

Proceedings SOR

Rupnik V. and L. Bogataj (Editors): The 1st Symposium on Operational Research, SOR'93. Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 1993, 310 pp.

Rupnik V. and M. Bogataj (Editors): The 2nd International Symposium on Operational Research in Slovenia, SOR'94. Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 1994, 275 pp.

Rupnik V. and M. Bogataj (Editors): The 3rd International Symposium on Operational Research in Slovenia, SOR'95. Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 1995, 175 pp.

Rupnik V., L. Zadnik Stirn and S. Drobne (Editors.): The 4th International Symposium on Operational Research in Slovenia, SOR'97. Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 1997, 366 pp. ISBN 961-6165-05-4.

Rupnik V., L. Zadnik Stirn and S. Drobne (Editors.): The 5th International Symposium on Operational Research SOR '99, Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 1999, 300 pp. ISBN 961-6165-08-9.

Lenart L., L. Zadnik Stirn and S. Drobne (Editors.): The 6th International Symposium on Operational Research SOR '01, Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 2001, 403 pp. ISBN 961-6165-12-7.

Zadnik Stirn L., M. Bastiè and S. Drobne (Editors): The 7th International Symposium on Operational Research SOR'03, Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 2003, 424 pp. ISBN 961-6165-15-1.

Zadnik Stirn L. and S. Drobne (Editors): The 8th International Symposium on Operational Research SOR'05, Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 2005, 426 pp. ISBN 961-6165-20-8.

Zadnik Stirn L. and S. Drobne (Editors): The 9th International Symposium on Operational Research SOR'07, Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 2007, 460 pp. ISBN 978-961-6165-25-9.

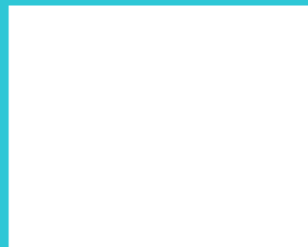
Zadnik Stirn L., J. Žerovnik, S. Drobne and A. Lisec (Editors): The 10th International Symposium on Operational Research SOR'09, Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 2009, 604 pp. ISBN 978-961-6165-30-3.

Zadnik Stirn L., J. Žerovnik, J. Povh, S. Drobne and A. Lisec (Editors): The 11th International Symposium on Operational Research SOR'11, Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 2011, 358 pp. ISBN 978-961-6165-35-8.

Zadnik Stirn L., J. Žerovnik, J. Povh, S. Drobne and A. Lisec (Editors): The 12th International Symposium on Operational Research SOR'13, Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 2013, 390 pp. ISBN 978-961-6165-40-2.

Zadnik Stirn L., J. Žerovnik, M. Kljajić Borštnar, S. Drobne (Editors): The 13th International Symposium on Operational Research SOR'15, Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 2015, 559 pp. ISBN 978-961-6165-45-7.

Zadnik Stirn L., J. Žerovnik, M. Kljajić Borštnar, S. Drobne (Editors): The 14th International Symposium on Operational Research SOR'17, Proceedings. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 2017, 567 pp. ISBN 978-961-6165-50-1.



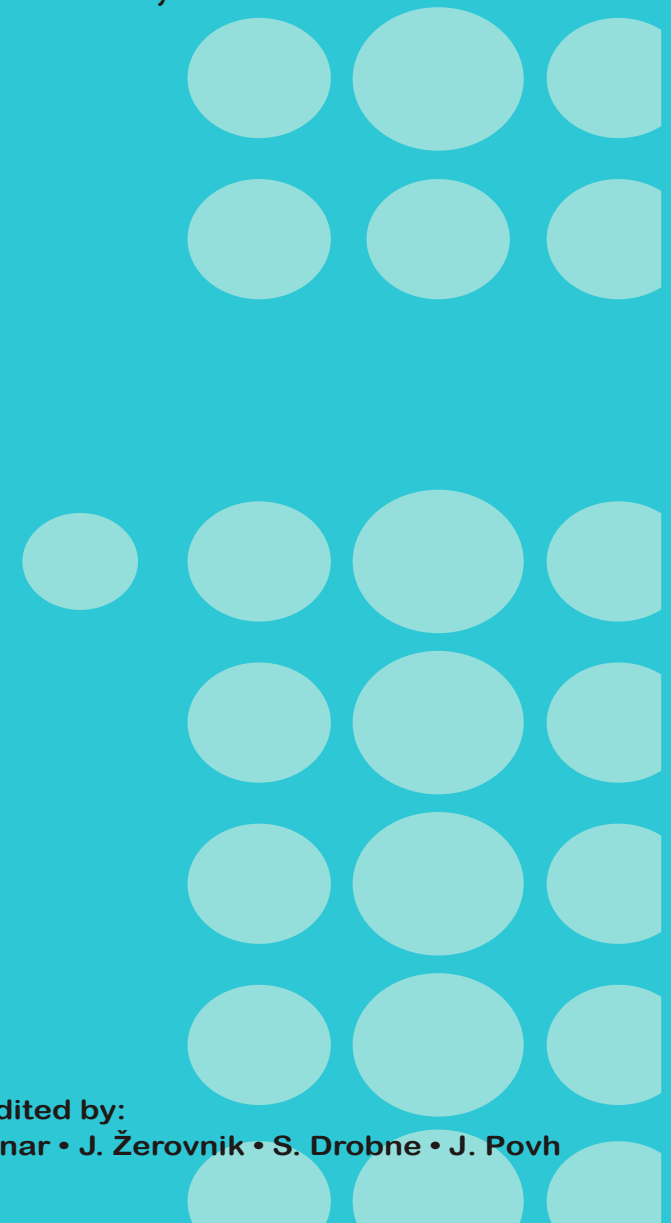
Proceedings of the 15th International Symposium on OPERATIONAL RESEARCH

