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Preface

This volume, Proceedings of the 16th International Symposium on Operational Research, called SOR'21, contains papers presented at SOR'21 (https://sor.fov.um.si/), organised by Slovenian Society INFORMATIKA (SDI), Section for Operational Research (SOR), University of Maribor, Faculty of Organisational Sciences, Kranj, Slovenia (FOV), and University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia (UL FS). The SOR'21 symposium, held 22-24 September 2021, was originally planned to take place in Bled, Slovenia, but was moved online due to the situation of COVID-19 in Slovenia and beyond. The volume contains blind peer-reviewed papers or abstracts of papers presented at the symposium.

The opening address at SOR'21 was given by Prof. Dr. Lidija Zadnik Stirn, President of SOR, Mr. Niko Schlamberger, President of SDI, representatives of FOV and UL FS, Prof. Dr. Mario Jadrić, President of Croatian Operational Research Society (CRORS), Dr Sarah Fores, manager of The Association of European Operational Research Societies (EURO), and presidents/representatives of some others Operational Research Societies from abroad.

SOR'21 is the scientific event in the field of Operational Research, another in the traditional series of biennial international OR conferences organised in Slovenia by SDI-SOR. It is the continuation of fifteen previous symposia. The main objective of SOR'21 is to promote knowledge, interest and education in the field of OR in Slovenia, Europe and worldwide in order to build the intellectual and social capital essential for maintaining the identity of OR, especially at a time when interdisciplinary cooperation is proclaimed as particularly important for solving problems in today's challenging times. By joining IFORS and EURO, the SDI-SOR has also agreed to collaborate with different disciplines, i.e., to balance the depth of theoretical knowledge in OR and the understanding of theory, methods, and problems in other fields within and outside OR. We believe that SOR'21 creates the advantage of these goals, contributes to the quality and reputation of OR by presenting and sharing new developments, opinions and experiences in the theory and practise of OR.

SOR'21 was highlighted by five distinguished keynote speakers. The first part of Proceedings SOR'21 contains invited abstracts, presented by five outstanding scientists: Assist. Prof. Nikolina Ban, University of Innsbruck (UIBK), Department of Atmospheric and Cryospheric Sciences, Innsbruck, Austria, Assist. Prof. Vedran Kojić, University of Zagreb, Faculty of Economics & Business, Zagreb, Croatia, Prof. Panos Patrinos, KU Leuven, Department of Electrical Engineering (ESAT), STADIUS Center for Dynamical Systems, Signal Processing and Data Analytics, Leuven, Belgium, Prof. Suresh P. Sethi, Eugene McDermott Chair Professor of Operations Management, Director, Center of Intelligent Supply Networks, Naveen Jindal School of Management, The University of Texas at Dallas, Dallas, USA, and Prof. Jerneja Žganec Gros, Alpineon Ltd, Ljubljana, Slovenia.

The Proceedings includes 118 papers or abstracts by 240 authors. Most of the authors of the contributed papers came from Slovenia (82), then Croatia (52), Hungary (23), Portugal (23), Serbia (17), Poland (9), Czech Republic (8), Slovak Republic (7), Spain (6), Netherlands (4), Bosnia and Herzegovina (2), Austria (1), Belgium (1), France (1), Germany (1), Romania (1), Ukraine (1), United Kingdom (1), and United States of Amerika (1). The papers published in the Proceedings are divided into Plenary Lectures (5 abstracts), eleven special sessions: Application of Operational Research in Smart Cities (6 papers), Computational Mathematical Optimization (7 papers and 6 abstracts), Data Science – Methodologies and Case Studies (10 papers), Graph Theory and Algorithms (2 papers), *High-Performance Computing and Big Data (3 papers), Industry & Society 5.0: Optimization in Industrial and Human Environments (6 papers), International Projects in Operations Research (2 papers), Lessons Learned from the COVID-19 Pandemic: Applications of Statistical and OR Methods (8 papers), Logistics and Sustainability (9 papers), Operational Research in Ageing Studies and Social Innovations (5 papers), Operations Research in Agricultural Economics and Farm Management (5 papers), and eight sessions: Econometric Models and Statistics (6 papers), Environment and Social Issues (5 papers), Finance and Investments (6 papers), Location and Transport, Graphs and their Applications (5 papers), Mathematical Programming and Optimization (5 papers and 1 abstract), Multi-Criteria Decision-Making (10 papers), Theory of Games (3 papers), and Problems Approaching OR (3 papers).*

Proceedings of the previous fifteen International Symposia on Operational Research organised by the Slovenian Section on Operational Research, listed at https://www.drustvo-informatika.si/sekcije/sor/sor-publikacijepublications/, are indexed in the following secondary and tertiary publications: Current Mathematical Publications, Mathematical Review, Zentralblatt fuer Mathematik/ Mathematics Abstracts, MATH on STN International and CompactMath, INSPEC. It is expected that Proceedings SOR'21 will be covered by the same bibliographic databases.

