows a Chi-square distribution. Besides, the quantity measure is constructed in order to determine number of clusters. The proposed method is presented in several numerical examples.

Key words | *clustering, EM, Gaussian mixture, Mahalanobis distance, Chi-square*

A Max Plus Algebra Approach for Generating Non-delay Schedule

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Abstract | Max-Plus Algebra is one of the promising mathematical approaches, that can be used for scheduling operations. It was already applied for Johnson's algorithm and cyclic job shop problem. In this article, Max-Plus algebra is used for generating Non-Delay schedule. When using Non-Delay schedule approach, in each step, task with earliest possible start is scheduled. If there is more than one task eligible for scheduling, we apply the priority (dispatching) rule, and in case of another tie, the tie-breaking rule is applied. We present simple step-by-step procedure for generating matrices of starting and finishing times of operations, using Max-Plus Algebra. We apply LRPT (Longest Remaining Processing Time) as priority rule and SPT (Shortest Processing Time) as tie-breaking rule.

Key words: *project scheduling, non-delay schedule, priority rules, Max-Plus Algebra*

Optimization of a Perishable Inventory System with Both Stochastic Demand and Supply: Comparison of Two Scenario Approaches

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Abstract | In this paper, we study a multi-period inventory model for a perishable product with both stochastic supply and demand in a rolling horizon framework. The product has a fixed shelf life such as fresh products, blood cells, chemicals, drugs and other pharmaceutical products. The objective is to minimize the expected total cost composed of ordering, purchasing, holding, shortage and waste costs. We focus on finding a high-quality solution close to the optimal solution of the model that provides decision support for decision-makers. We propose a stochastic programming model and transform it into a mixed integer linear programming (MILP) model based on Conditional Scenarios (CS) approach to reduce the computational burden. By comparing with the Sampling Approximation Approach (SAA) in a numerical study, we show that our method works efficiently.

Key words | *perishable product, inventory management, stochastic programming, optimization*

Use of Several Inequalities in the Comparison of Proportional Electoral Methods

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Abstract | Proportional seat allocation methods in electoral systems can give different results referring to the assignment of seats to the parties according to their votes (or to the districts or states according to their populations). We look at different proportional electoral methods. By using several inequalities, we obtain the conditions by which different proportional divisor methods give an equal assignment of seats. In order to illustrate these conditions, several numerical examples are used.

Key words | *proportional electoral system, seat assignment, divisor methods, quotient methods*

The Efficiency of 28 EU Member States in Travel and Tourism in 2017

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Abstract | In the last few decades growth of travel and tourism has surpassed all expectations, and it has transform from luxury to necessity. Given that, tourism has become one of the largest and labor most intense economic sectors which significantly contributes to GDP and employment of every country which manages it successfully. The goal of this paper is to measure the efficiency of 28 European Union member states in travel and tourism in year 2017. The efficiency of EU member states in travel and tourism has been measured by its influence on the GDP and employment using the non-parametric data envelopment analysis approach. As inputs were selected domestic tourism spending and visitor exports (foreign spending), while outputs were travel and tourism total contribution to GDP, and travel and tourism total contribution to employment. Observation period was year 2017. The results have been obtained using the software package DEA-Solver-Pro 7.0. The obtained results are presented, analysed, and interpreted showing the relative efficient and relatively inefficient member states.

Key words | *DEA, relative efficiency, travel and tourism, 28 EU member states*

**Dual Resources Constrained Flexible Job Shop
Scheduling Problem: Multi Objective Mathematical
Modeling and Solving Approach**

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Abstract | To coordinate with many practical production systems, in this paper we deal with representing both machines and workers on job shop capacity which is known as the dual-resources constrained (DRC) problem. The machinery are assumed to be multi-functional and consequently require multi skilled human resources. Such a system is called the dual-resources constrained flexible job-shop scheduling (DRCFJS) problem. We proposed a multi objective mix integer mathematical model for DRCFJS problem where the setup times are considered as sequence dependent. The objective of the model is to find the efficient assignment of operations to relative machines and also workers in order to optimize the three performance criteria such as makespan, machine workload and workers' idle cost. To solve the proposed model we utilized a reasonable heuristic method to generate the initial solutions. Then as the DRCFJS problem is NP-hard, a new efficient multi objective evolutionary algorithm namely, multi objective invasive weed optimization (MOIWO) is proposed and the numerical results are compared with NSGA-II and MOPSA (multi-objective parallel simulated annealing). Finally a multi attribute decision making method (AHP-TOPSIS) is implemented for analysis of solutions and prioritizing the algorithms' performance which implies the MOIWO supremacy in comparison with MOPSA and NSGA-II.

Key words | *dual-resources constrained flexible job-shop scheduling, multi-objective mathematical modeling, MOIWO, MOPSA, AHP-TOPSIS*

Grouping Products to Optimize the Production of Steel Coils

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Abstract | Manufacturing processes, in general, consist of three phases: 1) extraction of raw material, 2) conversion into industrial products (primary process), and 3) manufacture of final products (secondary process). Manufacturing of steel coils is an example of such a process. First, the raw materials (iron ore, and alloys such as manganese, silicon, carbon, aluminum, and niobium) are extracted. These minerals are combined to produce steel, which through continuous casting is shaped as steel slabs. A strip mill turns the slabs into cold roll coils. The optimization of a production process for products such as steel coil depends on the efficient utilization of the production facility and equipment. In particular, reducing the time to change from producing one product to another is critical to the fulfillment of demand at a minimum cost. We study the production of steel coils in the context of exploiting efficiencies from grouping products with similar characteristics. While it is simple to establish a one-to-one correspondence between an industrial and a final product, there are several advantages associated with producing in a setting where the relationship between industrial and final products is one-to-many. These

advantages include reduction of the labor needed to adjust the equipment, a decrease in the probability of personal injury or machine failure, and the simplification of inventory management along with the reduction of warehouse space needs. In order to create one-to-many mappings of industrial products to final products, it is necessary to create groups of final products based on a set of relevant attributes. For instance, in the manufacturing of steel coils, the relevant characteristics may be the width, weight, steel grade, and due date of each coil. We formulate the grouping problem as a mixed-integer program and develop a heuristic solution procedure. We show that a simplified version of the problem is equivalent to the clique partition problem, which in turn is equivalent to the graph-coloring problem. Our heuristic optimization is based on tabu search and is embedded in a multi-start framework. The procedure can be used to find solutions to the clique-partitioning problem and the original product-grouping problem that includes additional costs. Our computational testing includes comparisons with state-of-the-art solvers for the graph-coloring problem. We also compare against two commercial optimizers, CPLEX and LocalSolver. These computational experiments show that the heuristic procedure is effective in finding high-quality solutions to both the clique-partitioning problem and the original product-grouping problem that includes additional costs.

Key words | *product grouping, steel production, tabu search, graph coloring, partitioning*

A Decision Support Framework for Construction Logistics Using a Pickup and Delivery Model

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Abstract | We will overview some of the logistics activities of larger (typically at least 50 operators) construction companies. To find a relocation of non-self-propelled machines, we present a specific optimization procedure. The task is modelled as a variant of the so-called pickup and delivery problem. We describe our functional needs in relation to an application software. Such model of construction companies' activities is also justified by the following facts: (a) the activities and locations of the resources of the investigated companies are constantly changing, (b) the individual construction companies often cooperate with each other and work side-by-side on the same project, (c) a comprehensive examination of supply chains is required. Online team work can be effectively supported by SMART technologies.

Key words | *logistic, optimization, pickup and delivery problem*

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Identifying Challenges and Priorities for Developing Smart City Initiatives and Applications

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Abstract | By popularizing the concept of smart cities, information services/systems in G2C and C2G environments are getting radically altered. The ubiquity of the technology and the availability of (open) data automatically collected in urban environments generate new opportunities not only in tracking and managing public information services and resources, but also in the way we describe, implement and use these services. In an exhaustive report from June 2018 titled “Smart cities: digital solutions for a more livable future”, the authors analyze about 60 different smart city applications implemented worldwide and demonstrate that cities could use them to improve some quality-of-life indicators by as much as 10-30 percent. The report also elaborates on why even the cities that implement cutting-edge smart technologies are still at the beginning of their journey in some aspects. It provided us with a suitable research framework that we amended and operationalized within the scope of a scientific project “User-oriented process (re)design and information systems modelling - a case of smart city services”. In an effort to identify and explore the challenges and the potential for the implementation of the aforementioned smart city applications

in national/local contexts, we have conducted a workshop and a research survey. The results of the survey will inform the subsequent project phases aiming to develop new conceptual, experimental and creative models of smart city services/applications that would be scientifically and practically validated with relevant stakeholders based on the quadruple-helix model in a specific context. For this reason, three different groups of survey respondents ($N > 60$) with a keen interest in smart cities helped us to identify the most important short-, medium-, and long-term challenges (e.g. community engagement, digital divide and so on) for smart city initiatives in Croatia and to assess the potential and priorities for introducing the innovative smart city applications (under eight different categories: engagement and community, economic development and housing, energy, waste, water, mobility, security, and healthcare) in a city within the next five-year period. The results are efficiently visualized using modern business analytics tools.

Key words | *smart city, smart city applications, smart city challenges*

New Formulations for College Admission Problem with Common Quotas

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Abstract | College admission problem is a well-known and well-studied problem in operations research. College admission problems are usually solved by (Gale-Shapley) deferred acceptance algorithms. In national systems many special features appear which make it impossible to use this algorithm. Such a feature is the existence of common quotas in Hungarian higher education matching scheme. In this scheme two kind of programs appear: state financed and privately financed. Universities give quotas for the aggregate number of state and privately financed students, while the government has preferences over the number of state financed students. We present a new integer programming

formulation for college admission problem with common quotas. We tested this new IP formulation on real data, which contains about 300,000 applications, and we were able to solve the problem for this special feature of the Hungarian higher education college admission problem.

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

Linear Algorithms on Cactus Graphs

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Abstract | A natural generalization of trees are cactus graphs. Cactus are graphs in which every edge lies on at most one cycle. Many intractable problems on graphs that can be solved efficiently on trees can be also solved efficiently on cacti. Examples include a number of varieties of domination problem, including weighted domination and Weighted Independent k -domination, fair domination number. Another example is computation of the Hosoya-Wiener polynomial. A general framework was recently developed and a natural question is can we nicely say which problem scan be solved by this approach in linear time ? I will discuss the question and provide new examples.

This is joint work with Tina Novak and Darja Rupnik Poklukar.

Key words | *graph theory, discrete optimization, domination, Hosoya-Wiener polynomial*

Discrete Simulation Modelling as a Base for Decision Making in the Context of Smart Cities

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Abstract | For over a decade now, the concept of a smart city has been a popular and well-researched area. All definitions of a smart city put focus on technology as a driver and a prerequisite, but include aspects of socio-economic, managerial and multi-stakeholder approaches. The focus on citizen engagement and development of e-government services and the use of open data for creating services for citizens contributes to the increasing quality of life and thereby contributes to the achievement of strategy goals of the cities. However, as city planners and managers are faced with major changes and challenges arising from global shifts in the environment, rapid urbanization, as well as fast technical developments - the (strategic) decisions they have to make are becoming increasingly complex. Specifically, the continuous urbanization and technological advancement forces city planners to be more creative and supported by approaches that enable an abstract perspective on the complex reality as some studies have shown. The need to plan integral systems that can process massive amounts of data (for services such as smart parking, smart mobility provision, real-time monitoring, or citizen safety/security management);

the great availability of different commercial ICT solutions; and the need for devising new business models and services pose a real challenge. The described context is an ideal one for using concepts, models and tools from (discrete) simulation domain. The paper systematically reviews relevant studies where discrete event simulation has been used to support the design of the enabling ICT infrastructure for smart cities, either as a tool to predict the impact on user behaviors for the purpose of improving (key) urban business processes or to devise complex what-if scenarios related to present-day smart city challenges. Following the literature review, the studies are mapped to eight different categories (engagement and community, economic development and housing, energy, waste, water, mobility, security, and healthcare) followed by the discussion and identification of the promising scenarios for decision making in these specific areas.

Key words | *discrete simulation modelling, smart cities*

Clustering Hungarian Counties According to their Mortality Profile

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Abstract | For insurance companies and annuity providers it is necessary to make homogeneous risk groups to their life insurance products. In survival analysis many methods are available to decide whether two population have the same risk profile or not, but application of cluster analysis is less frequent. In the literature many clustering algorithms are available, but using them in survival analysis is not straightforward, mainly because we cannot use the crude data. We investigate how to aggregate the data, and how we can use clustering algorithms on the aggregated data. We also investigate the differences between the results of different cluster analysis techniques. We present a numerical example for Hungarian counties.

Key words | *survival analysis, cluster analysis, risk assessment*

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Joint Optimization of Transition Rules and Premiums in a Bonus-Malus System

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Abstract | Bonus-Malus systems are widely used methods in actuarial sciences that are applied to distinguish the policyholders by their risks. In a Bonus-Malus system there are several classes and the classification of the policyholders depends on the class in the previous period and the number of claims reported in the present period. Operating such a system one needs to set somehow the transition rules and premiums of each classes. In general, optimization of these systems usually means to calculate appropriate premium scales considering transition rules as outer parameter. We present a mixed integer programming formulation for determining jointly the premium scales with the transition rules for a given set of policyholders. Furthermore, we present numerical examples to demonstrate that this IP technique is suitable to handle existing Bonus-Malus systems.