SOR '19

Bled, Slovenia

September 25-27, 2019

Proceedings SOR'19



Edited by:

L. Zadnik Stirn • M. Kljajić Borštnar • J. Žerovnik • S. Drobne • J. Povh

SOR '19 Proceedings

*The 15th International Symposium on Operational Research in
Slovenia*

Bled, SLOVENIA, September 25 - 27, 2019

Edited by:

L. Zadnik Stirn, M. Kljajić Borštar, J. Žerovnik, S. Drobne and J. Povh



Slovenian Society INFORMATIKA (SDI)
Section for Operational Research (SOR)

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Proceedings of the 15th International Symposium on Operational Research
SOR'19 in Slovenia, Bled, September 25 - 27, 2019.

Organiser : Slovenian Society Informatika – Section for Operational Research, SI-1000 Ljubljana,
Litostrojska cesta 54, Slovenia (www.drustvo-informatika.si/sekcije/sor/)

Co-organiser : University of Maribor, Faculty of Organizational Sciences, SI-4000 Kranj, Kidričeva cesta
55a, Slovenia (<http://www.fov.um.si/>)

Co-organiser : University of Ljubljana, Faculty of Mechanical Engineering, SI-1000 Ljubljana,
Aškerčeva cesta 6, Slovenia (<https://www.fs.uni-lj.si/>)

First published in Slovenia in 2019 by Slovenian Society Informatika – Section for Operational Research,
SI 1000 Ljubljana, Litostrojska cesta 54, Slovenia (www.drustvo-informatika.si/sekcije/sor/)

CIP - Kataložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

519.8(082)
519.8:005.745(082)
519.81:519.233.3/.5(082)

INTERNATIONAL Symposium on Operational Research in Slovenia (15 ; 2019 ; Bled)
SOR '19 proceedings / The 15th International Symposium on Operational Research in Slovenia, Bled,
Slovenia, September 25-27, 2019 ; [organiser] Slovenian Society Informatika (SDI), Section for
Operational Research (SOR) ; [co-organiser University of Maribor, Faculty of Organizational Sciences
[and] University of Ljubljana, Faculty of Mechanical Engineering] ; edited by L. Zadnik Stirn ... [et al.] -
Ljubljana : Slovenian Society Informatika, Section for Operational Research, 2019

ISBN 978-961-6165-55-6
COBISS.SI-ID 301633536

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Proceedings of the 15th International Symposium on Operational Research in Slovenia (SOR'19)
is cited in: ISI (Index to Scientific & Technical Proceedings on CD-ROM and ISI/ISTP&B
online database), Current Mathematical Publications, Mathematical Review, MathSci,
Zentralblatt für Mathematic / Mathematics Abstracts, MATH on STN International,
CompactMath, INSPEC, Journal of Economic Literature

Technical editor : Samo Drobne
Designed by : Samo Drobne
Printed by : BISTISK d.o.o., Ljubljana, Slovenia
Number of copies printed: 160

Contents

<i>Plenary Lectures</i>	<i>1</i>
<hr/>	
<i>Ivan Bratko</i> Robot Learning and Planning with Qualitative Representations	3
<i>Mirjana Čizmešija</i> Economic Sentiment in Quantitative Analysis	4
<i>Tibor Illés</i> Sufficient Linear Complementarity Problems – Pivot Versus Interior Point Algorithms	5
<i>Joanna Józefowska (The EURO Plenary)</i> Just-in-Time Scheduling	6
<i>Matej Praprotnik</i> Scientific Case for Computing in Europe 2018-2026	7
<i>Special Session 1: Application of Operation Research in Agriculture and Agribusiness Management</i>	<i>9</i>
<hr/>	
<i>Karmen Pažek and Tina Kep</i> Project Planning for Cattle Stall Construction Using Critical Path Method	11
<i>Boris Prevolšek, Karmen Pažek, Maja Žibert and Črtomir Rozman</i> Using Data Envelopment Analysis and Analytic Hierarchy Process to Measure Efficiency of Tourism Farms: Case of Slovenia	17
<i>Aneta Trajanov, Jaap Schröder, David Wall, Antonio Delgado, Rogier Schulte and Marko Debeljak</i> Assessing the Nutrient Cycling Potential in Agricultural Soils Using Decision Modelling	23
<i>Jožef Vinčec, Karmen Pažek, Črtomir Rozman and Jernej Prišenk</i> Application of Weighted Goal Programming Method for Hybrids Selection of Endives	28
<i>Maja Žibert, Črtomir Rozman, Boris Prevolšek and Andrej Škraba</i> The System Dynamics Model for Diversification of Agricultural Holdings into Farm Tourism	34
<i>Special Session 2: Formal and Behavioral Issues in MCDM</i>	<i>39</i>
<hr/>	
<i>Ayşegül Engin and Rudolf Vetschera</i> Overconfidence in Electronic Reverse Auctions	41
<i>Helena Gasparis-Wieloch</i> A Scenario-Based AHP Method for One-Shot Decisions and Independent Criteria	47
<i>Sławomir Jarek</i> Consistency of Assessments and Reversal of the Ranking in Multi-Criteria Decision Making	53
<i>Nikola Kadoić, Nina Begičević Ređep and Blaženka Divjak</i> Application of PageRank Centrality in Multi-Criteria Decision Making	54
<i>Tadeusz Trzaskalik</i> Bipolar Sorting and Ranking of Multistage Alternatives	60