The success of the scientific events at SOR'21 and of the present conference proceedings should be seen because of joint efforts. On behalf of the organisers, we would like to express our sincere gratitude to all those who assisted us in the preparation of the event. Without the dedicated and advice of the active members of the Slovenian Operations Research Section, we would not have been able to attract so many top-class speakers from all over the world. Many thanks to them. In addition, we would like to express our deepest gratitude to the prominent keynote speakers, the members of the Programme and Organising Committees, the reviewers who improved the quality of SOR'21 with their useful suggestions, the section chairs and all the numerous people - far too many to list individually here - who helped in organizing of the 16th International Symposium on Operational Research SOR'21 and compiling this proceedings. Finally, we thank the authors for their efforts in preparing and presenting the papers that made the 16th Symposium on Operational Research SOR'21 a success.

We would like to give special thanks to the Partnership for Advanced Computing in Europe (PRACE) for their financial support.

Ljubljana and Kranj, September 22, 2021

Samo Drobne
Lidija Zadnik Stirn
Mirjana Kljajić Borštnar
Janez Povh
Janez Žerovnik
(Editors)

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The 16th International Symposium on
Operational Research in Slovenia

SOR '21

September 22 - 24, 2021, Online

Plenary Lectures

MOUNTAIN CLIMATE AT THE KILOMETER-SCALE GRID SPACING

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Abstract: Mountains play a major role in shaping the weather and climate of the world. However, the current understanding of mountain climate and how it will change with further warming of the atmosphere is still very limited. The uncertainty is in large part related to the coarse grid spacing of current climate models (12-50 kilometres in regional and >50 kilometres in global climate models), which are not able to properly represent the complex mountainous orography and related processes. Thus, employing climate models with a kilometre-scale grid spacing provides a promising path.
In this work, we use the COSMO (COnsortium for Small-Scale MOdelling) climate model (COSMO-CLM) that is capable of using Graphics Processing Units (GPUs), thus providing a significant performance increase in comparison to its standard version, which runs on CPUs. The model is run on Piz Daint (Cray XC50 with Nvidia Tesla P100 GPUs) system at the Swiss National Supercomputing Center, thanks to the computing resources awarded through the PRACE project.
In this presentation, I will present simulations performed with a horizontal grid spacing of 2.2 km over the region of Europe (focus on European Alps) and High Mountain Asia (HMA). The simulated domains, with 1542x1542 and 2640x1475 grid points for Europe and HMA, respectively, are unprecedented in their size and resolution for climate simulations of these regions in general and COSMO-CLM applications in particular. The focus of the presentation will be on the model performance and evaluation in present-day climate, as well as future climate simulations of extreme events like heavy precipitation.

APPLICATION OF BASIC MATHEMATICAL INEQUALITIES TO SELECTED PROBLEMS IN ECONOMICS

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Abstract: Although differential calculus is a powerful and often inevitable technique for solving numerous optimization problems, it is not always easy to implement. Therefore, many researchers propose different non-calculus methods as complementary tools in finding the optimal solution to certain problems whenever possible. In this talk, we give a short survey of an extensive research dealing with the application of mathematical inequalities when solving the economic order quantity (EOQ) inventory problems. Moreover, we present some ideas on how mathematical inequalities can be used as an easy-to-apply and simple-to-understand method to compute the global optimum, not only for EOQ models but for selected problems in microeconomics as well. We also give some guidelines for improving mathematical education by using mathematical inequalities as a non-calculus optimization method.