Key words | *integer programming, insurance pricing, adverse selection*

Generating Sufficient Matrices

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Abstract | The class of sufficient matrices (SU) has a strong connection with the linear complementarity problem (LCP) as it was proven that SU-LCPs can be solved in polynomial time. Many different interior point algorithms (IPA) have been published for SU-LCPs, but in most cases there is no numerical examination of the IPAs. Main reason for this lies in the fact that only few SU matrices are known that does not fall into the classes of PSD- and P-matrices. Our goal is to generate different SU matrices (that does not belong to the classes of PSD and P) and test problems on which the different IPAs can be tested, so the results can be compared. We present preliminary result of our work, namely some recently constructed SU matrices.

Key words | *sufficient matrices, interior point algorithms*

Adaptive Predictor-corrector Interior-point Algorithm Based on a Transformation of the Central Path

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Abstract | Predictor-corrector (PC) interior-point algorithms (IPAs) are one of the most efficient methods for solving different types of optimization problems. Some PC IPAs can be generalized to linear complementarity problems (LCPs) as well. In order to approach optimality we use a predictor step, but as side-effect the distance of the obtained iterates from the central path increases. Therefore, we need a corrector step to ensure that the new points become sufficiently close to the central path. Some variants of the PC method are characterized by the fact that the length of the predictor step is the same for all iterations of the algorithm. Moreover, the barrier update parameter is reduced by a constant factor. However, we can observe that in practical implementations these restrictions are not effective. Therefore, in this talk we consider special PC algorithms, where the barrier update parameter and the length of the predictor step are changed adaptively. The diversity of PC algorithms is achieved by considering different search directions in order to calculate the new iterates. An important class of directions can be obtained by applying an algebraic equivalent transformation to the central path, and using Newton's method. We follow this approach and we present a new adaptive PC algorithm for LCPs. We analyse this method and we prove its polynomial complexity. Furthermore, we discuss also the possibility of generalizing the method to symmetric cone optimization problems.

Key words | *interior-point algorithm, predictor-corrector method, algebraic equivalent transformation, linear complementarity problem, symmetric cone optimization*

Young Programming and its Solution Methods

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Abstract | Young programming is a convex optimization problem class introduced by Klafszky and Kas (1997). They used it as approximation of linear programming problem. The duality theory of Young programming also has been formulated by Klafszky and Kas. Numerous interesting applications were shown by Levente Mályusz in his PhD dissertation (1998). The first algorithm for Young programming was a row-action method developed originally by Csiszár (1993). Convergence of the row action method for Young programming has been discussed. Boratas et al. (2002) examined the problem in the view of self-concordance theory and showed that for some type of Young programming problems the usual barrier functions do not possess the self-concordant property. In this talk, we will revisit the solvability of the problem, present a modified convergence proof of the row action algorithm and present our new results.

Key words | *Young programming, structured convex optimization, algorithms*

New Algebraic Equivalent Transformation for a Predictor-corrector Interior-point Algorithm

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Abstract | In this talk we deal with predictor-corrector (PC) interior-point algorithms (IPAs) for sufficient linear complementarity problems (LCPs). It is well-known that by applying the algebraic equivalent transformation (AET) on the system which defines the central path different search directions for IPAs can be obtained. The PC IPAs use two types of steps, the affine-scaling one is responsible for getting closer to the optimal solution, and the purpose of the corrector one is to return in a proper neighbourhood of the central path. The AET method determines a class of search directions. However, in case of PC IPAs, using the AET technique, this decomposition into an affine-scaling and a corrector step can cause difficulties. In spite of this fact, we solved this problem in the case of a specific direction, obtained by the AET method. This led to a new PC IPA for sufficient LCPs. We also present the analysis of the proposed

algorithm and we prove that the introduced PC IPA provides an approximate solution in polynomial time in the handicap of the problem's matrix, the size of the problem, and the bit size of the data. Furthermore, we give a unification of the Newton-systems and scaled systems in case of PC IPAs for sufficient LCPs. Finally, we present some preliminary numerical results of the new PC IPA and compare it with some other PC IPA variants.

Key words | *sufficient linear complementarity problems, interior-point algorithm, predictor-corrector algorithm, algebraic equivalent transformation, polynomial complexity*

On the Existence of the Nonlinear Weighted Least Squares Estimate for the Shifted Power Law

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Abstract | The shifted power law $f(t; a, b, c) = a(t + b)^c$, where a , b and c are unknown parameters, has applications in numerous fields, including engineering, e-commerce, agronomy, informetrics, psychology and medicine. In practice, the unknown parameters must be estimated from the data (w_i, t_i, y_i) , $i = 1, \dots, n$, where t_i denote the values of the independent variable, y_i are observed values and $w_i > 0$ are data weights which describe the assumed relative accuracy of the data. One of the standard and widely used approach for parameter estimation is the method of least squares. In this paper we consider the problem of the existence of the best nonlinear least squares estimate (LSE) for the shifted power law. We show that it is possible that the least squares estimate does not exist. Necessary and sufficient conditions which guarantee the existence of the least squares estimate are obtained. Generalization in the l_p norm ($1 \leq p < \infty$) and some illustrative examples are also given. Some choices for an initial approximation are discussed.

Key words | *shifted power law, nonlinear least squares, parameter Estimation, existence problem, data fitting*

Future of Bitcoin Mining: A Game Theoretic Analysis**RAJANI SINGH**

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Abstract | Bitcoin is a decentralized cryptocurrency payment system, work without single administrator or a third party bank. A fixed amount of bitcoin is mined with the creation of each block in blockchain which is created by miners, using complex mathematical “proof of work” procedure by computing hashes. For each successful attempt, miners get rewards in terms of bitcoins and transaction fee. Miners participate in mining to get this reward of mining as income. Mining of cryptocurrency such as bitcoin becomes a common interest among the miners as the bitcoin market value is very high and the reward of mining is sufficiently large. On the other hand there is substantial cost of bitcoin mining. Bitcoin is a non-renewable resource, moreover the reward of mining a bitcoin decreases every four year by half so, an obvious question arises that what will be the incentive for miners in the bitcoin mining over time and how to maintain the balance in bitcoin mining market as time goes on. From the fact that at any time instant only one miner will be rewarded (the one who will win the mining game by first creating and updating the blocks and the remaining miners effort will be waste at that time), it is better for them to mine strategically. However this strategy could be any plan of action designed

to achieve a goal or objective, either *Cooperative*: where all the miners jointly maximize their total payoff or *Non-Cooperative*: where all miners individually mines the bitcoin and behave selfishly. Note that in our game theory model a player or miner represent a single “miner” or a single “mining pool” who is responsible to create a block in block chain. Therefore, in this paper we create a *linear quadratic dynamic game model* of bitcoin mining where we consider bitcoin mining as a continuous time dynamic game which is played over infinite time horizon. We assume that the current payoff is of quadratic form while the behavior dynamics of the bitcoin is linear in state variable. We investigate two different ways to solve our model: *Social optimum* — the miners play cooperative game and *Nash equilibrium* — the miners play non-cooperative game. We found that the bitcoin is never sustainable and depleted very fast for the Nash equilibrium even if it is sustainable for the social optimum. Our result is quite intuitive to the common belief that mining in cooperation will give the higher payoff than mining individually. Also, to retain the bitcoin market at equilibrium we propose a tax system which is of Pigovian type in order to enforce social optimality in our bitcoin model.

Key words | *bitcoin mining, dynamic game theory, Hamilton-Jacobi-Bellman equation, social optimum, Nash equilibrium, Pigovian tax*

The Application of Linear Programming to Employee Scheduling

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Abstract | Working in shifts is a must requirement for many companies and business who wish to optimize their work output and productivity or to provide a full coverage of their services. It is not limited to the manufacturing world, but also to many other fields such as healthcare, tourism and catering industry, law enforcement, fire stations, transportation, customer service call centers, retail, grocery stores and many others. Given the fact that working in shifts has significant health, cognitive and safety effects, as well as the fact that a significant percentage of the total workforce work in shift (e.g. some 15% of full-time wage and salary workers in the U.S. work in shifts), it is very important to create good shift schedules. In this paper we present the case study of a huge international company. We consider the problem of employee scheduling of one of its departments. Besides the full time employees, the department also hires the part-time employees as well as students. We present all of their requirements in creating the shift schedule and develop the linear programming model for its solution. Finally, we present the results and compare the solution obtained to the existing manual solution and study the improvements.

Key words | *employee scheduling, linear programming, working in shifts*

Using a Mathematical Model to Improve the Copper Mining Processing at the Mining National Company of Chile

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Abstract | This paper presents a linear programming model used for decision making in the mining process of copper concentration from sulphide minerals. The developed model allows to the decision maker to select the types of ore to be used in the mix in order to maximize the metallurgical recovery and the copper grade at the end of the process. The model corresponds to the mixture model of minerals to which economic variables such as processing costs, electric power, maintenance have been added. The process has four sub-processes that are crushing the ore, crushing the crushed ore, flotation of the ground ore to obtain copper concentrate and drying in which the water is extracted. The model uses a set of variables whose size varies according to the number of lots of minerals and the number of planning days considered. The model can be considered a big size problem when a long time of time is planned, but only

has been implemented with 3.000 variables and 2.000 constraints. The model developed is being implemented in the National mining company, which buys ore from small producers, to produce copper concentrate and then melt and refine it to obtain high grade copper. The generated model produces saving of the order of thousand dollars per day, when compared to the current methods of allocating minerals, which represents millions dollar by year. It also produces a benefit due to the fact that lower operating costs are obtained, whose savings are of the order of 5% of the current cost, whose exact amount has not yet been obtained.

Key words | *linear programming, mining, productivity*

Discontinuous Nash Equilibria in a Two Stage Linear-Quadratic Dynamic Game with Linear Constraints

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Abstract | In this paper, we study a simple example of a two-stage linear-quadratic dynamic game in which presence of simple linear state dependent constraints results in non-existence of continuous symmetric feedback Nash equilibria and existence of continuum of discontinuous symmetric feedback Nash equilibria. The example is not an abstract model; it has obvious applications in economics of resource extraction. Dynamic games are the only appropriate tool to model decision making by independent but coupled agents in an external environment changing in response to their decisions. In dynamic games; at least two simultaneous dynamic optimization problems in which each of the decision makers best responds to the choice of their opponents, are much more compound than analogous single agent dynamic optimization problems. From a mathematical point of view, finding a Nash equilibrium in a dynamic game requires finding a fixed point, in a functional space, of a multivalued correspondence defined by solving a set of coupled dynamic optimization problems. Linear quadratic (LQ) dynamic games, formulated in both discrete and continuous time, are the best researched class of nonzero-sum dynamic games. This class of dynamic games is very important because of their potential applicability in modeling decision making in real life problems and solutions can be found more easily than in the other nonlinear games. In standard LQ dynamic games, there are no constraints. On the other hand,

constraints play an important role in a vast majority of real life applications. For example, state variables like the biomass of fish in games of exploitation of fisheries, the state of physical capital in economic problems or the stock of pollutant in pollution games are always non-negative. Control variables in the corresponding problems like the catch, the production or the emission of pollutant, respectively, are also non-negative, while in the first case, also a constraint by the amount of biomass available has to be taken into account. The number of papers in which constraints, especially state dependent constraints which may be active at equilibrium, are considered, is small. We present an example of a symmetric deterministic LQ dynamic game with concave payoff but no continuous obviously, we consider the continuity with respect to the state variable, symmetric feedback Nash equilibrium and a continuum of discontinuous symmetric feedback Nash equilibria.

Key words | *linear quadratic dynamic game, discrete time, Nash equilibrium, state dependent constraints, common renewable resources, Bellman equation*

Mathematical Programing

The Worst Case Finite Optimal Value in Interval Linear Programming

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Abstract | We consider a linear programming problem, in which possibly all coefficients are subject to uncertainty in the form of deterministic intervals. Each coefficient can gain an arbitrary value from its interval domain, independently to other coefficients. The problem of computing the worst case optimal value has already been thoroughly investigated, and there are known basic facts about its characterization, computational complexity, approximation etc. Nevertheless, the worst case optimal value can be infinite due to infeasibility of some instances. This is a serious drawback if we know a priori that all instances should be feasible; this is the case, for instance, in the classical transportation problem. Therefore we focus on the feasible instances only and study the problem of computing the worst case finite optimal value. We present a characterization for the general case and investigate special cases, too. We show that the problem is easy to solve provided interval uncertainty affects the objective function only, but the problem becomes intractable in case of intervals in the right-hand side of the constraints. We also propose a finite reduction based on inspecting candidate bases. We show that processing a given basis is still an NP-hard problem even with non-interval constraint matrix, however, the problem becomes tractable as long as uncertain coefficients are situated either in the objective function or in the right-hand side.

Key words | *linear programming, interval analysis, worst case, uncertainty, NP-hardness*

Robust Emergency System Design Using Reengineering Approach

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Abstract | A robust emergency service system is usually designed so that the deployment of given number of service centers minimizes the maximal value of objective functions corresponding with the specified detrimental scenarios. If the problem is solved by any solving technique based on the branch-and-bound method, the min-max link-up constraints cause bad convergence of the associated computational process. Within this paper, we try to overcome the drawback following from the link-up constraints by usage of an iterative process applied to a series of surrogate problems. The surrogate problems represent a simple emergency system reengineering under a given scenario and chosen values of reengineering parameters. The results of the surrogate problems are used for considerable reduction of the initial set of possible service center locations. The robust emergency service system is obtained as the optimal solution of the reduced problem. We provide the reader with a comparison of the original min-max problem solution to the suggested approach.