<i>Tomasz Wachowicz and Ewa Roszkowska</i> Investigating the Self-Serving Bias in Software Supported Multiple Criteria Decision Making Process	66
<i>Tomasz Wachowicz, Ewa Roszkowska and Marzena Filipowicz-Chomko</i> Decision Making Profile and the Choices of Preference Elicitation Mode – A Case of Using GDMS Inventory	72

Special Session 3: Graph Theory and Algorithms **79**

<i>Kolos Csaba Ágoston, Snježana Majstorović and Ágnes Vaskövi</i> Spectral Clustering of Survival Curves	81
<i>Immanuel Bomze, Michael Kahr and Markus Leitner</i> Robust Clustering in Social Networks	87
<i>Sergio Cabello and Éric Colin de Verdière</i> Hardness of Minimum Activation Path	88
<i>Radosław Cymer and Miklós Krész</i> On the Complexity of a Filtering Problem for Constraint Programming: Decomposition by the Structure of Perfect Matchings	94
<i>Boštjan Gabrovšek, Tina Novak, Janez Povh, Darja Rupnik Poklukar and Janez Žerovnik</i> Five Heuristics for the k-Matching Problem	101
<i>Boštjan Gabrovšek, Aljoša Peperko and Janez Žerovnik</i> On the Independent Rainbow Domination Numbers of Generalized Petersen Graphs $P(n, 2)$ and $P(n, 3)$	107
<i>Nicolò Gusmeroli and Angelika Wiegele</i> An Exact Penalty Method over Discrete Sets	113
<i>Sandi Klavžar</i> The General Position Problem on Graphs	115
<i>Tina Novak and Janez Žerovnik</i> k-Fair Domination Problem in Cactus Graphs	116
<i>Darja Rupnik Poklukar and Janez Žerovnik</i> Networks with Extremal Closeness	122
<i>Gregor Rus and Alenka Brezavšček</i> Graph Theory Applications in Computer Network Security: A Literature Review	128
<i>Anja Žnidaršič, Manja Krajncič and Drago Bokal</i> Fraud Detection in Transactions Using Social Network Analysis	135

Special Session 4: High-Performance Computing and Big Data **141**

<i>Agnès Ansari, Alberto Garcia Fernandez, Bertrand Rigaud, Marco Rorro and Andreas Vroutsis</i> Running Deep Learning Experiments over the PRACE 5IP Infrastructure	143
<i>Blaž Gašperlin, Tomi Ilijaš and Mirjana Kljajić Borštnar</i> Opportunities of Cloud High Performance Computing for Smes – A Meta-Analysis	149

<i>Timotej Hrga and Janez Povh</i> Accelerated Alternating Direction Augmented Lagrangian Method for Semidefinite Programs	155
<i>Alen Vegi Kalamar, Drago Bokal and Janez Povh</i> Parallelization of BiqMac Solver	161

Special Session 5: Optimization in Human Environments **167**

<i>Evin Aslan Oğuz and Andrej Košir</i> Multimedia-Content-Index Based Experimental Content Selection	169
<i>Drago Bokal, Robert Repnik, Špela Tertinek, Alen Vegi Kalamar and Tadej Žerak</i> Optimality of Flipped Learning Experience: A Case Study of Using 2-Crossing-Critical Graphs for Early Research Exposure	175
<i>Drago Bokal and Špela Tertinek</i> Bounded Time Availability is What Narrative Incohesion, Behavioral Sink, Behavioral Addiction, and Online Social Bubbles Have in Common	181
<i>Petra Fic and Drago Bokal</i> Innovative Veristic Perceptions do Have a Chance: An Instance of Artificial Technological Valley of Death	187
<i>Ludmila Jánošíková, Peter Jankovič and Stanislav Mikolajčík</i> Demand Point Aggregation in Urban Emergency Medical Service: A Case Study from Slovakia	193
<i>Dean Lipovac, László Hajdu, Sølvi Therese Strømmen Wie and Anders Qvale Nyrud</i> Minimizing Human Stress in Social Networks with Targeted Interventions	199
<i>Andreja Smole, Timotej Jagrič and Drago Bokal</i> Principal-Leader-Follower Model with Internal Signal	205

Special Session 6: System Modelling & Soft Operational Research **211**

<i>Dariusz Banas</i> A Unified Environment for Quantitative and Qualitative Modelling of Dynamic Systems	213
<i>Katarína Cechlárová, Diana Plačková and Tatiana Baltosová</i> Modelling the Kidney Transplant Waiting List	219
<i>Mario Jadrić</i> Framework for Discrete-Event Simulation Modeling Supported by LMS Data and Process Mining	225
<i>Jerzy Michnik</i> IT Service Business Analysis with Balanced Scorecard and Weighted Influence Non-Linear Gauge System	231
<i>Polona Pavlovčič Prešeren and Aleš Marjetič</i> Particle Swarm Optimization in Geodetic Datum Transformation	237

Special Session 7: Towards Industry 4.0

243

<i>Mihael Debevec and Niko Herakovič</i> Digital Twin of Unique Type of Production for Innovative Training of Production Specialists	245
<i>Matic Muc, Vili Malnarič, Jernej Klemenc and Janez Žerovnik</i> Physical Testing of a Trailing Arm by Discrete Optimization	251
<i>Miha Pipan, Jernej Protner and Niko Herakovič</i> Distributed Manufacturing Node Control with Digital Twin	257
<i>Jaka Toman, Uroš Rajkovič and Mirjana Kljajić Borštnar</i> Scrap Determination with Process Mining – Literature Review	263
<i>Tena Žužek, Lidija Rihar, Tomaž Berlec and Janez Kušar</i> Use of a Standard Risk Model and a Risk Map for Product Development Project Planning and Management	269