Keywords: optimization, non-calculus method, mathematical inequalities, economics, mathematical education

ALGORITHMS FOR LARGE-SCALE STRUCTURED NONCONVEX OPTIMIZATION

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Abstract: Optimization problems are ubiquitous in many engineering and science disciplines, such as machine learning, signal processing, data science, communications, control and robotics. Optimization methods have to cope well with the demanding requirements of modern applications. These include handling large numbers of variables and constraints, being amenable to distributed computations and finally being able to cope with nonconvexity, typically encountered in applications such as deep learning. In fact, it is has long been recognized that the great watershed in optimization is between convexity and non convexity. However, in recent years important progress has been made in bridging these two fields. On one hand, it has been recently discovered that certain structured nonconvex problems posses benign landscapes which means they are easier to solve to global optimality. On the other hand, numerical algorithms that have been traditionally developed under the realm of convexity, have had recently many successes in nonconvex optimization. In this talk, I will present highlights of these achievements and focus on our recent work on provably convergent algorithms for nonconvex, nonsmooth, large-scale optimization, as well as ways of accelerating them. The key enabler for these advancements is the concept of proximal envelopes. Examples coming from the fields of machine learning, signal processing and control of autonomous systems will be presented.

MANAGING WITH INCOMPLETE INVENTORY INFORMATION

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Abstract: A critical assumption in the vast literature on inventory management has been that the current level of inventory is known to the decision maker. Some of the most celebrated results such as optimality of base-stock have been obtained under this assumption. Yet it is often the case in practice that the decision makers have incomplete or partial information about their inventory levels. The reasons for this are many: Inventory records or cash register information differ from actual inventory because of a variety of factors including transaction errors, theft, spoilage, misplacement, unobserved lost demands, and information delays. As a result, what are usually observed are some events or surrogate measures, called signals, related to the inventory level. At best, these relationships may provide only the distribution of current inventory levels. In the best case, therefore, the relevant state in the inventory control problems is not the current inventory level, but rather its distribution given the observed signals. Thus, the analysis for finding optimal production or ordering policies takes place generally in the space of probability distributions. The purpose of this talk is to review recent developments in the analysis of inventory management problems with incomplete information.

SPEECH SYNTHESIS IN LANGUAGE DIGITISATION: THE SLOVENIAN USE CASE

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Abstract: In an attempt to increase user experience when using digital products and services, it is crucial to improve the interaction with smart devices using multimodal user interfaces. Speech represents one of the most natural ways of interaction. In order to successfully develop and use speech-enabled user interfaces, effective and high-quality components of the speech dialogue system need to be provided: accurate automatic speech recognition and high-quality, intelligible, and natural-sounding speech synthesis. Here we quickly encounter a constantly widening gap between technologically "supported" and "unsupported" languages; that is, between languages where users can use advanced speech and language technology solutions and those that are more or less "useless" for these purposes. The role of speech technologies in digitisation of language technology products and services will be presented and demonstrated for the Slovenian use case, along with relevant ethical aspects.

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Special Session 1:

Application of Operational Research in Smart Cities

EXAMINING THE GAP BETWEEN SMART CITY DEFINITIONS AND SMART CITY INDEXES: A CALL TOWARDS UNIFIED INDEX

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Abstract: The concept of smart cities is evolving faster and faster. More and more cities claim to have smart initiatives, and it is difficult to compare the success of individual initiatives as well as the maturity of such a city, as there is no generally accepted measure. This article highlights the issue of defining the concept of smart cities and the problem of non-compliance of their index components with their definitions. It presents the foundation for future research and opportunities to improve the existing indexes of a smart city. Analysis of 170 components of the relevant indexes shows that indexes extend to common areas, however in some places they overlap. Despite reviewing many smart city definitions and indexes, the paper focuses on the key or most commonly used ones. Combining components within one index would be a suitable solution to eliminate the repeating. The most optimal solution for researchers is to combine index components that exclude the size of the city.

Keywords: smart city index, smart city definitions, DESI, SCI, CIMI

1 INTRODUCTION

In the past years, the world's population has been growing rapidly. As the population grows, so do the cities, populated by more and more highly educated and intellectually active citizens, establishing diverse personal networks [5]. These actions are often associated with the phenomenon called urbanization, which can either help us in the light of the future or lead us into disappointing path problems [15]. Smart cities, which stem from rapid urbanization, appeared as a possible solution to sustainability problems.