Key words | *robust emergency system design, detrimental scenarios, reengineering approach*

Kernel-like Search for Robust Emergency System Designing

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Abstract | Emergency service system, which satisfies randomly emerging demands of public for necessary treatment, is determined by deployment of limited number of service centers at positions from a given set of possible locations. The objective is to minimize average response time of the nearest ambulance vehicle usually located at a service center. The robust service system is designed to comply with specified scenarios by minimizing the maximal value of the above mentioned objective functions corresponding to the particular scenarios, which represent consequences of random failures in the road network. The detrimental events may correspond to congestion, disruptions or blockages of roads. The robust emergency system design problem can be modelled by means of mathematical programming. The model includes scenarios and the associated link-up constraints, which connect average response time connected with individual scenarios to the general objective function, which is maximum of these objective functions. The min-max link-up constraints and the cardinality of the scenario set represent an undesirable burden in any solving process used for design solution. Within this paper, we present a kernel-like search algorithm, which tries to replace a solving process of the huge problem above by a series of smaller problems, which deal with either small subset of scenarios or reduced set of possible center locations.

Key words | *kernel-like search, robust emergency system design, detrimental Scenarios*

The Best and the Worst: Computing the Optimal Value Range in Interval Linear Programming

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Abstract | Optimization under uncertainty plays an important role in solving real-world problems coming from various areas of operations research. One of the various approaches to handling uncertainty is presented by interval optimization. In a model of interval optimization, it is assumed that the input data of the optimization problem can be perturbed independently within given lower and upper bounds. Our talk is devoted to the problem of computing optimal values of the objective function in interval linear programming. Since an interval program represents an entire family of classical optimization problems (scenarios), the aim is usually to describe the set of optimal values across all possible scenarios or to find the tightest interval enclosing this set. Such interval, known as the optimal value range, is determined by the optimal values corresponding to the best-case and the worst-case scenario. First, we will review

the results providing formulas and methods for computing the optimal value range of an interval linear program exactly. For some special classes of problems, for example for programs with variables restricted to a single orthant, both of these extremal values can be found in polynomial time. However, for general interval linear programs, finding the exact bounds of the optimal value range can be computationally challenging. Therefore, fast algorithms for computing a sufficiently tight approximation of the best-case and worst-case optimal values are of interest. In this talk, we will present several different ways of designing an algorithm for approximating the extremal optimal values, such as iterative improvement techniques or convex relaxations. We will compare the resulting algorithms to evaluate the quality of the obtained approximation with respect to the required computation time and illustrate their respective strengths and weaknesses.

Key words | *interval Optimization, linear programming, optimal Value range*

A Stochastic Programming Based Multi Objective Modelling Approach to Configure Sustainable Logistics and Transportation Networks

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Abstract | Due to the increasing number of large scale systems that require enhanced logistics operations and long distance transportation, efficient optimization procedures should be developed for design and management of reliable logistics systems that materials are transported by a combination of different transportation modes. The high costs of logistics operations and significant amount of atmospheric emissions caused by transportation activities lead to a debate about the environmental and economic sustainability of logistics systems. Hence, sustainable logistics and transportation systems should be designed considering the trade-offs between costs, environmental impacts and service quality. In addition, uncertainties related to demand, prices and resource supply should be captured in design phase. Co-modal transportation benefits from utilizing the most appropriate transportation mode or combination of modes to increase productivity and decrease environmental impacts. In this study, a stochastic programming based multi objective modelling approach is developed to optimize logistics and transportation networks for materials transportation considering co-modality principles. Economic, environmental and service quality objectives are considered by the approach, of which applicability is illustrated by a case study conducted in Aegean region, Turkey.

Key words | *logistics system design, mathematical modelling, stochastic modelling, multi Objective optimization*

Optimizing the Number of Teaching and Researching Staff within Croatian Higher Education System

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Abstract | Human resources represent crucial resource and capital for any organization's success, because they generate knowledge, skills, abilities and experience which distinguish organizations and emphasize their competitive advantage. Nowadays, managers are struggling in with their competition in order to maximize performance results and other positive effects obtained by their crucial resource and in the same time minimizing production costs and other belonging losses. Although, higher education does not represent production in the true sense of the word, management leads the same battle, related to faculty teaching and researching staff workload, set goals and various constrains, especially costs. The main aim of this paper is optimization of human resource allocation within Croatian higher education system. It will be done according to several constraints, related to their teaching and researching staff workload, minimizing deviation from set goals defined according to Croatian higher education regulation system and available financial resources. Presented model for human resource allocation in higher education system considers different constrains, such as: total number of teaching hours per employee at given

position, total number of final and master thesis per employee, total number of students at the institution, different teaching and researching positions within each department (junior researcher, postdoctoral researcher, assistant professor, associate professor, full professor and lecturer) as well as annual gross salary per employee. The paper suggests usage of integer goal programming model in order to find optimal solution presented with the number of teachers and researchers within each department of chosen faculty. The model will be applied on the example of Croatian faculty, due to certain specificities of Croatian higher education system and will be applicable to any other Croatian faculty. Different optimal model solutions, obtained for different number of constraints, will be compared within the paper. This model will secure optimal level of teaching and researching positions, considering multiple goals, with the emphasize of evolution and progression on individual level, simultaneously providing the best quality for students, as well as competitive and profitable work of the institution.

Key words | *higher educational system, human resource planning, mixed-integer goal programming model*

Location-Scheduling Approach to the Electric Buses Charging Infrastructure Design in Urban Areas

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Abstract | Transportation has major influence on greenhouse gasses production with 23% share on global CO₂ emissions. Reduction of emissions and associated costs can be achieved by the support of public transport and alternative fuels such as electric buses. Nowadays, there are a lot of charging technologies and several types of electric buses. Major limitation of current electric buses is mostly in their driving range that is much smaller in comparison to the fuel buses. This problem can be solved by continuous charging during breaks between connections on the line during the day or by overnight charging in the depot. In our contribution we propose an optimization approach to design a charging infrastructure for a fleet of electric buses in urban areas with the respect to current schedules of the vehicles that have to be fulfilled. We are dealing with the location of the charging stations for continuous charging of electric buses in the terminal stops of the lines or overnight charging in the depots. Each charging station can have more charging points to provide charging for several buses in the same time. Charging stations can also use different charging technologies and various charging speeds. We formulate a mathematical model that combines location and scheduling decisions to ensure that requirements of electric buses can be satisfied. We validate our approach by applying it to data from the local public transport operator in the Zilina municipality (DPMZ company). To test proposed model we have created a number of scenarios that differ by the consumption of electricity during various

seasons of the year. Proposed mathematical model and scenarios are solved using IP solver Xpress. Our results indicate that our approach can be used to estimate the minimal requirements to set up the charging infrastructure for electric buses in the public transport of urban areas.

Key words | *location problem, electric buses, charging stations, scheduling, IP Solver*

When High-Performance Computing Meets Combinatorial Optimization

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Abstract | Over the past decades a vast number of algorithms have been proposed to solve problems in combinatorial optimization either approximately or up to optimality. But despite the availability of high-performance infrastructure in recent years only a small number of these algorithms have been considered from the standpoint of parallel computation. We present new method for solving specific NP-hard combinatorial optimization problem that combines techniques from semidefinite optimization and efficient implementation using high-performance computing. We will review the most important aspects of the Branch-and-Bound scheme and present a method for finding exact solutions of Stable Set problem, the problem of finding the independent set in the graph with the maximum cardinality. We use parallel Branch-and-Bound algorithm that applies exact-subgraph constraints to efficiently approximate original problem using semidefinite relaxations. Depending on the sparsity of the graph combination of two SDP solvers is used to compute solutions of the obtained relaxations. The result is the new open-source high-performance solver BiqBin. Preliminary computational results show that the proposed algorithm outperforms other algorithms in speed and in size of the instances that can now be solved in a routine way.

Key words | *semidefinite programming, stable set problem, high-performance computing, parallel branch-and-bound*

Efficiency and Productivity Analysis of Turkish Electricity Distribution Companies with Data Envelopment Analysis

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Abstract | With the enactment of Electricity Market Law No 4628, a new era based on liberalization and privatization has started in Turkish electricity market. In this context, while the production, wholesale, and retail parts of electricity market has been opened for competition, transmission and distribution, which have natural monopoly characteristics, has been subjected to regulation. This study analyzes the relative performance of 21 electricity distribution companies by using a non-parametric method, Data Envelopment Analysis. The results obtained are used to choose the most suitable model specification, to determine the factors affecting the efficiency levels and to find out by far the most inefficient companies??? common characteristics. From the results, it has been concluded that large companies compared to small ones and the companies operating in more developed areas compared to ones operating in underdeveloped areas utilize resources and manage costs more efficiently. Then, when trying to detect the common characteristics of the most inefficient companies, the major problem is found to be the low volume of energy delivery and low customer number. If these companies increase the delivery amount and the customer number by merging, their inefficiency problem would decrease considerably. Lastly, companies??? total factor productivity changes are accounted and found out that their productivity decreased over time. Low efficiency levels and not operating at the optimum scale has been determined as fundamental reasons for this total factor productivity decrease.

Key words | *DEA, efficiency, total factor productivity, electricity distribution*

Solving Profit Maximization Problems using Geometric Programming

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Abstract | Profit maximization is one of the most important (micro)economic problems and therefore it is of great importance to understand the problem itself, the solution procedure as well as the solution itself. In the relevant literature there are several solution procedures for the problem in question. The basic solution procedure is based on differential calculus used to solve optimization problems with or without constraints. Hereby for optimization problems with constraints we have substitution method and Lagrange multiplier method. However, there is also a more elegant way to solve the profit maximization problem, which does not involve differential calculus whose application is nontrivial. It involves the use of geometric programming. There are many papers which emphasize the strength of techniques of geometric programming in solving the problem in question, as well as in solving the wider class of problems. However, one should be careful when applying geometric programming, especially on of its parts called signomial programming. In the existing literature there are some explanations on how to solve certain profit maximization problems by using signomial programming. Nevertheless, it has not been proved that solutions obtained in this way are indeed (global) optimum. Therefore, the aim of this paper is to pinpoint the shortcomings of signomial programming approach and its application, as well as to highlight the advantages of geometric programming approach on selected examples of profit maximization. We transform the chosen profit maximization problems

into equivalent problems that can be solved directly by applying geometric programming. In this way, we derive the solutions for which we know for sure that they are (global) optima, which is not the case with the application of signomial programming. To the best of our knowledge, this is the first time that the problem of profit maximization has been solved by transforming it into equivalent problem suitable for application of geometric programming.

Key words | *long-run and short-run profit maximization, Cobb-Douglas production function, signomial geometric programming, geometric programming*

**A New Predictor-corrector Interior-point Algorithm for
Linear Optimization Problem Based on a New Darvay
Search Direction**

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Abstract | We introduce a predictor-corrector interior-point algorithm (PC IPA) for solving linear optimization (LO) problems which is based on a new search direction. We use the algebraic equivalent transformation (AET) of the system which defines the central path and we apply the difference of the identity map and the square root function to this system. After that we use Newton's method in order to obtain the new search directions. Moreover, we

prove the polynomial complexity of the proposed predictor-corrector algorithm. This is the first predictor-corrector interior-point algorithm which is based on the above mentioned search direction. Finally, we present some preliminary numerical results of the new PC IPA for LO problems.

Key words | *linear programming, interior-point algorithm, predictor-corrector algorithm, algebraic equivalent transformation, polynomial complexity*

Multi-objective Programming Methodology for Solving Economic Diplomacy Resource Allocation Problem

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Abstract | In contemporary business circumstances, there are many well-known characteristics such as globalization, computerization, interconnectedness, etc. which any country in the world cannot neglect. Mentioned characteristics have to be considered if a country wants to achieve higher rates of economic growth, what is one of the most important economic goals of every country in the world. All mentioned has to be considering in terms of economic diplomacy. Economic diplomacy is an unavoidable precondition for fulfilling the mentioned goal. That puts economic diplomacy for a very significant problem and the reason for the scientific investigation. According to that, this paper gives the first step in that direction especially because of a lack of literature in the field. Actually, there is no scientific papers connecting the economic diplomacy and the multi-objective programming methodology. Focus in this paper is on clear exposition and explanation of multi-objective programming methodology and their connection with the economic diplomacy. Moreover, that means construction of a model that gives funds allocation optimization for economic diplomacy costs. Model uses multi-objective programming methodology and takes into account all

economic diplomacy funding determinants. The model defines measurements of criteria, budget limitation, efficiency maximization, and location. After an introduction, the structure of the paper consists of a theoretical review of multi-objective programming methodology and a brief overview of the main determinants and conceptual framework of economic diplomacy. The third part of the paper gives a model of multi-objective programming methodology applied to economic diplomacy efficiency. The main contribution of the fourth part is visible in the concrete theoretical example of a suggested model in the previous part of the research. The conclusion takes into account all research results with its limitations and recommendations.