Session 1: Econometric Models and Statistics

275

<i>Samo Drobne and Marija Bogataj</i> The Role of Local Action Groups for the Optimal Allocation of Investments in the Long-Term Care	277
<i>Samo Drobne and Metka Mesojedec</i> Multi-Constrained Gravity Model of Labour Commuting: Case Study of Slovenia	284
<i>Ksenija Dumičić and Ivana Cunjak Mataković</i> Challenges of Benford's Law Goodness-of-Fit Testing in Discovering the Distribution of First Digits: Comparison of Two Industries	290
<i>Ksenija Dumičić, Berislav Žmuk and Anita Harmina</i> Clusters of European Countries Regarding Recent Changes in Business Demography Statistics	296
<i>Aljaž Ferencek, Mirjana Kljajić Borštnar, Davorin Kofjač, Andrej Škraba and Blaž Sašek</i> Deep Learning Predictive Models for Terminal Call Rate Prediction During the Warranty Period	302
<i>Ljubica Milanović Glavan</i> Determining Business Process Maturity Levels by Using Cluster Analysis: Case of Croatia	308
<i>Petra Tomanová</i> Clustering of Arrivals and Its Impact on Process Simulation	314
<i>Josipa Višić</i> Predicting Future Markets for Personal Service Robots	320
<i>Bože Vuleta, Elza Jurun and Nada Ratković</i> Statistical Analysis of the Public Opinion Survey on Free Sunday	326
<i>Jovana Zoroja, Anton Florijan Barišić and Mirjana Pejic-Bach</i> E-Government Usage in European Countries: Gender and Educational Differences	332

Session 2: Environment and Social Issues **339**

<i>Wellington Alves, Ângela Silva and Helena Sofia Rodrigues</i> Sustainable Practices: An Analysis of Portuguese Companies	341
<i>János Baumgartner and Zoltán Süle</i> Cost Optimal Process Design with Reliability Constraints	347
<i>Petra Grošelj, Lidija Zadnik Stirn and Gregor Dolinar</i> Aggregation of Individual Judgments into Group Interval Judgments in AHP	348
<i>Marek Kvet and Jaroslav Janáček</i> Population Diversity Maintenance Using Uniformly Deployed Set of p-Location Problem Solutions	354
<i>Lorena Mihelač and Janez Povh</i> The Impact of Harmony on the Perception of Music	360
<i>Marija Vuković, Snježana Pivac and Marijana Šemanović</i> Waste Management Consequences - Case Study on the Island of Brač	366

Session 3: Finance and Investments **373**

<i>Kolos Csaba Ágoston, Márton Gyetvai and László Kovács</i> Optimization of Transition Rules Based on Claim Amounts in a Bonus-Malus System	375
<i>Michaela Chocholatá</i> Co-Movements of Exchange Rate Returns: Multivariate Garch Approach	381
<i>Nataša Erjavec, Boris Cota and Saša Jakšič</i> Barriers to International Trade and Export Competitiveness of the EU New Member States	387
<i>Margareta Gardijan Kedžo and Ana Škrlec</i> Are Investment Constraints of Mandatory Pension Funds Restricting their Performance: Case of Croatia	393
<i>Vladimír Holý</i> Score-Driven Count Time Series	399
<i>Marko Jakšič</i> Benefits of Inventory Information Sharing in a Hybrid MTS/MTO System	405
<i>Erzsébet Kovács and Ágnes Vaskövi</i> Rational or Irrational? - Pension Expectations in Hungary	411
<i>Aleš Kresta and Anlan Wang</i> Efficiency Test as the Benchmark for Minimum-Risk Portfolio Optimization Strategies	417
<i>Tihana Škrinjarić and Mirjana Čižmešija</i> Investor Attention and Risk Predictability: A Spillover Index Approach	423
<i>Tihana Škrinjarić and Boško Šego</i> Grey Systems Modeling as a Tool for Stock Price Prediction	429
<i>Petr Volf</i> Optimization of Costs of Preventive Maintenance	435

Session 4: Location and Transport, Graphs and their Applications **441**

<i>Francisco Campuzano-Bolarín, Fulgencio Marín-García, José Andrés Moreno-Nicolás, Marija Bogataj and David Bogataj</i> Evaluation of Net Present Value in Supply Chains Using Network Simulation Method	443
<i>Samo Drobne, Alberto Garre, Eloy Hontoria and Miha Konjar</i> Functional Regions Detection by Walktrap and Chains' Methods	449
<i>Dobroslav Grygar and Michal Kohani</i> Data Conversion and Exact Approach to Overhead Wires Network Minimisation for the Battery Assisted Trolleybus Fleet	455
<i>Slobodan Jelić</i> RealForAll Pollen Semaphore: A Short-Term Prediction System for Airborne Pollen Concentrations Based on Neural Nets	461