The concept of a smart city goes beyond as it also involves smaller municipalities and towns. Given the popularity of the concept, there are a number of initiatives by place to transform places into smart habitats. As a result, many places are self-flagged as smart, as there is no single system for assessing the maturity of the places. Yet there hasn't been a unified index that measures the level of its smartness. Although the smart city concept is becoming popular, it is hard to identify what smartness means as there are numerous definitions of a smart city. Definitions of different authors contain different components, therefore there is no consistency [9].

At this point, we highlight the need for further research to focus on how to define the city as smart. In the following, we highlight what is missing and what is necessary to focus on. All of the research consists of similar dimensions of smart city and components, which depend on the size of the city. This research aims to review the definitions of smart cities and existing indexes and to aggregate their components in such a way as to exclude the size of the city. The definitions presented are taken from academic papers and institutes definitions, which ensures representativeness.

In the Literature review, we present how individual authors and studies define smart city's components. Further on are presented selected indexes and a comparison of their components. The analysis procedure is described in the Research Methodology, while the results and recommendations for further research are explained in the Results and Discussion section. Finally, the research is summarized in the Conclusion.

2 LITERATURE REVIEW

2.1 Elements of a smart city

Numerous authors identify Urban Infrastructure as one of the crucial components for defining smart cities as it improves urban economic development as well as addresses urban social progress. It covers crucial infrastructure connected with energetics, water supply, transportation, sanitation, communication and infrastructure that deals with damage prevention [3, 4, 14, 10, 13]. Different studies also incorporate the ecological aspect into the Environment component, emphasizing the conservation of natural resources and the environment, and also promoting the production of clean energy [11, 13]. Generally, all these studies promote the principles of sustainable development. The attractiveness of the natural environment, the level of pollution, activities in the field of environmental protection, and resource management methods are stated as criteria for the component Smart Environment [15]. The carrier of intergenerational capital is the Sustainability component. Sustainable orientation is considered as care for the environment, which includes e.g. preserving the natural environment and reducing the use of non-renewable resources, as well as the social aspect, namely the preservation of economic diversity, the preservation of community autonomy, the well-being of citizens, and also the satisfaction of basic human needs [12, 13].

Another important component included in the definitions is also the Economy referring mainly to the competitiveness of the city, which is defined by factors such as productivity, innovation, and flexibility of the labour market [11, 13]. Moreover, Citizens as a component present important stakeholder, as they build social capital and connect with the active presence in public life into the wider ecosystem [1, 2, 11-13]. One of the components is Government. With open data, which also influences more transparent public information, smart government motivates citizens to participate in public life as they are more included [11, 12]. Component Technology consists of ICT and its elements (wireless sensor networks, IoT, AI, etc.). It is vital for the building and maintenance of a smart city as it embraces each of its elements [7, 10, 12, 14, 15]. By setting up and providing infrastructure and transportation, the component Smart mobility supports technology (ICT) and all other smart city systems [11]. The component Quality of Life aims at improving the quality of life for their citizens through the use of smart technologies [1, 7, 12]. The component Open data includes gathering data from smart technologies and allows citizens to collect data through the use of smart software [1, 12].

Definitions of smart cities differ by various studies, as is shown in Table 1 representing important definitions together with main components.

Table 1: Definitions of a smart city by different authors and their recognized components.

Author	Definition	Components of definitions
Academic definitions		
[10]	"Smart city is a city that uses digital technology and ICT to manage urban infrastructure."	Technology, Urban Infrastructure
[13]	"Smart city is a concept of urban transformation that should aim to achieve a more environmentally sustainable city with a higher QoL … enabled by various types of technologies."	Urban Infrastructure, Environment, Sustainability, Economy, Citizens
[12]	The smart city contains the following components: "Architecture to sense economic information by/from citizens for QoL … Systems to process environmental data by governments ... Policies to communicate technical knowledge… Processes to translate political information to citizens."	Quality of Life, Citizens, Open Data, Environment, Sustainability, Government, Technology
[11]	"Smart city is when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high QoL with a wise management of natural resources, through participatory governance."	Economy, Citizens, Government, Mobility, Environment, Quality of Life