Key words | *economic diplomacy, resource allocation, multi objective programming*

Multicriteria Decision Making

Deep Reinforcement Learning for Dynamic Multi-objective Optimization

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Abstract | Implementation of drugs always requires an optimisation scheme. Most of the cases this optimization deals with multi-objective criteria. To handle the conflicting objectives such as for a cancer patients, it is always desirable that there should be minimum side effects compare to healing with less time. The most common approach to solve this problem is evolutionary approach. On the other hand, after the breakthrough of the Mnih et al. in 2015, deep reinforcement learning has become an emerging and promising area that needs to be properly explored to identify the applicability and significance in health domain. In addition, deep reinforcement learning has harnessed its applications in different domains including finance, video games, portfolio optimisation, computer vision and health sector. In this study, we discuss the applicability of multi-objective optimisation in a Multi-objective Markov decision process (MOMDP). Our proposed algorithm can effectively handle many objective especially conflicting objectives using a novel approach named object relational mapping (ORM). This process helps the agent to balance the different Q points in a deep Q network and determine the highest expected reward in a deep neural network. The other important feature for the proposed algorithm is to govern the policy which requires to correlate the policies and find the best

optimum policy. Thus, the agent learns the environment in the less elapsed time. Our proposed algorithm outperforms other multi-policy algorithms. This research work can be enhanced in the context of Drug optimisation/Dose optimisation/ Side-effect optimisation/Prescription optimisation/Drug-Drug interaction optimisation where the dynamic multi-objective optimisation is needed due to the changing parameters over the time.

Key words | *multi objective optimization, deep reinforcement learning, machine learning, dynamic environment*

Weights of Importance of Decision Makers in Analytic Hierarchy Process

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Abstract | The complexity of socioeconomic environments demands inclusion of a group of decision makers (experts, stakeholders) into the decision making process. They could provide the variety of knowledge, experiences and perceptions that enable the consideration of all important aspects of the decision problem. The group decision making process requires to aggregate individual preferences into collective preferences. In the aggregating process, the weights of importance of decision makers play an important role. Decision makers are not necessary equally important because of their different hierarchical ranks, knowledge, accomplishments. Two main approaches to assign the weights to decision makers are known from the literature. The first possibility is that the leader of the decision making process or the decision makers themselves allot the weights of importance in the stage of the problem definition and model formation prior the start of the evaluation phase. The second option is that the weights of importance are assigned to the decision makers based on their preferences and their compatibility or closeness to the other decision makers. In the paper, we focus on the analytic hierarchy process, as one of the most known multi-criteria decision making method and discuss the two options of assigning weights of importance. For the second approach, we present a new projection method that is adapted from TOPSIS. We demonstrate its employment in a case study.

Key words | *AHP, group decision making, weights, projection method*

A Hybrid AHP-ISM Method for Analyzing Passenger Preferences on a Public Transport Development Decision

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Abstract | Involving passengers in a public system development decision has become a major issue recently. However, this decision is so complex that an appropriate methodology has to be created in order to support public participants in expressing their preferences. Within the wide range of MCDM techniques, AHP is often selected for this purpose due to its simplicity and consistency with the condition of independency of the decision elements. ANP is often applied in case of the interdependency of the decision elements but offended for its complexity. This paper aims to combine AHP with ISM technique for supporting public decision makers maintaining the advantages of AHP and amending it with the consideration of element interdependency. The application of the created model is also introduced on the problem of developing a public transport system in Mersin, Turkey.

Key words | *AHP, interpretive structural modelling, public transport, public preferences*

Acknowledgment | This research has been supported by NKFIH (Project No. K124644)

**Prioritization of BSC Strategic Goals of Higher
Education Institutions using the AHP, ANP and
PageRank Centrality**

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Abstract | Strategic planning using the balanced scorecard (BSC) is a standard activity in many higher education institutions (HEIs). In BSC, goals are deployed into BSC perspectives. In non-profit HEIs, those perspectives are (from bottom to top): the finance perspective, the learning and growth perspective, the internal processes perspective, the customer perspective, and the mission perspective. In terms of for-profit HEIs (e.g. private universities), the finance perspective is at the top of the map (rather than the mission perspective). In the current literature, we can also find totally new BSC perspectives that are adjusted to the particular HEI's needs. Nevertheless, when a HEI's administration selects a specific, strategic map design, they place strategic goals into the map and connect them with respect to the existence of the influences between goals. In theory, a goal from a particular perspective can influence any other goal from the same perspective, as well as any goal from any other perspective that is above its perspective. Following the creation of the strategic map of goals, there is often a request to prioritize goals within the strategic map to

determine the most crucial goals. In this paper, we present several possible means of prioritizing BSC goals. Three of them are the direct applications of three specific methods: the analytic hierarchy process (AHP), the analytic network process (ANP), and the PageRank centrality. Additionally, we propose the use of an integrated approach of two of them. The main disadvantage of applying the AHP is that influences between goals are generally not included in the goals' priorities calculations. The main disadvantage of the ANP is that many BSC goals will weigh 0.0, because the graph that is associated with the BSC strategic map of goals is almost always reducible. This issue can be solved through the application of the PageRank centrality. The use of this method ensures that the original BSC map will become irreducible. However, applying the ANP or PageRank only considers the influences between goals in a BSC map and does not take the importance of each goal to the HEI into consideration. To ensure that both goals are achieved, we proposed and applied an integrated approach that combines the AHP with PageRank centrality. In this paper, all the aforementioned concepts are applied and demonstrated in the case of the BSC strategic map of goals for the Faculty of Organization and Informatics at the University of Zagreb and can be applied to other HEIs' strategic maps of goals.

Key words | *ANP, AHP, PageRank centrality, balanced scorecard*

Prioritization of Lean Tools in Emergency Departments using Analytical Hierarchy Process (AHP)

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Abstract | Purpose: The purpose of this paper is determination and lean thinking tools' Prioritization in emergency departments from the physicians and nurses' viewpoints. Design/Methodology/Approach: In the first stage, using literature review, an appropriate model was selected for finding lean tools selection criteria and indicators. In the second step, the selected criteria's accuracy was investigated and most important of them were selected using experts' opinion. In the third stage criteria and tools are compared and ranked using a questionnaire. In the fourth stage, final ranking of lean tools was done using AHP and data obtained from the third step. Finding: In this paper we find that, in physician's viewpoint, criteria such as patients' satisfaction, percentage of patients admitted within six hours, mean triage time on each level and treated patients volume were respectively prioritized. Also, they prioritized the following tools in order of importance: Theory of Constraints (TOC), Poka-yoke, 5s, Value stream mapping (VSM), Kaizen and Jidoca. The nurses also prioritized the following criteria in order of their importance: percentage of admitted patients within six hours, patient satisfaction, treated

patients volume and average duration of triage on each level. The nurses also prioritized the following tools in order of their importance: 5s, TOC, Jidoca, VSM, Poka-yoke and Kaizen. Originality/Value: Offers the appropriate approach for leadership and increase productivity in emergency departments.

Key words | *lean thinking, emergency department, healthcare, AHP*

Characteristics of the Analytic Network Process, a Multi-Criteria Decision-Making Method

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Abstract | The analytic network process (ANP) is one of the most complex multi-criteria decision-making methods. It was developed by Professor Thomas Saaty, who also created the analytic hierarchy process. In the network, we model the dependencies and influences between decision-making elements. A network contains much more information on the decision-making problem than the hierarchy does. By applying the ANP, we, therefore, obtain more accurate results (the decision). As identified in the literature, the main disadvantage of the ANP is the duration of the implementation process, which is correlated with a large number of pairwise comparisons that need to be implemented. This disadvantage is decreased through different integrations of the ANP method with other methods, such as the decision making trial and evaluation laboratory approach and interpretive structural modelling. In this study, we focus on the three characteristics of the ANP, which are (1) the inseparability of criteria and alternatives, (2) the influence of the goal node on the priorities in the decision-making problem and (3) the stochasticity of the supermatrix in the ANP method. The inseparability of criteria and alternatives means that the ANP is not designed to be used for determining only criteria weights, without inputting the alternatives into the model (which can be a real-case request). If we create a network that consists only of criteria, some of the criteria can possibly weigh 0.0 if the related supermatrix is reducible. A reducible matrix means that the related graph is weakly connected-at least two nodes have no directed path between them. The influence of the goal node on the priorities implies that in most decision-making problems, which consist of one goal node, the priorities derived from the comparisons of the elements with respect to the goal do not influence the final priorities of the decision-making elements. If we delete the goal node, we get the same priorities as if the goal node is present

in the model. Finally, the stochasticity of the supermatrix is related to the method request that the sum of all columns in the supermatrix has to be equal to 1. This request relativizes the decision-making problem; the ANP often does not handle the strengths of the influences (dependencies) between criteria (ANP uses the same supermatrix for many decision-making problems). All these three characteristics are theoretically analyzed in depth and demonstrated through examples. The paper concludes with proposals on how the ANP can be used with respect to these three characteristics.

Key words | *Analytic Network Process, stochasticity, supermatrix, reducibility*

A Fuzzy Goal Programming Approach to Solve Decentralized Bi-level Multi-objective Linear Fractional Programming Problems

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Abstract | There are many economic examples where decentralized bi-level multi-objective linear fractional programming can be applied. In decentralized business systems, decision makers are deployed at two levels. At the top level there is one decision maker that can have one or more goals, and on the second level there are more decision makers each of which can also have one or more goals. These goals can be conflicting, which can lead to insufficient efficiency of the entire business system. Decision makers at the first level control their variables and try to maximize their goals represented by objective functions. Decision makers at the second level are observing decisions at the first level and try to maximize their goals represented by their objective functions on a given set of constraints. This problem is known as Stackelberg's model. The Stackelberg's model suggests that this problem is solved by the decision maker from the first level in a way to place the role of decision maker in the second level maximizing his objective function by the variables he controls. In this way, the optimal values of the decision variables of the second level decision-maker are presented

as functions of the variables of first-level decision-maker. Subsequently, the first-level decision maker incorporates the obtained optimal value of the decision variables from the second level and maximizes its objective function by the variables he controls. The application of this model to solving problems of mathematical programming problems faces a number of problems because in such problems it is practically impossible the optimal value of the decision variables at the second level express as the function of the decision variables at the first level. To solve such problems, there are a number of methods that can be grouped into two groups: (a) methods without co-operation between decision makers and (b) methods involving some form of co-operation. The methods from the first group can solve small size problems, and they are inefficient. The methods from the second group involve co-operation between decision makers. They are much more efficient than the methods from the first group. However, they do not apply Stackelberg's procedure in solving the problem. This paper presents a new fuzzy goal programming approach to solve bi-level multi-objective linear fractional programming problems. First we optimize all the linear fractional programming models on a given set of constraints. Later we use the optimal values of the objective functions to linearize all the linear fractional objective functions. After that we determine membership functions of the objective functions and of the decision variables at the first level. Later we determine weights for all the membership functions, and form a fuzzy goal programming model. The solution of the model should be acceptable for all decision makers on both levels. To demonstrate the efficiency of the proposed approach we solve a business planning problem.

Key words | *multi objective fractional programming, multi level programming, goal programming, fuzzy programming, production planning*

Decision Support Concept to the Management of Urban Improper Parking-measures and Construction Works

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Abstract | This paper presents new decision support concept (DSC) which serves to urban road infrastructure managers (especially within planning activities) when dealing with ever growing problem of improper parking within city centers. This indicates problem of improper parking as multicriterial one whose complexity arises from the large number of diverse data (particularly spatial data) and from requests that needs to be fulfilled by provided measures and construction works (solutions). Additional contribution to the problem complexity also arises from the different attitudes of stakeholders towards the solution of the analyzed problem. Therefore proposed DSC based on combination of MCDM method PROMETHEE (The Preference Ranking Organization METHOD for Enrichment of Evaluations) and Geographic Information System (GIS) is find as appropriate approach to provide support when such planning problems occur. It enables inclusion of relevant stakeholders within planning process trough identification and introduction of several different criteria and their importance respectively (criteria weights, determined by Analytic Hierarchy Processing method - AHP). These approach to criteria determination is

find to be important/crucial when assessing variant solutions (with combinations of different traffic regulation measures, construction works and financial expenditures - different by dynamic and/or volume) because it provides holistic insight to the problem resolving in all of its phases (from problem definition to solution selection). Proposed DSC is validated in the city of Split, even more precise in one of its neighborhoods.

Key words | *PROMETHEE, AHP, GIS, DSC, improper parking, planning*

Survey-based Ranking of Online Technology Retailers

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Abstract | This paper intends to explore the elements that consumers point out to be the most important when purchasing online and to find out the extent to which the selected online technology retailers possess them. Additionally, the online technology retailers are compared and ranked based on criteria such as price level, warranty, employee helpfulness and promptness, web page informativeness, the variety of offers, the availability of delivery service, promotions and discounts, striving to find a company that meets customer desires, their price needs and the corresponding level of product quality. Namely, based on the real data obtained from the web pages of online technology retailers the decision matrix is formed. The relative importance of the criteria in the decision-making process is determined using an eigenvector method for group weight assessment based on customer survey. Through the application of multi-criteria decision making the final ranking is obtained through the set-up of the analytical hierarchy process (AHP) which evaluates and ranks the alternatives according to selected criteria and the obtained weights. In addition, the companies are ranked using PROMETHEE, SAW and TOPSIS method. The obtained results are further compared to the ones obtained from the AHP method. This paper

contributes to the existing literature by introducing the eigenvector method for group weight assessment based on customer survey to obtain the weights of the criteria. Moreover, this research is conducted in the field of consumer behavior and contributes to the existing literature by defining the most important factors that influence the purchase in online technology retails.