Session 5: Mathematical Programming and Optimization **467**

<i>Aua-aree Boonperm and Wutiphol Sintunavarat</i> An Artificial-Variable-Free Simplex Method Involving the Choices of Initial Solutions	469
<i>Zsolt Darvay, Petra Renáta Rigó and Eszter Szénási</i> Infeasible Interior-Point Algorithm for Linear Optimization Based on a New Search Direction	475
<i>Balázs Dávid</i> A Tabu Search Method for Optimizing Heterogeneous Structural Frames	481
<i>Marianna E.-Nagy</i> Linear Complementarity Problem and Sufficient Matrix Class	487
<i>Milan Hladík</i> Interval Robustness of Matrix Properties for the Linear Complementarity Problem	488
<i>Jaroslav Janáček and Marek Kvet</i> Usage of Uniformly Deployed Set for P-Location Min-Sum Problem with Generalized Disutility	494
<i>Dragan Jukić and Kristian Sabo</i> An Existence Criterion for the Sum of Squares	500
<i>Miroslav Rada, Elif Garajová, Jaroslav Horáček and Milan Hladík</i> A New Pruning Test for Parametric Interval Linear Systems	506
<i>Anita Varga, Marianna E.-Nagy and Tibor Illés</i> Interior Point Heuristics for a Class of Market Exchange Models	512

Session 6: Multi-Criteria Decision-Making **513**

<i>Andrej Bregar</i> Experimental Evaluation of Multiple Criteria Utility Models with Veto Related Preference Structures	515
<i>Rok Drnovšek, Marija Milavec Kapun, Vladislav Rajkovič and Uroš Rajkovič</i> Multi-Attribute Risk Assessment Model for Developing Ventilator-Associated Pneumonia	523

<i>Shiang-Tai Liu</i> A Heuristic Algorithm Approach to Imprecise Malmquist Productivity Index	529
<i>Josip Matejaš, Tunjo Perić and Danijel Mlinarić</i> On Sustainable Principles in Multi Objective Programming Problems	535
<i>Tunjo Perić, Zoran Babić and Slavko Matanović</i> Decision Making in Complex Decentralized Business Systems by Multi-Level Multi-Objective Linear Programming Methods	541
<i>Srečko Zakrajšek, Eva Jereb, Uroš Rajkovič, Vladislav Rajkovič and Mojca Bernik</i> A Multi-Criteria, Hierarchical Model for the Evaluation of Scenarios that Facilitate the Development of Digital Competences of Gymnasium Students in the Republic of Slovenia	547

Session 7: Human Resources **553**

<i>Andrea Furková and Michaela Chocholatá</i> Spatial Interactions and the Regional Employment in the EU	555
<i>Blaženka Knežević, Petra Škrobot and Berislav Žmuk</i> Perceptions on Social Supermarkets' Managers in Croatia, Lithuania, Poland and Serbia	561
<i>Maja Rožman and Vesna Čančer</i> Structural Equation Modeling in the Case of Older Employees in Financial Service Companies	567
<i>Berislav Žmuk and Anita Čeh Časni</i> Nonresponse in Business Web Surveys: Sources and Measures	573

Session 8: Production and Management **579**

<i>Helena Brožová, Tomáš Šubrt, Jan Rydval and Petra Pavličková</i> Fuzzy Threatness Matrices in Project Management	581
<i>Liljana Ferbar Tratar and Ansari Saleh Ahmar</i> The Comparison of Holt-Winters Methods and A-Sutte Indicator in Forecasting the Foreign Visitor Arrivals in Indonesia, Malaysia, and Japan	587
<i>Vedran Kojić and Zrinka Lukač</i> On the Cost Minimization Problem with CES Technology: Reverse Hölder's Inequality Approach	593
<i>Vedran Kojić, Zrinka Lukač and Krunoslav Puljić</i> On the Properties of the Sato Production Function	599
<i>Ângela Silva, Wellington Alves and Helena Sofia Rodrigues</i> Level of Implementation of Lean Manufacturing Tools: A Case Study in the North of Portugal	605
<i>Ilko Vrankić, Mirjana Pejić Bach and Tomislav Herceg</i> Cooperativeness in Duopoly from an Evolutionary Game Theory Perspective	611

APPENDIX **617**

<i>Authors' addresses</i>	
<i>Sponsors' notices</i>	

LEVEL OF IMPLEMENTATION OF LEAN MANUFACTURING TOOLS: A CASE STUDY IN THE NORTH OF PORTUGAL

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Abstract: Nowadays business environment is very unstable, complex and requires a quick response from the companies, with a better allocation of their scarce resources, and a clearer strategic focus. The Lean Manufacturing requires that companies make the best use of their resources eliminating wastes. In this research, in order to evaluate the level of implementation of Lean tools in the companies located in the North of Portugal, an online survey was conducted. Results show that the 5S and TPM methods are the ones that have higher progress of implementation, and the Kanban tool has a lower level.

Keywords: Lean Management, 5S, Kanban, Kaizen, Just in time

1 INTRODUCTION

The instability of the business market and the growth of companies supply chain has been improved the organization's performance to become more efficient, flexible and faster to answer first to the changes in the business environments.

Lean Manufacturing plays an important role in supporting companies to overcome environmental, social and economic impacts attributed to the production processes, which has been a major concern for the industrial sector lately.

The Lean philosophy promotes efficiency and elimination of waste, focusing on a high customer service level. Based on that, Lean tools have been adopted by many companies to best improve their operations. Implementation of Lean manufacturing tools in any type of organizations can bring many benefits, such as waste reduction and improving operating efficiency [2]–[6]. This shows that Lean is not limited to one type or size of the company, but rather all types, sizes and industries that attempt to increase their competitive advantages, operations and profits in the regional and global markets [2]. However, in the literature, some studies were made suggesting that the implementation of the Lean Manufacturing concepts in industries are different in function of their dimension.

In this research, to evaluate the level of implementation of Lean tools in different types and dimension companies, an online survey was conducted with a set of companies from the North of Portugal. Then, Lean issues and practices such as Kaizen philosophy, 5S (Sort/Set in order/Shine/Standardize/Sustain), Total Productive Maintenance (TPM), Kanban, Just in time (JIT), stock reduction, Kaizen circles and collaboration with suppliers were analysed.