[3]	"A city's networked infrastructure that enables political efficiency, social and cultural development, emphasizing urban growth … social capital in urban development … the natural environment as a strategic component for the future."	Government, Urban Infrastructure, Citizens, Environment
[15]	"The goal of the smart city concept is modern urban management using technical tools that offer state-of-the-art technologies, considering the applicable ecological standards while saving resources and achieving the expected results."	Technology, Environment
[14]	"In a smart city, ICT-infused infrastructures enable the extensive monitoring and steering of city maintenance, mobility, air and water quality, energy usage, visitor movements, neighborhood sentiment …"	Technology, Urban Infrastructure, Mobility, Environment
[7]	"Smart cities are all about networks of sensors, smart devices, real-time data, and ICT integration in every aspect of human life."	Technology, Quality of life
Selected institutes' definitions		
[1]	"Smart cities are defined as "initiatives or approaches that effectively leverage digitalization to boost citizen well-being and deliver more efficient, sustainable and inclusive urban services and environments as part of a collaborative, multi-stakeholder process."	Quality of life, Citizens, Open Data, Technology, Environment
[2]	"Smart City is an urban area that is more environmentally friendly and more socially inclusive through the use of digital technologies. The goal is to improve its attractiveness to citizens and businesses by enhancing and adding city services."	Environment, Technology, Citizens, Urban Infrastructure

2.2 Comparison of indexes and their components

Researchers approach the measurement of smart cities differently. Common to all definitions is that they define cities as sustainable, but when we add an ICT component to them, they become smart. The comparison includes the Smart City Index (SCI), The Digital Economy and Society Index (DESI), and the Cities and Motion Index (CIMI). The smart city index (SCI) "is a composite indicator, by aggregating various domains and indicators, which are: Smart Environment, Economy, Society, Governance, Energy, Infrastructure, Transportation, Pandemic Resiliency [2]." DESI or The Digital Economy and Society Index "monitors Europe's overall digital performance and tracks the progress of EU countries in their digital competitiveness". It is calculated as the weighted average of five dimensions, which are Connectivity, Human Capital, Use of the Internet, Integration of IT, and Digital Public Services. Each of these dimensions has subdimensions, the majority of them are furtherly divided. Dimensions, as well as their components, are pondered by different weights [6]. The goal of the IESE Cities and Motion Index (CIMI) is to measure the future of urban sustainability and the quality of life of its citizens. CIMI includes nine fundamental dimensions of a city: Economy, Governance, the Environment, Mobility and Transportation, Urban planning, International projection, and Technology [8]. The indexes are comparable to each other, as they contain similar components. In Table 2, the components and the number of subcomponents of different indexes are presented. The total number of subcomponents of all indexes is 145, but for some indexes, the subcomponents are further divided so the final number is 170.

Table 2: Definitions of a smart city by different authors and their recognized components.

SCI index components	Number of SCI subcomponents	DESI index components	Number of DESI subcomponents	CIMI index components	Number of CIMI subcomponents
1. Smart Environment	4	1. Connectivity	4	1. Environment	11
2. Smart Economy	4			2. Economy	12
3. Smart Society	4	2. Human Capital	2	3. Human Capital	10
4. Smart Governance	4			4. Social Cohesion	15
5. Smart Energy	4	3. Use of Internet Services	3	5. Governance	12
6. Smart Infrastructure	4			6. Mobility and Transportation	13
7. Smart Transportation	4	4. Integration of Digital Technology	2	7. Urban Planning	5
8. Pandemic Resiliency	4			8. International Outreach	6
		5. Digital Public Services	1	9. Technology	17
The total number of subcomponents	**32**		**12**		**101**

3 RESEARCH METHODOLOGY

In this paper we used three earlier mentioned indexes (SCI, DESI, CIMI) for the comparative analysis. The paper presents a data collection technique for index construction in which the existing components of smart city definitions were linked to the components of the indexes. Based on the definitions of smart cities, we identified the main components that a smart city is supposed to contain. We obtained data about that index components. By combining the components of indexes according to the content of their subcomponents, were able to identify the unified components. We examined how many times the identified main components of smart city definitions appear within definitions and how many times they appear in indexes. The analysis of the relationship of the smart city definitions with index components is presented in the following sections.

4 RESULTS AND DISCUSSION

Based on the examination and aggregation of identical subcomponents between indexes, the results show that subcomponents of different indexes are not consistent between the different indexes. There are 170 subcomponents in the indexes. By extracting 15 of them, we provide that each one is repeated only once. After all, merging and eliminating repeating components enabled us to obtain, 155 different components.