Key words | *AHP, PROMETHEE, SAW method, TOPSIS, survey-based ranking*

A Framework for Group Decision-making in Historical Building Reconstruction Investment Projects

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Abstract | Investment in public construction projects, especially in reconstruction of heritage buildings, is a complex process from technical/technological, social, environment and economic view that requires awareness, attention, clarity and social responsibility from all stakeholders. Managing such projects is a rather difficult task when one takes into account the complexity, uncertainties and large number of activities involved. Selecting among variety of reconstruction investment projects can often be challenging because of projects' diversity, and because the various stakeholders view projects in different ways. As they are involved in different stages through projects' life-cycle, implementation of their opinions becomes even greater challenge. To implement their opinions as a consensus into decision-making process towards projects success, a multi-

criteria methods as well as group decision-making can help. In order to do so, a framework for group decision-making is proposed as a part of decision support concept for evaluation and ranking projects in public administration, which is based on combination of AHP and PROMETHEE methods. The whole concept is tested on existing industrial heritage buildings in the city of Rijeka which require a reconstruction for their future exploitation. Proposed approach helps decision-makers to come up with consistent investment decisions but also provides reassurance that the decision is based on a proper comparison of all projects even with a change of stakeholders during decision-making process.

Key words | *construction management, multi-criteria decision support, planning, project management, reconstruction*

A Decision Support Concept to the Historic Pedestrian Bridges Rehabilitation Planning

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Abstract | Historic pedestrian bridges are the crucial assets for the villages, cities or regions transportation, not just because of the connections they provide but also for their cultural aspects, as objects build in important parts of the history. For their proper functioning and acceptable serviceability and security it is very important to develop a quality historic bridge management. For a quality management, an expert assessment of bridges, precisely its elements is needed, because this way current condition of bridge is determined and by that a proper activity can be defined. Activity can include maintaining, repairs, replace, remove or rehabilitation. In this research only rehabilitation is observed as is decided by experts who made visual inspection of those bridges, so the crucial part of managing historic pedestrian bridges is the planning of their

rehabilitation which so far has been done unsystematically and unorganized, often lead with political interests. For this reason a new decision support concept (DSC) to the historic pedestrian bridges rehabilitation planning is designed in combination with multicriteria analysis. Goal hierarchy structure is formed in three levels by three different stakeholders' groups, containing main goal, sub-objectives and criteria. The Analytic Hierarchy Process (AHP) method is used for definition of the criteria relative importance (weights), then the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is used for priority ranking of historic bridges for the rehabilitation. The main goal of this research is to develop a model of decision support concept that will assist to the final decision maker to carry out the rehabilitation planning of historic bridges in systematic and organized manner. The model was validated on the case of historical pedestrian bridges in the area of Split-Dalmatia County (SDC), built during or before the Austro-Hungarian Monarchy.

Key words | *historic pedestrian bridges, rehabilitation planning, DSC, AHP, TOPSIS*

The Evaluation of Health-care: A Case Study

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Abstract | Turkey's spending on health-care rose by 23.6% year-on-year. As one of the most important point, \$8.5 billion is consumed on health-care sector, exceeding the initial annual country budget of \$8.3 billion. The highest share of costs went to hospitals at \$4.3 billion. Public health services followed at about \$2.4 billion. This paper aims to measure hospital units by using Fuzzy TOPSIS and Data envelopment analysis (DEA) for solving the performance measurement of pilot hospital units in Ankara. The study demonstrates a real-life problem utilization of the proposed methodology, mainly designed for hospitals. TOPSIS - Data envelopment analysis (DEA) methodology provides different benefits, one of which is the ability to make the most suitable decision thought the value of the weights calculated by the data. We developed a TOPSIS - Data envelopment analysis (DEA) methodology, which determines the hospital units full-efficient directly.

Key words | *DEA, TOPSIS, health-care*

Developing Project Concept with Interactive Multiobjective Discrete Stochastic Dynamic Programming

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Abstract | The success of any project is strongly determined by decisions made in the initial phase of its life cycle, concerning the basic issues related to its implementation. They define the general formula for project realization, specifying how the main goal of the project is going to be reached. The result of the activities undertaken at this stage is the project concept which includes, among others, the general rules that should be followed in project planning. The definition of project concept requires interdependent decisions, leading step by step to the final solution. Two main factors make this process difficult: multiple criteria used for evaluating various options and uncertainty. It is generally accepted that the project goal should be defined clearly and unambiguously. However, when the project approach is defined, a lot of detailed issues still need to be clarified. They affect all the project attributes: scope, cost, schedule and quality, which means that trade-offs among them must be taken into account. Discrete stochastic dynamic programming is a widely used technique for modeling and solving such problems. It assumes that the decision process consists of a finite number of periods, at which various decisions are made. For each decision, a finite, and usually relatively small number of alternatives is defined. In the paper a new method for solving problems related to the formulation of the project concept is proposed. We use multiobjective stochastic dynamic programming and interactive approach. The dynamics of the decision

process is taken into account. We assume that the decision maker is able to define the hierarchy of the criteria. In each iteration a candidate solution is proposed to the decision maker. If this solution is not satisfactory, next proposal is determined using the procedure for identifying near-optimal solutions of dynamic programming problem. The procedure is continued until satisfactory solution is identified. A numerical example illustrating the applicability of the procedure is presented.

Key words | *multi objective dynamic programming, interactive approach, trade-offs, project approach*

The WINGS Method and its Applications in Multiple Criteria Decision Making

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Abstract | The WINGS method (Weighted Influence Non-linear Gauge System) belongs to the family of systemic approaches which are based on mapping of causal relations among system elements. This paper shows WINGS ability to aid decision making and to address such issues like group decisions, uncertainty and dynamic evolution of the system under study. The practicality of the method is demonstrated by various cases: selection of innovation projects, allocation of public funds for sport development, and city image building.

Key words | *dynamic evolution, group decisions, MCDM, uncertainty, WINGS*

Quantitative Methods in Banking and Finance

Transparency Report Delay of Audit Firms

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Abstract | The aim of this paper is to investigate determinants of transparency report delay for audit firms who audited Croatian listed companies. Transparency report delay is measured as the number of days between the financial year-end and the publication date of the transparency report by an audit firms. We used multiple regression for modeling the transparency report delay as a function of the following variables: number of certified auditors, number of audits per year, return on assets and transparency report index. Our results indicate that transparency report delay is shorter when audit firms have a greater number of certified auditors and a higher transparency report index, i.e. when audit firms incorporate more elements into the transparency report of audit firms.

Key words | *transparency report, delay, audit firms*

Fair Value Hierarchy and Earnings Volatility

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Abstract | International Financial Reporting Standard 13 establishes a fair value hierarchy that categorizes sources of information used to measure fair value into three levels: Level 1 (quoted prices in active markets for identical assets or liabilities); Level 2 (other observable inputs for the asset or liability); and Level 3 (unobservable inputs). The reliability of reported fair values is expected to decrease with decreasing hierarchy level due to higher level of subjectivity and higher probability of measurement error. This estimation error in the measurement of assets and liabilities can be a source of additional financial statement volatility. Accordingly, when assets and liabilities are volatile, so are earnings. The aim of this paper is to investigate the relation between the use of Level 3 fair value inputs and earnings volatility. The main assumption is that Level 3 inputs are more subjective, contain more measurement errors and allow managers to use their earnings management practices more often. Consequently, the use of Level 3 inputs will increase earnings volatility. Most prior studies were mainly focused on the impact of the fair value hierarchy on the earnings value relevance. However, there is a lack of reliable empirical evidence on fair value hierarchy effects on earnings volatility and this study tries to fill that void. Fair value accounting is mostly related to measurement of financial assets and liabilities, therefore empirical evidence is provided through the sample of commercial and investment banks available via BankFocus BvD database.

Key words | *fair value, earnings volatility, fair value hierarchy, level 3 inputs*

Analyzing of Banks Balance Sheet Adjustments to Regulatory Capital Requirements

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Abstract | The main objective of this paper is to explore the adjustment of bank business activities to new regulatory capital requests using panel data analyses of the European Banking System. The research hypothesis assumes that increase in capital requirements affect banks' balance sheet adjustment and bank lending to non financial sector. Higher regulatory capital ratio banks can maintain by increasing in volume of share capital or in decreasing of risk weight assets and bank lending activities. High equity premium upon new equity issue due to asymmetric information about bank's net worth discourage current shareholder to issue additional capital. The results is in constrains in bank lending and increasing non risk bank assets. Banks response to new capital requirement can announce a long term negative impact to real economy and bank depending borrowers. Model of empirical analyze of adjustment of banking sector to new capital requirements will be done on the sample of public listed banking firms in the European Union in the period of 2000-2016 using dynamic panel-data estimation with Generalized Method of Moments (GMM) in one-step.

Key words | *dynamic panel, bank capital, bank lending, risk weight assets*

Identifying Characteristics of Financially (il)Literate Consumers in Croatia: Evidence From Cluster Analysis

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Abstract | Croatian labour force is becoming increasingly responsible for securing its own standard of living after retirement. The existing retirement system is confronted with various problems related to population aging, increased life expectancy, younger population emigration and an unfavorable ratio of retirees to workers. Also, many individuals in Croatia have not managed to develop an adequate retirement saving plan. This paper deals with Croatian consumers cluster analysis, which should provide the foundation for developing an appropriate program of enhancing financial literacy necessary for improvement in the retirement saving. The research is aimed at discussing financial literacy of Croatian financial consumers and classifying them based on the level of financial literacy. The purpose is to investigate characteristics

related to financial literacy, especially planning for retirement and to conclude whether financially literate individuals are more engaged in making plans for retirement. A literature review revealed the relationship of financial literacy with respondents' characteristics, namely age, education, number of household members, income, and retirement planning. Clusters of financially (il)literate consumers are obtained using K-means approach. Clustering output defines two clusters consisting of consumers with similar characteristics. Obtained clusters are further studied for selected characteristics. ANOVA and F-test are conducted in order to assess the equality of means among clusters. It is shown that cluster means differ significantly indicating that two groups of respondents, namely financially literate and financially illiterate, exhibit differences on the set of socio-demographic variables and retirement planning. The conducted empirical analysis reveals that individuals with higher level of financial literacy are older, have a higher level of general education, are highly involved in retirement planning, have higher income and lower number of household members. The results of this research are important in the context of the educational policy and further development of both financial literacy and retirement planning programs.

Key words | *k-means cluster analysis, financial literacy, socio-demographic characteristics, retirement planning*

Modelling a Stock Index on Croatian Stock Market: A Complex Numbers Approach

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Abstract | In his book *Complex-Valued Modeling in Economics and Finance* (2012), Sergey Svetunkov proposed the methodology for constructing a stock index by using the complex number theory. By comparing this new complex index with the existing stock index (of real-valued variables) on Russian stock market, Svetkunov (2012) has shown that the complex index captured some important market features whereas the index of real variables did not. However, the complex index is not an alternative to indices of real variables - it is rather a supplementary tool for stock market analysis. In this paper, we test the methodology proposed by Svetunkov (2012) on Croatian stock market in the period of 2008. to 2017. using the composition of index CROBEX. Obviously, Croatian stock market is small and rather illiquid, so it is interesting to discuss the application of the complex index methodology on such market.

Key words | *complex numbers, stock index of real variables, complex index, Croatian stock market*

Return and Volatility Spillover Between Stock Prices and Exchange Rates in Croatia: Spillover Methodology Approach

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Abstract | Relationship between stock returns and exchange rates has been in spotlight for many years now. Research tries to obtain information on the direction of causality between movements in stock prices and exchange rates. Usual line of the approach is to examine flow-oriented or stock-oriented model. The flow-oriented approach explains that changes in exchange rates influence changes in stock prices: depreciation of domestic currency improves local firms' competitiveness and stock prices move up as a response. Stock-oriented model assumes that changes in exchange rates are driven by changes in stock prices, as a consequence of changes of demand and supply of foreign and domestic assets in international portfolios. Researchers examine these concepts due to results being important to policymakers in order to tailor macroeconomic policies which will promote economic growth, but it is important to firms, (potential) investors and investment funds who consider real investment projects, forecast asset's return and risk, etc. This research will focus on the stock return and exchange rates co-movements in Croatia, by utilizing VAR (Vector AutoRegression)

and MGARCH (Multivariate GARCH) approach for the stock market index CROBEX and three exchange rates relative to Croatian Kuna: Euro, American Dollar and Swiss Franck. There exist only several studies in Croatia which deal with mentioned issues. However, this research extends the existing literature twofold. Firstly, this study will observe volatility spillovers between each pair of time series of interest as well (not only return series). Secondly, the study will apply the Spillover Index and Table as defined in Diebold and Yilmaz (2009), which has not yet been examined on the Croatian market. Based upon the results in the empirical research, more insights can be obtained for the relationship between return and volatility of stock market and the exchange rates in Croatia, as well as recommendations for parties of interest.

Key words | *spillover between markets, spillover index, stock market, exchange rate*

Is Croatian Stock Market SAD?