2 LITERATURE REVIEW

Lean Manufacturing is focused on the reduction of waste and improvement of operational efficiency using a set of different tools to get these objectives. Many of these tools can be successfully used in isolation, which makes it much easier to get started, but on the other hand, the benefits will propagate as more tools are used, as they do support and reinforce each other.

In the literature, some studies demonstrate the influence of the application of the Lean methods and tools in different performance indicators: Belekoukias *et al.* [9] have analysed the impact of Lean methods and tools on the operational performance of manufacturing organisations and the results indicate that JIT and Autonomation have the strongest significance on operational performance while Kaizen, TPM and value stream mapping (VSM) seem to have a lesser, or even negative, effect on it. More recently Garza-Reyes *et al.* [10] investigate the effect of the same five essential Lean methods, i.e., JIT, Autonomation, Kaizen/continuous improvement, TPM and VSM, on four commonly used indicators for the compliance of environmental performance, i.e., material use, energy consumption, non-product output, and pollutant releases.

Regarding the implementation of the Lean tools based on the companies' dimension, the large amount of research was focused on large scale organizations. More recently, the research on Lean concepts applications in Small, Medium Enterprises (SME) is increasing ([2], [12], [13]), due to the existence of a large number of these organization in the global territory [8].

There are many Lean methods and tools that can be used to improve the organization's performance. One of these consists in the JIT method [14]; the authors suggest that JIT is playing a significant role to achieve a high service level at a minimum cost. As mentioned, the TPM and Kaizen/continuous improvement methods also have a huge impact on the organization's performance. Different tools are used to implement these methods. The 5S, for example, is a simple tool which develops discipline and cleanliness at the workplace, maximizing efficiency and productivity.

Another important aspect related to Lean implementation is related to the close relationship between human resources and all the supply chain elements (suppliers, partners, and clients). The involvement of the top managers and the engagement of the workers in the implementation process is very important to get the performance objectives intended [15].

To evaluate the level of implementation of Lean tools in different companies dimension, in the North of Portugal, a survey was developed. It was implemented to a sample of 120 organizations, from micro to large scale dimension, focusing in a specific group of 9 methods and tools identified as Engagement of workers, Continuous Improvement, 5S, TPM, Kanban, JIT, Stock Reduction, Kaizen Circles, and Suppliers Relationship.

3 METHODOLOGY

To study the level of implementation of lean procedures in a set of Portuguese companies, a survey was conducted. The questionnaire was designed based on the work developed by Jabbour *et al.* [16]. The questionnaire consisted of two parts; the first contains general questions about the characterization of the companies, such as dimension, number of employees related to logistics, and turnover. The second part, the main one, consists of nine Lean attributes (Table 1). Each company was asked to rate their level of implementation of lean practices, with each item on a five-level Likert scale, from 1 (Not implemented) to 5 (Completely implemented).

The sample taken is a convenient one due to time and budget constraints. Companies were asked their willingness to fill out the questionnaire, published online through Google Docs forms, and 102 answers were obtained from multisector companies.

Table 1: Level of "Lean Management" practices

Question	Description
LM1	Engagement of workers
LM2	Continuous improvement
LM3	5S (Sort/Set in order/Shine/Standardize/Sustain)
LM4	Total productive maintenance (TPM)
LM5	Kanban (pull system)
LM6	Just in Time (JIT)
LM7	Stock reduction
LM8	Kaizen Circle (discussion groups to improve processes)
LM9	Collaboration with suppliers

4 ANALYSIS OF THE RESULTS

An analysis and discussion of the results were made, using a statistical approach through the software IBM SPSS version 24.

4.1 Sample characterization

The selected companies had a large spectre of characteristics, as summarized in Table 2. The results showed that the dimension of the companies related to the number of workers is very heterogeneous. More than 50% of the companies had a micro or small dimension, meeting the Portuguese business fabric.

Regarding the number of employees associated with the logistics area, it is possible to observe that a large number of companies had up to three workers associated with this field. It should be noted that the companies inquired are multisector, so this value is within the expected. Besides, a great number of companies had a turnover, by year, more than five million euros (36.3%).

Table 2: Technical record of participating companies

Dimension on the company (number of employees)	Percent	Number of employees associated with logistics	Percent	Turnover (in euros)	Percent
Micro (up to 10)	32.4	[0;3[	34.3	[0;100k[	13.7
Small (10-50)	25.5	[3;6[	20.6	[100k; 250k[	10.8
Medium (50-250)	16.7	[6;9[	5.9	[250k; 500k[	9.8
Large (more than 250)	25.5	[9;12[	9.8	[500k; 1M[	10.8
		[12;15[	2.0	[1M; 5M[	18.6
		15 or more	27.5	5M or more	36.3

4.2 Lean management practices

Lean management practices should be implemented by managers, who are trained in lean concepts, and they are passed on throughout the organization. To understand the level of Lean procedures in Portuguese companies, there were pointed out nine questions. Table 3 compiles some descriptive statistics related to these procedures. For all items, the five points Likert scale achieve the highest score (five), meaning that the level of implementation of the environmental practices is unequal between companies.

For the case of practices LM3 and LM4 are the ones that have higher means values, meaning more progress of implementation. On the other hand, the lowest means values are related to the procedures LM5 and LM1. This could be explained by the fact that the 5S tool and the TPM method are considered hard lean practices which are more extensively used than soft Lean practices (Engagement)[15]. Also, the 5S is a simple implementation tool which allows

rapid results with high visual impacts, consisting on the first tool to use for clean and straighten the workplace.