In Figure 1, a dashed line presents the frequency of individual definition components that occur in individual smart city definition from the Literature review section. We find that the most common factor is Technology, followed by Environment, Citizens, Quality of Life, Government and Urban Infrastructure, lastly Open Data and Mobility. The red full line represents the frequency of individual definition components that occur in individual indexes as main components. Index components are related to definition components based on the definitions of individual index components in the Comparison of indexes and their components section. The second index component is Technology and it includes four components, more precisely Technology from CIMI and Connectivity, Use of Internet Services, Integration of Digital Technology from DESI. Citizens are another index component perceived also in the definitions. It includes three components, such as Smart Society from SCI, Human Capital from CIMI, and Human Capital from DESI. Smart Economy from SCI and Economy from CIMI are index components connected to the definition component Economy. Another index component is Environment, which includes two components - Smart Environment from SCI and Environment from CIMI. Urban Infrastructure includes two index components, namely Smart Infrastructure from SCI, Urban Planning from CIMI. Mobility has two index components, as Smart Transportation from SCI and Mobility and Transportation from CIMI. Government includes three index components, such as Smart Governance from SCI, Governance from CIMI, and Digital Public Services from DESI. Based on definitions, components Quality of Life, Sustainability and Open Data cannot be associated with any of the index components. For unified illustration and comparability, the results are weighted and shown as percentages.

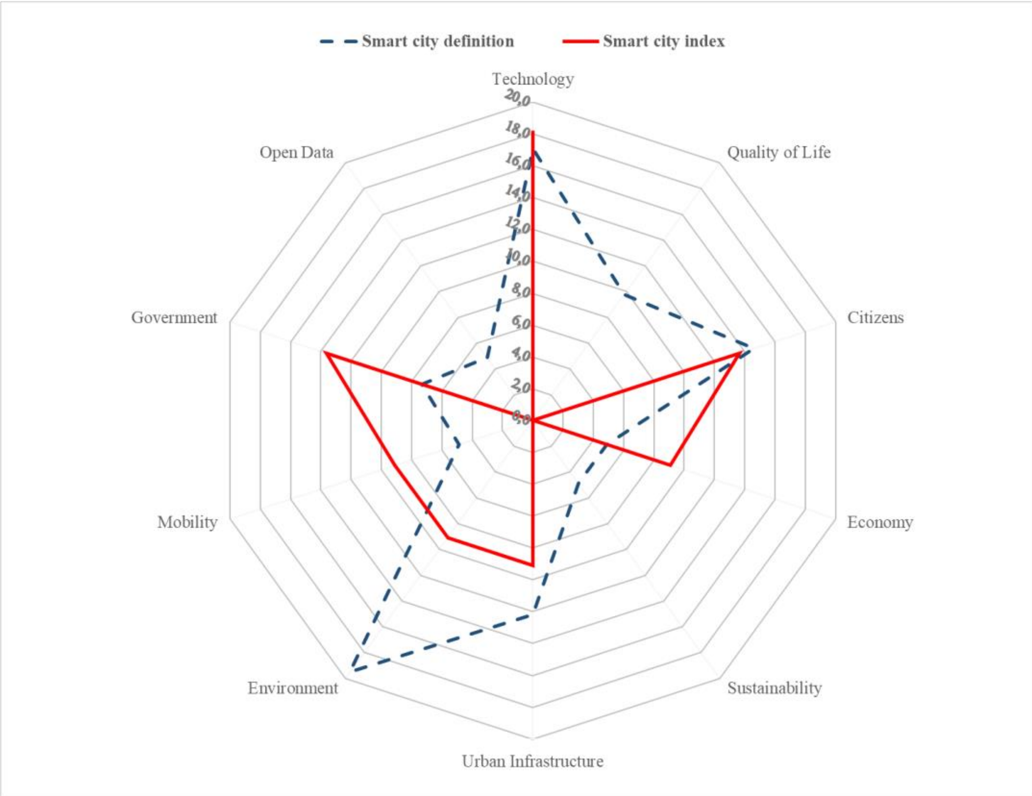

Figure 1: Recurrence frequency of components in %.