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Abstract | The validity of Efficient Market Hypothesis of Eugene Fama has been questioned and tested on stock markets ever since it has been formed. Behavioural economists have stronger and louder support in the last 15 years regarding stock market anomalies. A main concept of behavioural finance is the assumption that investors are not always rational utility maximizers. Due to psychological, cognitive and other factors which influence human behaviour, investors do not always act rationally on stock markets. This paper explores mood anomalies, specifically the SAD (Seasonal Affective Disorder) effect on the Zagreb Stock Exchange (ZSE). Since behavioural effects are rarely observed on ZSE, this paper is the first one in Croatia which explores such behaviour on the stock market. Seasonal affective disorder is defined as a syndrome of depressive episodes in human behaviour due to changing of the season. Using daily data on stock market return CROBEX for the period January 2010 - May 2018, SAD effects will be tested in order to explore if seasonal changes affect the stock returns in Croatia. SAD effects in this study are measured via photoperiod, since previous research has shown that photoperiod is linked to SAD, characterised by mood, energy, sleep and eating habits of humans, as

seasons change over the year. Besides the SAD variable in the model, some control variables will be included as well: January effect and Monday effect as most popular calendar anomalies in stock returns. Methodology used in the study will include univariate GARCH modelling via maximum likelihood method of estimation. Two main contributions of the research will be the following. First one is to summarize main theoretical findings and contributions regarding SAD effect in literature. The second one is reflected in the empirical part of the study where we explore mentioned effects for the first time in Croatia. Based upon the results of the empirical part of the study, conclusions will be made for the Croatian investors and some recommendations for investment strategies on the Croatian stock market.

Key words | *seasonal affective disorder, stock market, seasonality, behavioural finance*

Fraud Analytics in the Banking Sector by Cycle Detection in the Transaction Network

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Abstract | Nowadays, financial institutions have large amount of data based on the client activities and the related transactions. A bank can maximize its profit only if the underlying processes are understood on an analytical level. The main motivation behind this research is to detect the possible fraud activities of the clients which can have a significant influence on the business lifecycle of the bank. If a network is built based on the financial transactions, non-trivial connections between the bank accounts and unusual usages of the system can be explored. The main objective of this research is to find “financial cycles” in a transaction network. Generally the basic cycle detection algorithms focus on the nodes in networks, but in the case of financial transaction networks the main information are on the “flow” of the edges. Along a cycle the edges must have consecutive timestamps and the financial amount can have only a small α parameter gap compared to the initial edge. Because of this special nature of the transfer cycles general cycle detection methods are not able to detect the

above dynamic type cycles in the networks. In this talk we will present a new cycle detection algorithm which can follow the flow of the financial transactions along the transfers with taking into consideration of the time and the transfer amount. Our method can identify if the original “financial package” returns to the initial sender bank account. To show the efficiency and usability of our method we will present the results through a case study based on real data.

Key words | *network science, bank transaction network, cycle detection*

Acknowledgment | László Hajdu and Miklós Krész acknowledge the European Commission for funding the InnoRenew CoE project (Grant Agreement 739574) under the Horizon 2020 Widespread-Teaming program.

**The Impact of Fiscal Policy Convergence on Business
Cycle Synchronization between Croatia and Eurozone
Countries: Panel Analysis**

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Abstract | Although OCA theory emphasizes the importance of fiscal policy for functioning of currency unions, there is no clear theoretical framework linking fiscal policy convergence and business cycle synchronization as meta criterion of monetary integration. From a theoretical viewpoint, the impact of fiscal convergence on business cycle synchronization is not unambiguous. Counter-cyclical fiscal policy has important role as absorption mechanism to smooth out business cycle fluctuations. On the other side, fiscal policy, by generating large demand side effects, becomes the source of business cycles (shocks) which implies negative impact of fiscal policy divergence on business cycle synchronization. That negative impact is complicating conduction of common monetary policy, as well as increasing macroeconomic costs of adopting a common currency that is especially significant for Croatia.

The aim of this paper is to analyze how fiscal policy convergence impacts the business cycle synchronization between Croatia and eurozone countries and consequently indirectly affects the costs of monetary integration. In the empirical model the dependent variable is the business cycle synchronization, and the main independent variable is fiscal policy convergence. The problem of simultaneity (reverse causality) between dependent (the business cycle synchronization) and independent variable (fiscal policy convergence) is solved by using cyclically adjusted budgetary balance as indicator of fiscal policy

that represents discretionary fiscal policy. Applied control variables in the model are determinants of business cycle synchronization often used in this kind of research - financial integration, trade integration and sectoral structure similarity. Parameter estimation in the model will be done by static panel, where the choice of effect (fixed or random) will be determined by Hausman test. Student t test will determine is there statistically significant difference in averages (means) of business cycle synchronization before crisis (2001-2008) and crisis plus post-crisis period (2009-2016). If needed, the sample will be divided in two subsamples. Next, we will do a correlation matrix which will be an indicator of possible multicollinearity and enable us to partially eliminate correlated variables from the model. Potential problem of heteroscedasticity of residuals will be solved by using robust standard errors, and serial correlation problem will be tested by Wooldridge test of autocorrelation in panel data and solved by using lagged dependent variable as needed. Our dataset consists of Croatia and 19 eurozone countries. Data for indicator construction will be collected from several databases (AMECO, Eurostat, WIIW, MMF, UN Comtrade). Time span includes the period from 2001 to 2016. Unlike similar research which mostly use cross-sectional analysis (averaging variables over certain time spans), this paper includes time dimension (time variability) and puts Croatia in the focus of research which has not been done before. Spatial dimension includes 19 bilateral observations (Croatia with every eurozone country) and together with time dimension of 16 years that gives us a total of 304 observations.

Panel preferred Cerqueira-Martins index (Cerqueira and Martins, 2009) will be used as an indicator of business cycle synchronization, fiscal policy convergence will be calculated as the absolute difference of cyclically adjusted budgetary balance, financial integration will be calculated as the sum of bilateral foreign direct investments normalised by GDP, trade integration will be calculated as the sum of bilateral import and export normalised by GDP and sectorial similarity will be calculated as the sum of the absolute difference in gross value added of sectors.

Key words | *fiscal policy convergence, bank transaction network, cycle detection*

A Test of Portfolio in Factor Space in the Croatian Equity Market

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Abstract | Recent research for the Croatian stock market has shown that it is hard to construct a portfolio which can outperform the existing benchmarks (CROBEX and CROBEX10), regardless of their inefficiency. Research findings point out that failure of such efforts is mostly related to poor out-of-sample estimation of stocks' expected returns. However, the need to improve covariance matrix estimation has also been reported. This paper focuses on analyzing potential improvements to (co)variance estimation by examining stock portfolio in factor space. The key benefit of such approach to analysis is that it enables the use of PCA (Principal Components Analysis) method which has been shown to improve covariance matrix estimation in the developed markets by decomposing covariance matrix and exposing the unobservable underlying risk factors from data. Observation period in this paper covers the period beginning in March 2005 and ending in September 2017 with a total of 25 regular revisions of CROBEX index. Therefore, the analysis is carried out based on 25 rolling window time samples of monthly excess total returns matching the CROBEX index composition in each sample. Relying on the principal components which

capture most of the in-sample variability, out-of-sample covariance matrix and corresponding GMV (Global Minimum Variance) portfolios are estimated. Thus we obtain a time series of GMV portfolio returns based on which its performance is compared to CROBEX index. We find that unlike in the developed markets, the PCA method does not seem to improve covariance estimation. Compared to earlier research based on the statistical shrinkage method the estimated out-of-sample GMV portfolios performed worse (measured by Sharpe ratio) and more importantly exhibited an increase in volatility. The research results corroborate the view that there is too much noise in the data in illiquid and undeveloped markets. Therefore, even simple sample covariance estimation yielded better and more robust results.

Key words | *efficient portfolio, covariance estimation, PCA method*

Statistics and Econometrics

External Competitiveness and the Role of Fiscal Policy: Does Fiscal Austerity Matter?

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Abstract | During and after the sovereign debt crisis that hit most of the EU member states after the Great Recession the question of effectiveness of fiscal policy vis-à-vis ensuring sustainable growth rates and changing the economic structure of member states has been highly debated. Accordingly, this paper investigates the effects of shocks in government purchases and net taxes on the export competitiveness of the 11 new EU member states: Bulgaria, Czech Republic, Estonia, Croatia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and Slovakia. The countries are treated as a homogenous sample, but the empirical analysis extends beyond this. Namely, the paper examines two sub samples based on the exchange rate regimes of the 11 new EU member states: fix vs flex ex-rate regime. By applying panel VAR analysis, over 1999-2015 period, we report following conclusions. First, fiscal austerity influences the level of exports in our sample. Second, the effects of shocks in fiscal policy on the level of exports are short. Third, shocks in government purchases are the most important determinant in the total and in the fixed ex-rate countries sample. And fourth, shocks in net taxes influence level of export only in the

countries that have flex exchange rate regimes. Our results contribute to the literature that examines the effects of fiscal policy on the level of competitiveness of national economies by highlighting both the duration effect of fiscal policy on the level of export and also by pointing to the optimal economic instrument used with respect to the currency arrangement of the country.

Key words | *external competitiveness, new EU member states, fiscal consolidation, panel data analysis, export*

Acknowledgment | This research has been supported by Croatian Science Foundation under the project “The Role of Structural Reforms in Promoting the External Competitiveness of the European Union” [no. 5476]

Statistical Analysis and Application of Competing Risks Model with Regression

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Abstract | The contribution deals with the methods of statistical analysis of dependent competing risks in the presence of covariates influencing competing random variables. The competing risks situation occurs frequently in areas of reliability, biostatistics and medical studies, as well as in statistical demography, labor statistics, insurance, and in econometrics generally. First, the problem of identification of marginal and joint distributions of competing random variables is recalled and certain identifiability results achieved in the framework of regression models are presented. The main objective is then to study the case when the correlation of competing variables depends on covariates, as this phenomenon has not been taken into account in the most of papers dealing with the identifiability of competing risks models with regression. In an example, we use the data of Kadane and Woodworth (2004) stored in the Statlib database. The data record two competing terminations of employment, in a certain company. It is expected that both risks are dependent mutually and also on the age of employers taken as a covariate. It will be shown that the model parameters and, in particular, the correlation of the risks, depend on this covariate, too. The Gauss copula and the Cox regression model are used to describe the data, the numerical solution consists in a randomized search for the maximum likelihood estimate combined with the Metropolis MCMC algorithm in the Bayes framework.

Key words | *competing risks, copula model, Cox regression, MCMC, unemployment*

The Impact of Physical Symptoms of Burnout on Work Engagement of Older Employees

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Abstract | The main objective of this paper is to determine the impact of physical symptoms of burnout on work engagement of older employees in Slovenia. We conducted a survey among older employees in medium-sized and large companies in Slovenia. Physical symptoms of burnout and work engagement of older employees are described with numerous variables in a research instrument for older employees. Factor analysis was used to reduce a large number of variables into a smaller number of factors and to select the variables that best describe each factor. We also used factor rotation to improve the interpretability of factors. Afterwards we performed a simple regression analysis. The first hypothesis that physical symptoms of burnout of older employees in companies have a statistically significant negative impact on the work engagement of older employees is confirmed. Following the results presented in this paper companies should take the following measures: work hour flexibility, flexibility of place and promoting health and a healthy lifestyle.

Key words | *factor analysis, regression analysis, physical symptoms of burnout, work engagement, older employees*

Jordan Neural Network for Inflation Forecasting

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Abstract | In times of pronounced nonlinearity in macroeconomic variables and in situations when variables are not normally distributed, i.e. when the assumption of identically and independently distributed variable is not fulfilled, neural networks (NNs) should be used for forecasting purposes. In this paper Jordan neural network (JNN) as a special type of NNs is examined, which is because of its advantages in forecasting time series suitable for inflation forecasting. The variables used for inflation forecasting are the most commonly used in previous literature and include labour market variable, financial variable, external factor and lagged inflation. The research is conducted at the aggregate level of euro area countries in the period from January 1999 to January 2017. Based on 450 estimated JNNs, which differ in variable parameters (number of iterations, learning rate, initial weight value intervals, number of hidden neurons, weight value of the context unit), the model adequacy indicators for each JNN are calculated for two periods: “in-the-sample” and “out-of-sample”. Finally, the optimal JNN for inflation forecasting is obtained as the best compromise solution between low mean squared error “in-the-sample” and “out-of-sample” and low number of parameters to estimate. This paper contributes to existing literature in terms of using JNN for forecasting purposes since it is rarely used in macroeconomic time series prediction and especially in inflation forecasting. Moreover, JNN is examined thoroughly by fixing certain parameters of the model and alternating the other parameters to contribute to the existing JNN literature, i.e. finding the optimal JNN in this case of application.

Key words | *Euro zone, forecasting, inflation, Jordan Neural Network*

Asymmetric and Nonlinear Dynamics in Trade Flows Sustainability: Serbian and Romanian Case

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Abstract | The research examines sustainability of trade flows for two European post communist economies, namely Serbian and Romanian. The paper brings two nonlinear forms of the relationship between exports and imports that can not be explained using frequently applied linear model specifications. Newly developed nonlinear autoregressive distributed lag approach revealed the asymmetric and nonlinear long-run equilibrium between Serbian exports and imports. Nonlinearity tests indicated and SETAR model specification confirmed threshold nonlinearity form in the Serbian trade flows pattern. Serbian trade flows still approach its sustainable equilibrium but development pattern is promising. The results for the Romanian case revealed another nonlinear form of the relationship between exports and imports. The results for the Romanian case indicate threshold dependent cointegration between exports and imports. The paper provided robust results and supported the hypothesis that relationship between exports and imports might be nonlinear and symmetric.