Table 2: Descriptive statistics for Lean management practices

<i>Environment managment practices</i>	<i>Min</i>	<i>Max</i>	<i>Mean</i>	<i>St. Dev.</i>
LM1	1	5	2.49	1.481
LM2	1	5	3.12	1.381
LM3	1	5	3.20	1.328
LM4	1	5	3.42	1.238
LM5	1	5	2.25	1.369
LM6	1	5	2.65	1.426
LM7	1	5	3.16	1.241
LM8	1	5	2.63	1.400
LM9	1	5	3.06	1.296

Figure 1 shows the boxplots for all questions. This graphic is according to Table 3, giving information about the use of the entire scale. Besides, 50% of inquired companies, partially implemented (level 3) the practices LM6 to LM9. All these practices are related to Production Pull System which requires the collaborations with the suppliers and the implementation of JIT method, getting stocks reduction. The enterprises that are trying to implement the Pull System should implement all these methods and tools at the same time, on the same level. In contrast, practice LM5 has a lower level of implementation, where 50% of companies selected levels 1 (not implemented) or 2 (starting to implement). The methods like Kanban, JIT are used by large companies and international groups generates a certain fear and barrier [7] Another curiosity is that only 25% of the companies have selected the full achievement/implementation of these practices.

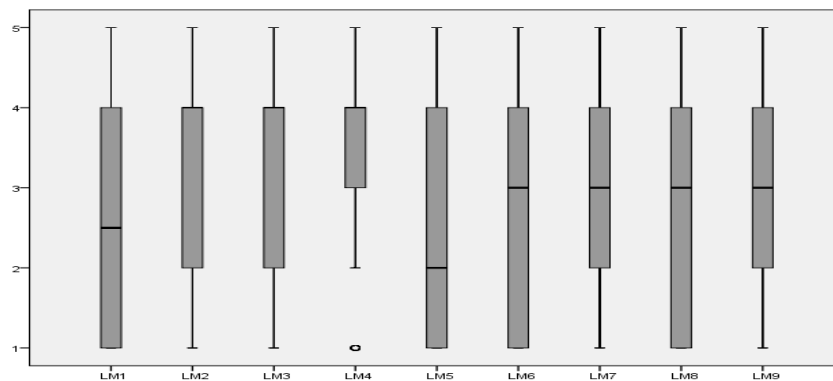


Figure 1: Boxplots of Lean management practices

In order to understand how these practices are correlated, Table 4 is presented. The correlations between items are not very high. However, the item LM4 stands out to the correlation with LM2 and LM3. TPM supports the predictive, preventive and corrective maintenance activities to achieve efficient production equipment and relies on tools such as 5S, single minute exchange of die (SMED), overall equipment effectiveness (OEE), planned, autonomous and quality maintenance and initial control before starting production [10].

Another important question related to this theme, is the level of implementation of Lean practices, according to the numbers of workers. According to Matt and Rauch [7], the Lean production methods and instruments are not equally applicable to large and small companies. Consequently, the level of accomplishment of Lean procedures was also analyzed, taking into consideration the dimension of the company.

Table 3: Matrix correlation between environment management practices [For all values, correlation is significant at the 0.01 level (2-tailed)].

Item	LM1	LM2	LM3	LM4	LM5	LM6	LM7	LM8	LM9
LM1	1								
LM2	0.591	1							
LM3	0.625	0.576	1						
LM4	0.572	0.671	0.696	1					
LM5	0.558	0.518	0.555	0.491	1				
LM6	0.660	0.464	0.675	0.489	0.655	1			
LM7	0.572	0.532	0.600	0.607	0.454	0.586	1		
LM8	0.528	0.633	0.530	0.537	0.587	0.385	0.581	1	
LM9	0.398	0.560	0.505	0.435	0.388	0.338	0.407	0.695	1

The results presented in Figure 2, show from the consulted companies, micro and small companies have the lowest levels of implementation of Lean procedures, which can be justified by the fact that these companies do not feel the need to implement these systems to be productive. Another explanation is related to the challenge of the implementation of some integrated Lean production systems due to specific knowledge and money spent.