The selected aggregated components contain many subcomponents that define each component in more detail. Subcomponents of components that are not in the selected indexes must be taken from other indexes or obtained when reviewing definitions. Therefore, our proposed solution for future researchers is to construct the unified index by using all of the components from smart city definitions and indexes taking into account also the size of cities. Not all measures are namely proper and valid for all types of cities. Thus, additional technical and quantitative methods for the new index creation should be used in the future research. Independent subcomponents from the city size of the selected components could also be selected by surveying various residents in different cities. After all, the newly built index could allow the comparison of smart cities regardless of their size; and thus enable comparing the success of different smart initiatives in different cities.

6 CONCLUSION

It is difficult to compare cities that use different indexes to determine their "smartness". Moreover, it is even more difficult to compare cities with different size, needs and function. In this paper components of smart city definitions were matched to the components of the indexes. We, therefore, propose that future index construction should take into account key components that are consistent with the definitions and appropriate for both small and large cities, without making the "smartness" of a city dependent on components that are inherently found in smaller or larger cities or villages and that have so far been included in existing indexes. An additional technical and quantitative methods for developing a more universal, generally applicable and widely used smart city index should be used. A possible approach could also examine citizen's behaviour, needs and preferences. Moreover, the emphasis should be on the components that have been identified as suitable for both large and small towns and cities. This would achieve uniformity in the very definition of smart places, regardless of size. After all, since smaller places are also increasingly adopting the smart city concept, a proper and comparable index should measure their smartness maturity and progress.

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INVESTIGATING SINGULAR VALUE DECOMPOSITION AS A TOOL FOR DATA MANAGEMENT IN TOURISM

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Abstract: This paper contains a brief description of a singular value decomposition method as a tool for data management and performance improvement in the context of tourism activities – online hotel ratings. Throughout the paper, the authors introduced elementary linear theory background and SVD mathematical algorithm in a simplified way in order to express its contribution to the analytical value of data. Demonstrated algorithm and achieved results indicate two decisions. To perform high compression despite potential analytical and misinterpretation risks due to the details loss or keeping the data volume, only with minimal reduction for a largely dependent, false, and outlier data.

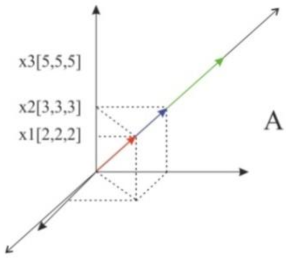
Keywords: singular value decomposition, tourism, data management, dimensionality reduction

1 INTRODUCTION

The continuous rise of digital technologies in everyday activities has led to an exponential volume increase of digital data [29], drawing attention to big data terminology [13]. Generally, big data can be defined across three dimensions: Volume, Velocity, Variety [24], with volume as its main characteristic [9]. Along with an increased volume, various data types started to appear, making it challenging to analyze. Some studies pointed out key challenges such as analytical complexities, data storage, and data management [6][33]. Over the years, the impact of big data also grew on tourism due to the influential role of customers' online activities [10]. Hotels and other tourism and hospitality companies become closer to the big data, considering helping them generate more revenue and deliver a better experience for customers. Moreover, the ability to manage a large amount of data means an option for value creation from big data and its supporting technologies, which justifies considering hotel reviews in a smart tourism context. It is often used for predictive and behavioral analytics to assist companies in recognizing the patterns related to their business practices [17]. But occasionally, defining relations between data, information, and knowledge is not always fully transparent. Knowledge is often seen as an organized data structure that creates information uniquely observed by specific users due to its experiences and practices [2]. Therefore, depending on the data source, type, and user perception, data receive different traits that define its meaning [1]. The accepted view of data is a fact that becomes valuable as it is formed into a structure that creates high-quality information [30]. The quoted definition is accepted regardless of differences between scientific and practical disciplines, but at the same time doesn't answer questions about what data structure is and how it is manageable. For that matter, it is essential to add a suitable numerical representation, a collection of individual numerical values that accurately describes the data [31]. Correspondingly, this paper aims at presenting the simplified mathematical view on data management as the numerical presentation of elemental pieces of information, in this case, the hotel reviews.