Key words | *asymmetric cointegrat, nonlinearity, international trade, sustainability*

Structural Equation Modeling in Acceptance of Internet Banking in the City of Split

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Abstract | Electronic banking and electronic commerce have lately experienced numerous technological improvements, so they have become an inevitable aspect of financial services. According to data referring to the percentage of users of Internet banking in European countries, Croatia is at the bottom of the list. This number of users is far below the European Union average, as well as below the most of developed countries individually. Thus, the question of acceptance and use of this kind of technology arises, especially for less developed countries. This research is focused on exploring whether the motivation for acceptance and use of Internet banking can be explained by the technology acceptance model in the city of Split, Croatia using structural equation modeling. This model explains the intent of using information systems through perceived ease of use and perceived usefulness of a system. For the purposes of the research, a survey analysis was designed and applied on the sample of 282 working residents of Split. To make the results more credible, gender and age structure of the sample was harmonized with the population. Testing through non-parametric tests has shown that both of these psychological elements of the technology acceptance

model significantly affect the acceptance of Internet banking. Considering the research hypothesis and the fact that the technology acceptance model consists of multiple causal relationships, structural equation modeling was used to test the hypothesis. Structural equation modeling is a multivariate technique which combines aspects of factor analysis and multiple regression. It enables simultaneous examination of a series of interrelated dependence relationships between the measured variables and latent constructs, as well as between several latent constructs. The latent constructs in the model are those according to the proposed technology acceptance model, and they are measured through several variables, which are represented by the questions from the survey. It is concluded that both elements of TAM positively influence the acceptance of Internet banking in the city of Split. These results can help bank managers to understand the factors of Internet banking acceptance, especially in countries with lower number of users of Internet banking and to develop expansion strategy.

Key words | *internet banking, structural equation modeling, survey analysis, technology acceptance model*

Identifying the Interdependence between Consumer Confidence and Macroeconomic Developments in Croatia

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Abstract | This paper represents an empirical attempt to discern the interrelationship between consumer confidence and macroeconomic trends in Croatia. Previous studies that employ both subjective and objective variables show that consumer confidence, consumption and GDP in other countries are interdependent to a great extent. Apart from the mentioned variables, our study additionally includes savings, as another important determinant in household's economic decision making. The results indicate that consumer confidence Granger-causes all selected macroeconomic variables and vice versa. Also, there are many significant interrelations between the macroeconomic variables. These findings confirm the predictive ability of consumer sentiment in Croatia, and suggest that combining subjective and objective indicators has an important role in understanding household's economic behaviour.

Key words | *consumer confidence, consumption, savings, GDP, Granger causality*

**Asymmetric Impact of External Debt on Economic
Growth in Croatia: Nonlinear Autoregressive Distributed
Lag Approach**

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Abstract | This paper brings the external debt effect on economic growth in Croatia based on the autoregressive distributed lag approach and quarterly data over the 2000 - 2016 period. The research results revealed asymmetric and positive impact of external debt on economic growth in a long run while the short-run effect appeared to be negative. The effect from external debt reduction was not found to be significant in the long as well as in the short run. The research outlines that Croatian economy is highly indebted and experienced positive effects from external indebtedness. However, external debt reduction should not damage economic growth in Croatia.

Key words | *external debt, economic growth, NARDL*

On the Optimized Polynomial Smoothing Approach to the Seasonal Time Series Analysis

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Abstract | Inspired by the results obtained during our numerical experiments with the Walsh transformation applied to the seasonal time series analysis we continue investigations aimed to find other Walsh-like transformations better (resulting more accurate predictions) than the Walsh's one. We introduce a new "row-wise" forecasting process based on the optimized Walsh-like transformation matrix for seasonal times series. The main idea may be formulated as follows: first we regroup the known monthly values by different months and then solving the appropriate optimization problem we determine an invertible transformation matrix which smooths the data in the best way. In the second step we apply the tools of R-Studio from the "state-of-the-art" package forecast to calculate prediction values for transformed times series, and finally, we apply an inverse matrix to get predictions for the original time series. Our numerical experiments were performed using the MComp data set of seasonal time series collection containing 1001 time series from the M-competition and 3003 another one from the IJFM3 competition collection known as the most hard seasonal times series to predict. In the talk to be presented we compare numerically in RStudio using the MComp data set and the tools the following two approaches: (1) "direct" - we apply built-in generic function forecast to time-series directly in "conventional" mode, (2) "Walsh-like row-wise" - we apply the same function forecast to transformed time-series row-wisely. A significant advantage of the proposed forecasting process is that when forecasting more than one-step ahead it does not use previously forecasted values and, hence, does not accumulate inaccuracy, thus the forecasted results can be more proper compared to other mainstream techniques. Moreover, as show our numeric results the longer the horizon of forecasting, the more attractive relative accuracy achieved.

Key words | *time-series, polynomial smoothing, forecast, optimization*

Statistical Modeling of Self-employment Intentions in Higher Education

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Abstract | Higher education is underpinned by the growth of individuals and society and thus building of a better world. A higher education institution is in the position to develop a statistical methodology for the analysis of one's own effects and focus on training academic citizens for their proactive participation in building the society. Self-employment is a fundamental indicator of proactiveness of individuals, groups or society as a whole, while the measure of success of higher education is the number of participants educated and trained in higher education programs for future proactive inclusion in the society. The aim of this paper is to indicate characteristics of the proposed model (i.e. Model XP) applied to data collected on a higher education institution, which is used for modelling self-employment intentions. The described Model XP tests the predictive ability of different constructs (motivation for achievement, higher education, theory of planned behavior and control variables) related to self-employment intentions. The sample in this paper (n=426) consists of graduate students, who were faced with two future career choices - either self-employment or employment in the company (working for someone else). The proposed Model

XP was analyzed by hierarchical multiple regression analysis and it was found that the academic context the students are exposed to affects the process of modeling self-employment intentions. The proposed Model XP is characterized by a high predictive ability (adjusted $r^2 = 0.63$), while the higher education construct is confirmed as a statistically significant construct ($p < 0.05$), that can reasonably be used for predicting self-employment intentions. Characteristics of the Model XP are explained in the conclusion presenting the model as convenient for clarifying predictions of young people's intentions (students) in the process of making decisions about their future career choices.

Key words | *hierarchical regression analysis, measuring intentions, higher education, self-employment*

Living Longer. Working Longer?

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Abstract | Mortality trends in aging societies such as Croatia, Hungary, and the European Union have become one of the most important economic and political considerations. Significant growth in life expectancy of the last 20 years did not result considerable changes in pension systems of most countries, longevity trends are not followed by raising official retirement ages. Controversial tendencies lay down major challenges to societies: on state level it has high importance to create a sustainable pension system, and on individual level the well-grounded personal/family life-long financial stability is a key issue for well-being. The employment period, i.e. the active working time depends on - among other factors - the official retirement age. Despite the rise of longevity, the effective retirement age in most countries does not increase in the same pace. We have analyzed 20 years data of 35 OECD members (plus Croatia), applied linear factor models on the life expectancy at birth and at age 65 years old for both male and female, and compared the age-gain, defined as the difference between the two life expectancies with effective retirement age. This factor model fits statistically well, however life factor and retirement factor form orthogonal axis, meaning we could not find correlation between longer life expectancy and retirement age. Using hierarchical and k-means clustering, we conclude the longevity and retirement age does not move parallel in these countries, we can find all combination of lower and higher values.

Key words | *longevity Risk, pensions, mortality forecasting*

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**Do the Most Frequently Used Dynamic Panel Data
Estimators Have the Best Performance in Small Sample?
A Monte Carlo Comparison**

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Abstract | This paper compares the small sample properties of two most popular dynamic panel data estimators: differenced GMM and system GMM estimators with standard dynamic LSDV and LSDV bias-corrected estimators. Regardless the fact that GMM estimators are proposed for data set with large N and small T both of them are very frequently used for empirical studies with small or moderate N and small or moderate T. Therefore, this simulation study compares properties of these estimators in term of bias and root mean square error (RMSE) to confirm or deny the frequent use of GMM estimators in empirical studies with small sample. Six different data sets are considered: $\{(15,10); (10,15); (12,12); (30,10); (10,30), (17,17)\}$. From results of this simulation study it is obvious that most popular and frequently used estimators difference GMM and system GMM do not show superiority in any simulated design. The results show that LSDV bias-corrected estimator has the smallest RMSE in almost all designs while in term of bias results are mixed. LSDV bias-corrected outperforms both GMM estimators in term of bias in design when number of individuals is 10 and number of time periods is 30. Moreover, bias of difference GMM and system GMM estimators is comparable with standard LSDV estimator while LSDV has smaller RMSE. This results indicate that researchers have to avoid the use of any of two GMM estimators in data set with this characteristics regardless their popularity and existence of empirical studies which use one of two estimators. On the other hand, GMM estimators show somewhat better properties in term of bias in design where number of individuals is 30 and number of time periods is 10.

Key words | *dynamic panel data, small samples, GMM estimators, LSDV bias-corrected*

Predicting Energy Consumption Using Panel Data Analysis

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Abstract | Every economy that thrives for sustainable development faces the challenge of reducing energy consumption. Buildings are the largest consumers of energy. In order to manage and monitor the consumption of energy and water in public sector buildings in Croatia, the Information System for Energy Management has been established. However, the current system does not include predictive models that would forecast energy consumption. Therefore, the aim of this paper is to develop a model for predicting energy consumption of public buildings based on panel analysis. In Croatia, different energy sources are used for heating and cooling of buildings, depending on the geographical area. Two energy sources dominate - gas and electricity. In this paper, the focus is on the gas consumption of public buildings expressed in KWh. Dataset of public buildings from the Information System for Energy Management provided by the Agency for Legal Trade and Real Estate Brokerage (APN) in Croatia was used. The dataset includes data about construction, geospatial, occupational, meteorological and energetic characteristics of public's buildings. This research uses available monthly data on energy consumption of public buildings in the

period 2012-2017. Each building is represented in every year creating a balanced panel dataset. To be able to derive conclusions from the panel dataset, the panel analysis with fixed and random effects was used. The variables selected by panel analysis were compared to the predictors identified in previous research. The suggested model could be beneficial to the government by providing a tool for identifying public buildings with the highest energy consumption in the near future and therefore serving as an intelligent support in the decision making process regarding the investments into the energy renewal projects.

Key words | *energy consumption, energy management, prediction model, panel analysis*

**Multivariate Analysis of the EU Member States
According to Knowledge Society, Social Contributions
and Income Inequality Indicators**

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Abstract | The aim of the paper is to continue the research process started in 2017 related to classification of the EU countries according to differences in their income inequality, social spending and Internet usage. In the past research post-transition EU countries were analyzed according to 4 indicators and this research is broadened to the EU-28 member states which are classified according to 3 indicators of economic development (social contributions as % of total taxation, Gini coefficient of equalized disposable income, real GDP per capita) and 5 indicators of knowledge society development (tertiary education; internet purchases; individuals who have basic or above basic overall digital skills; individuals using the internet for interaction with public authorities, individuals using the internet for looking for information about education and training). The data source was Eurostat and the last available data for some variables were for 2015. Knowledge society indicators were included in analysis based on previous studies, which show that the EU member states significantly differ according to the achieved knowledge society development

level. Thus, the goals of this research also include disclosure and explanation of the causes or origins of income inequality among the EU member states as an indicator of relative poverty, evaluation of the influence of education on income distribution and decomposition of impacts of social contributions on income inequality. The empirical analysis consists of two parts. In the first part the factor analysis with varimax rotation was used to analyze eight chosen variables and to extract smaller number of factors. Two factors were extracted, which together account for 74% of the total variance. The factor scores were calculated and used in subsequent analysis. In the second part the cluster analysis was conducted on those two extracted factors and associated factor scores to classify the EU-28 member states. First, the Ward's method with squared Euclidean distances was performed and four clusters were chosen by the dendrogram and intuitive interpretation. Croatia was clustered in the second cluster with the EU member states that have similar political and historical background, respectively with Czech Republic, Hungary, Poland, Slovakia, and Slovenia. For those four clusters, k-means method was used and again Croatia was clustered with mentioned countries. The analysis confirms that EU member states differ according to the knowledge society indicators and economic development because of their heterogeneous levels of development and policy differences.

Key words | *cluster analysis, factor analysis, income inequality, knowledge society, social contributions*

The Impact of MAUP on Internal Migration Distance and its Frictional Effect

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Abstract | In this paper, we analyse the impact of the Modifiable Areal Unit Problem (MAUP) on the internal migration distance and its frictional effect. MAUP is described by scale and zonation components; a scale component is related to the different number of zones/regions, a zonation component is related to spatial definition of analysed zones. We analyse the MAUP effects and estimate internal migration distances and their frictional effects by producing a large number of aggregations using IMAGE Studio software. In the case study, we analysed the impact of migration distance and its friction on inter-municipal migration in Slovenia for nine selected years in the period between 2000 and 2014. In this period, the number of municipalities in Slovenia changed several times that affected MAUP. The results show that the mean migration distance is higher than median one, which means that there are much more inter-municipal migrants that migrate on short distance than other ones. Mean and median migration distances increased in the analysed period, what meant that the migration distance became less important for internal migrants in Slovenia in general. By modelling the relationship between mean migration distance and mean area size, we discovered that the frictional effect of distance remained remarkably stable across spatial scale, except where zones had small populations and were poorly connected. This stability allowed robust comparisons between analysed years even though municipal system differed.