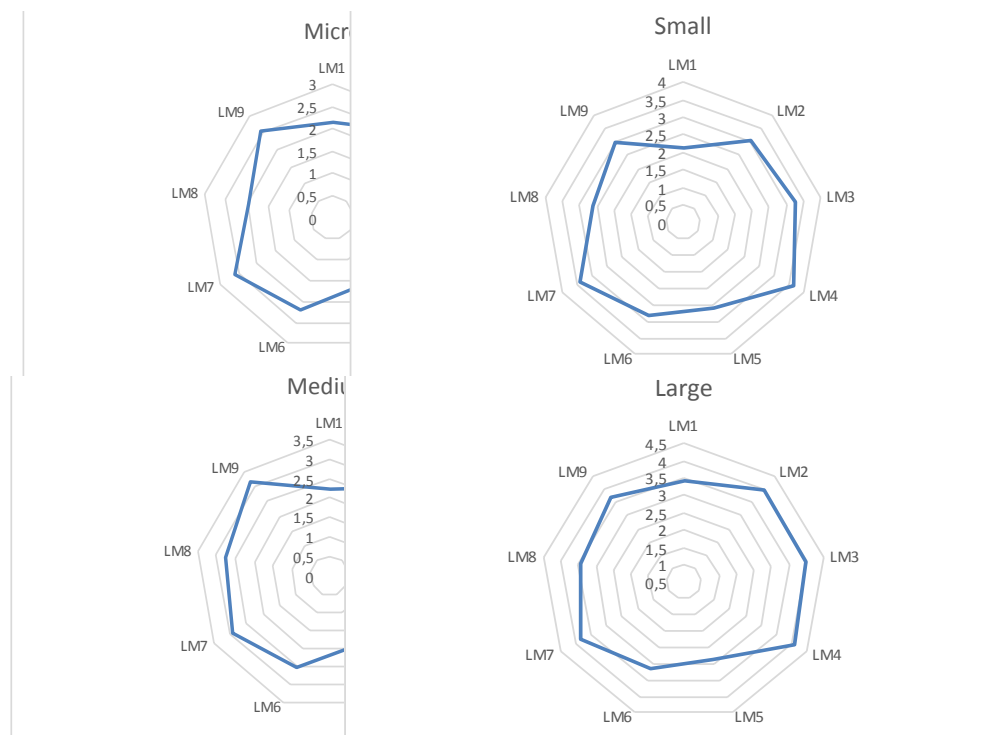


Figure 2: Average level of environment management practices, by companies' dimension

5 CONCLUSIONS

In this work, it was possible to analyze the implementation level of Lean practices in the North of Portugal. Despite being an initial analysis, the results showed the 5S and TPM methods are the ones that have higher progress of implementation, and the kanban tool has a lower level of implementation, in general. It is also possible to conclude that micro and small companies have the lowest levels of implementation of Lean procedures.

Acknowledgement

This research was supported by the FCT – Fundação para a Ciência e Tecnologia, through the project UID/EMS/04005/2019 (Silva); the project UID/CEC/00319/2019 (Alves); and the project UID/MAT/04106/2019 (Rodrigues).

References

- [1] M. A. Lewis, “Lean production and sustainable competitive advantage,” *Int. J. Oper. Prod. Manag.*, vol. 20, no. 8, pp. 959–978, Aug. 2000.
- [2] A. Alkhorairif, H. Rashid, and P. McLaughlin, “Lean implementation in small and medium enterprises: Literature review,” *Oper. Res. Perspect.*, no. December, p. 100089, 2018.
- [3] N. Cardoso, A. C. Alves, M. Figueiredo, and A. Silva, “Improving workflows in a hospital through the application of lean thinking principles and simulation,” *Proceedings Int. Conf. Comput. Ind. Eng. CIE*, no. October, pp. 11–13, 2017.
- [4] V. Resende, A. C. Alves, A. Batista, and Â. Silva, “Financial and human benefits of lean production in the plastic injection industry: An action research study,” *Int. J. Ind. Eng. Manag.*, vol. 5, no. 2, pp. 61–75, 2014.
- [5] J. A. Garza-Reyes, V. Kumar, S. Chaikittisilp, and K. H. Tan, “The effect of lean methods and tools on the environmental performance of manufacturing organisations,” *Int. J. Prod. Econ.*, vol. 200, 2018.
- [6] I. Belekoukias, J. A. Garza-Reyes, and V. Kumar, “The impact of lean methods and tools on the operational performance of manufacturing organisations,” *Int. J. Prod. Res.*, vol. 52, no. 18, pp. 5346–5366, Sep. 2014.
- [7] D. T. Matt and E. Rauch, “Implementation of Lean Production in small sized Enterprises,” *Procedia CIRP*, vol. 12, pp. 420–425, 2013.
- [8] A. D. Jewalikar and A. Shelke, “Lean Integrated Management Systems in MSME Reasons, Advantages and Barriers on Implementation,” in *Materials Today: Proceedings*, 2017, vol. 4, no. 2, pp. 1037–1044.
- [9] I. Belekoukias, J. A. Garza-Reyes, and V. Kumar, “The impact of lean methods and tools on the operational performance of manufacturing organisations,” *Int. J. Prod. Res.*, vol. 52, no. 18, pp. 5346–5366, 2014.
- [10] J. A. Garza-Reyes, V. Kumar, S. Chaikittisilp, and K. H. Tan, “The effect of lean methods and tools on the environmental performance of manufacturing organisations,” *Int. J. Prod. Econ.*, 2018.
- [11] A. K. Möldner, J. A. Garza-Reyes, and V. Kumar, “Exploring lean manufacturing practices’ influence on process innovation performance,” *Journal of Business Research*, 2018.
- [12] A. Pearce, D. Pons, and T. Neitzert, “Implementing lean—Outcomes from SME case studies,” *Oper. Res. Perspect.*, vol. 5, pp. 94–104, 2018.
- [13] M. Almani, K. Salonitis, and Y. Xu, “Lean Implementation Frameworks: The Challenges for SMEs,” *Procedia CIRP*, vol. 63, pp. 750–755, 2017.
- [14] S. Abdul, R. Khan, D. Qianli, and Y. Zhang, “A Survey Study : Important Factors in Just-in-Time Implementation,” *Traffic Transp. Eng.*, vol. 2, no. 5, pp. 74–80, 2017.
- [15] Y. Larteb, A. Haddout, and M. Benhadou, “Successful Lean Implementation: The Systematic and Simultaneous Consideration of Soft and Hard Lean Practices,” *Int. J. Eng. Gen. Sci.*, vol. 3, no. 2, pp. 1258–1270, 2014.
- [16] A. B. L. de S. Jabbour, C. J. C. Jabbour, W. R. de S. Freitas, and A. A. Teixeira, “Lean and green?: evidências empíricas do setor automotivo brasileiro,” *Gestão & Produção*, vol. 20, no. 3, pp. 653–665, 2013.