Key words | *distance decay, zonal aggregation, spatial interaction model, internal migration, mean migration distance, inter-municipal migration*

Acknowledgment | Author acknowledge the financial support from the Slovenian Research Agency (research core funding No. P2-0227, Geoinformation infrastructure and sustainable spatial development of Slovenia)

Has the Accession of Croatia to EU Affected Business Sentiment in Industry? Synthetic Control Method Approach

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Abstract | Synthetic control methodology (SCM) has become more interesting in economic research in the last decade, since seminal papers of Abadie & Gardeazabal (2003) and Abadie et al. (2010). This methodology was developed to look at “what if” scenarios and impacts of “treatments” being applied to one observation unit in a sample of interest. The main assumption is that one unit has undergone a treatment in a point in time, whilst other units (e.g. countries, people, stocks, markets, etc.) have not. The methodology is then useful to estimate the value of an output of interest of the unit which has undergone the “treatment” and compare it to the real output which has been realized. In that way, the researcher can estimate the impact of the “treatment”. In this study, we observe the impacts of Croatia’s accession to the European Union in 2013 on the Industrial confidence indicator (ICI) as a measure of business sentiment in industry. The main hypothesis in the research is that Croatia’s entrance to the EU had a positive impact on the ICI, which can be explained as euphoria. This will be tested by applying the SCM methodology on quarterly data. Variables in the model are: ICI, index of industrial production, employment in industry, domestic and non-domestic output prices in industry, in the period 2008Q3 - 2017Q4. In the study, EU countries that have similar characteristics of factor variables are included, in order to construct a synthetic Croatian ICI counterpart, due to recommendations in SCM literature. The

study will try to estimate relative importance of the factor variables in the model, as well as relative weights of countries used in the sample. This is the first study of this type in Croatia, so, conclusions derived from the research will be a pioneer attempt to the improvement of popularization and implementation Business and consumer surveys (BCS) in predicting macroeconomic changes.

Key words | *industrial confidence indicator, synthetic control method, business and consumer survey, counterfactual methodology*

A Structural Equation Model of Innovative Capabilities and Competitive Advantage

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Abstract | In this research the impact of innovative capabilities, as one of the main elements of company's dynamic capabilities, on competitive advantage is examined. After extensive analysis of the current theoretical and empirical findings related to innovative capabilities, the construct of innovative capability was operationalized through following variables: development of new products and services, development of new production methods, risk-taking by key executives, market innovation, and firm's innovative strategic orientation. Empirical analysis was conducted on 108 large Croatian companies from all industries. Measurement model was evaluated through analysis of discriminant validity, indicator reliability, construct reliability and convergent validity. The loadings of all PLS analysis's reflective indicators were examined to assess the indicator reliability and they are all above critical level of 0.5. The reliability of individual indicators is obtained by squaring the loading and all indicators of these two reflective constructs are above the minimum acceptable level for outer loadings. Construct reliability is analyzed using composite reliability (CR) measure. Using PLS analysis the impact of innovative capabilities on competitive advantage was analyzed. The results of structural model evaluation show that all paths are statistically significant, nontrivial and in expected direction. It is shown that development of new products and services, development of new production methods, risk-taking by key executives, market innovation, and firm's innovative strategic orientation are important because they enable company to achieve competitive advantage and outperform their rivals. So, commitment to invest in developing innovative capabilities could be crucial if company want to become leader in its industry.

Key words | *competitive advantage, dynamic capabilities, innovation, innovative capability, PLS modelling, SEM*

Childhood Mortality in Nigeria: A Multiple Logistic Analysis of Paternal and Household Characteristics

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Abstract | Globally, child survival rate is still very low in the developing countries.. By 2015 World Health Organization reported that under-5 mortality in Nigeria was 108 deaths per 1000 live births. This implied that, Nigeria could not achieve the Millennium Development Goals (MDGs) target of reducing the under-5 mortality to 64 deaths per 1.000 live births. In the recent times, researchers have addressed the role of maternal related factors and socio-economic characteristics of area on child survival. In this study we hypothesized that the outcomes of child's survival is not limited to the effect of mother's characteristics, but also those of the father's and household. The aim of this study is to comprehensively investigate the independent effects of some paternal and household characteristics on child survival with or without accounting for maternal socioeconomic variables using Multiple Logistic Regression Method.

Key words | *survival, logistic, socioeconomic, demographic, under-5 mortality*

Machine Learning and Data Mining

A Fast Algorithm for Solving the Multiple Ellipse Detection Problem

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Abstract | The multiple ellipse detection problem has practical importance in a wide variety of applications such as pattern recognition, robotics, computer vision, medical image analysis, ultrasound image segmentation, etc. In this paper we consider the multiple ellipse detection problem which is based on a data points set coming from a number of ellipses in the plane not known in advance. An ellipse is considered as a Mahalanobis circle with some positive definite matrix. We propose a new method that uses the k-means algorithm with Mahalanobis circles as cluster-centers. The initial approximation is obtained with only a few iterations of the globally optimization algorithm DIRECT applied to the objective function. We also consider the problem of recognizing the number of ellipses data sets come from. For this purpose we construct a

new index adjusted to partitions with ellipses as cluster-centers. The proposed algorithm is implemented in C++. Our goal was to find a solution to the problem in real time, and the demo version of the program available on <http://cs.mathos.unios.hr/~pnikic/ells/> is capable of recognizing a set of up to five ellipses in 1 - 1.5 sec. Given an image, the program will return the detected ellipses and their parameters: centers, semiaxes and angles of rotation. In the case of non-intersecting ellipses, our method gives outstanding results. However, for the case of intersecting ellipses, results are slightly worse and require further work in order to improve a given method. In the case when a data points set comes from a number of ellipses with clear edges, the proposed method gives results similar to other known methods. However, when a data points set comes from a number of ellipses with noisy edges, the proposed method performs significantly better than the other methods. The method is illustrated and tested on numerous synthetic and real-world data sets.

Key words | *multiple ellipse detection problem, adaptive mahalanobis k-means algorithm, real-time detection, globally optimal partition, DIRECT*

Fuzzy Expert System for Land Valuation in Land Consolidation Processes

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Abstract | Land fragmentation is one of the main obstacles to sustainable agricultural and rural development. The main goal of sustainable agriculture development is the production of food by the synergy of economic, social and ecological requirements. The ineffective and defective legislation and even its complete absence have led to land degradation globally. The most adaptable and globally recognized method that has the effect to solve the existing land fragmentation and to prevent the trend of even more intensive land fragmentation is the method of land consolidation. Land consolidation is carried out in a way that each participant in the process of land consolidation gets new land of equal value, with land value reduction for general and common needs of settlements and participants of consolidation. The value of the land included in consolidation process is determined and shown in land consolidation assessment which is conducted by land classification in the defined classes, and the value in the land consolidation evaluation is shown in the estimation units. The estimation unit is the relative relation between the exemplar parcel and the parcel which need to be valued, taking into account all the relevant

factors that can affect the land valuation. This paper proposes a model of land classification in the evaluation classes based on the Fuzzy Logic Method. The paper aims to develop an expert system that would improve and optimize the process of relative valuation of agricultural land as one of the critical steps in the implementation of the land consolidation. The proposed expert system would provide effective support in conducting the negotiation procedures and planning of land consolidation implementation with the involvement of different stakeholder groups with different requirements and wishes. The model will be validated for agricultural land on the island of Hvar in the Split-Dalmatia County.

Key words | *land fragmentation, land consolidation, land valuation, fuzzy expert system*

Searching for an Optimal Partition of Incomplete Data with Application in Modeling Energy Efficiency of Public Buildings

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Abstract | In this paper, we consider the problem of searching for an optimal partition with the most appropriate number of clusters for an incomplete data set in which several outliers might occur. Special attention is given to the application of the Least Squares distance-like function. The procedure of preparing the incomplete data set and the outlier elimination procedure are proposed such that the clustering process gives acceptable solutions. An incremental algorithm for searching for optimal partitions with 2, 3, ... clusters is applied on the prepared data set. After that, by using the Davies-Bouldin and the Calinski-Harabasz index the most appropriate number of clusters is determined. The whole procedure is organized as an algorithm given in the paper. In order to illustrate its applicability, the above steps are applied on the real data set of public buildings and their energy efficiency data, providing clear clusters that could be used for further modeling procedures.

Key words | *clustering, incomplete data, missing data, optimal partition, energy efficiency, public buildings*

How to Predict the Beginning of the Pollen Season?

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Abstract | The beginning of the pollen season is extremely important for the timing of antiallergic therapies for people with allergic rhinitis. In this paper we analyze the influence of meteorological variables, such as average temperature, precipitation, humidity and wind speed, to the beginning of the pollen season for *Ambrosia*, *Betula* and *Poaceae*. In the first part of the paper we give different definitions of the season start. In the second part we combine different statistical and machine learning methods to predict the season start with respect to the given definitions. One of the biggest challenges is to extract predictable features from data that give the best prediction performance. All methods are tested on real data for Osijek, Sombor, Vrbas, Sremska Mitrovica and Novi Sad.

Key words | *machine learning, allergic rhinitis, season start*

An Exploration of CNN-based Time-series Prediction

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Abstract | Time-series prediction is considered for a long time an attractive research topic since the data exhibiting temporal dynamics is generated wherever there is a sign of human activity, with important applications ranging from healthcare, finance, economy or industry, to name just a few. However, due to their often high-nonlinearity and low signal-to-noise ratio, modeling and prediction of real-world data remains challenging. Moreover, large volumes of continuously generated data, along with the business requirements for their rapid analysis, call for a fully automated process which can be greatly enhanced by modern representation learning methods based on deep neural networks. Over the last few years, convolutional neural networks (CNNs) have revolutionized the field of computer vision. Favored by the availability of the GPU hardware, which allowed parallelization of computations, and large labeled datasets, CNNs ability to automatically learn hierarchical feature representations directly from raw image data has led to results even surpassing human performance on some tasks. This has encouraged researchers to adopt them also on tasks of sequential modeling, such as machine translation or music composition, where recurrent neural networks (RNNs) were usually considered as a natural choice, and there is an increasing interest in building end-to-end time-series prediction systems with CNNs as their main building blocks. In this paper, we explore CNN-based approaches for time-series prediction. In line with the recent research, we follow two paths: in the first, time series are encoded as images, which enables direct application of image classification techniques. The second approach adapts the CNN architecture to specificities of time-series processing. The performance is tested on real-world data from different domains as choosing the appropriate approach for a specific task can contribute to better decision-making.

Key words | *time-series prediction, convolutional Neural Networks, deep learning*

Sensitivity Analysis of Neural Networks in Predicting High-growth of SMEs

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Abstract | High growth enterprises have shown to be of great importance for most economies. The volume of research of high-growth is growing but is still scattered. Many studies that deal with high-growth are focused on investigating factors that have significant impact on growth. However, finding them is not straightforward as it might seem. First, it depends on how growth is measured. Growth of sales and growth of number of employees are the most frequently used growth measures. Previous studies have shown that there are not the same factors relevant for growth in sales as for growth in assets or number of employees. Second, level of importance of different factors is not equal. It would be valuable to realize which factor of growth is more important compared to other factors. This is especially noticeable when different growth models are compared and when we want to find out whether the same variable has the same contribution to both models. In order to give some contribution to the aforementioned problems, in this study we will develop models for predicting high-growth of SME where two different measurement of growth will be used – sales and number of employees. Neural networks will be used for models

development. After that, by using sensitivity analysis we will discover factors that are relevant for predicting high-growth in sales and separately high-growth in number of employees. Additionally, we will analyse importance of each factor in both models – what is the level of importance of a single factor in the model that predicts sales compare to its importance in the model that predicts number of employees. In this research there are two datasets consisted of 688 Croatian SMEs in each – one according to high-growth in sales and the other in number of employees. The longitudinal datasets cover the time period 2012-2015 and consist of financial ratios, industry sector and region. Results suggest that in predicting growth defined by number of employees the most important factors are industry sector and activity ratios, while in growth of sales the most important factors are region and indebtedness ratios. The paper should be beneficial to researchers because it shows how to use neural networks and sensitivity analysis in order to develop a model and to investigate the level of importance of variables in the model. Other beneficiaries include entrepreneurs because the results show which factors are relevant for achieving high-growth in sales and in number of employees.

Key words | *predictive model, neural networks, sensitivity analysis, high-growth enterprises, financial ratios*

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 annually, while from the 1996 onwards 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.

15 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, Trogir, Pula, Split, Zagreb and Osijek. 15th International Conference KOI 2016 is organized in Osijek, a small but charming university city in the northern part of Croatia. From 1991-2008 the papers that were presented at the conference and positively reviewed, were published at the conference proceedings. 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 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 154 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 <http://www.hdoi.hr>). 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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Marijana Zekić-Sušac, University of Osijek (2012-2016)

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