2 MATRIX STORAGE AND DIMENSIONALITY REDUCTION

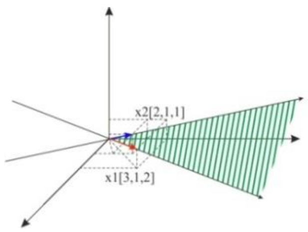
Every numerical analysis starts with a single number, a numerical representation of data with the corresponding value called a scalar [12]. An array of scalars creates a vector where each value is in order according to the corresponding index. As the scalar index in an array defines the vector, the corresponding index of vectors describes the matrix structure ordered in *m* rows and *n* columns of unit vectors [31]. A more practical way to think about matrix is to view it as a data set, where columns and rows represent particular data attribute and each attribute make its dimension. Dimensionality reduction within stored data aims at reducing the number of data attributes for future analytical examination [8]. But before reviewing data reduction, it is necessary to analyze the term dimension. Generally speaking, term dimension can be associated with mathematical space and related objects positioned in correspondence with spatial coordinates needed to specify its location. From a data point of view, a dimensional „feature“ of a scalar is determined by its data attributes that create dimension [22]. The dimensionality of a data set filled with scalar values is the minimum number of attributes needed for data representation without significant information loss [3]. With additional added dimensions, data is stored in multidimensional tensor-based structures [32]. From the tensor perspective, a vector with two scalar values is a principal component of the first-rank tensor in a two-dimensional space [25]. A vector with three scalar values requires a third space dimension - a second-rank tensor. An example of a typical additional dimension for a large proportion of stored data within numerous databases is time series [4]. Depending on the analytical approach, the structural rank of a matrix can be viewed as the maximum achievable rank among all matrices taken into an analytical procedure with the same structure but different scalar values [23], as a number of its positive singular values [20] or as a number of linearly independent column vectors of the matrix [28]. The simplest forms of the data structures are one-dimensional matrices, where each of the scalar values is positioned on the component line in space (*Figure 1*).



$$A = \begin{bmatrix} 2 & 3 & 5 \\ 2 & 3 & 5 \\ 2 & 3 & 5 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} = x1 \begin{bmatrix} 2 \\ 2 \\ 2 \end{bmatrix} + x2 \begin{bmatrix} 3 \\ 3 \\ 3 \end{bmatrix} + x3 \begin{bmatrix} 5 \\ 5 \\ 5 \end{bmatrix}$$

Figure 1: Matrix A rank 1

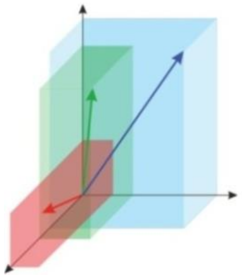
For each matrix transformation from an array of scalars *x1, x2, x3*, newly calculated values will be on the hypothetical line – rank one. Just by looking at the presented example, the simplicity of the formed matrix can't be unnoticed. However, most of the time, connections between values within data sets aren't noticeable and acquire more data aggregation. In order to show that the maximum number of column vectors of the matrix does not always define its structural rank and that linear dependence can be more challenging to see, a simple matrix A *rank 2* (*mxn* = 3x3) is presented in the example below.



$$A = \begin{bmatrix} 3 & 2 & 5 \\ 1 & 1 & 2 \\ 2 & 1 & 3 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} = x1 \begin{bmatrix} 3 \\ 1 \\ 2 \end{bmatrix} + x2 \begin{bmatrix} 2 \\ 1 \\ 1 \end{bmatrix} + x3 \begin{bmatrix} 5 \\ 2 \\ 3 \end{bmatrix}$$

Figure 2: Matrix A rank 2

If we examine matrix A (*Figure 2*), at first glance, it could look like the scalar values within the matrix are randomized. If that is true, it would mean that the structural rank of the matrix A equals 3. But in this case, this is not true because there is linear dependence of the third column vector as a sum of the scalar values of first and second vectors. Thus, a presence of linear dependence among column vectors suggests that stored values can lower their dimensionality level [31]. For each matrix transformation from an array of numbers *x1, x2, x3*, newly calculated values will be on the hypothetical two-dimensional plane because the third matrix column is linearly dependent as a sum of the first two column vectors. In statistical terms, there is a multicollinearity problem of the third column vector, so its values are predictable as a combination of the first and second column vector - the column has no analytical value [7]. If none of the vectors are a linear combination of other vectors, the matrix is linear independent [12].



$$A = \begin{bmatrix} 1 & 3 & 1 \\ 2 & 5 & 3 \\ 5 & 2 & 2 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} = x1 \begin{bmatrix} 1 \\ 2 \\ 5 \end{bmatrix} + x2 \begin{bmatrix} 3 \\ 5 \\ 2 \end{bmatrix} + x3 \begin{bmatrix} 1 \\ 3 \\ 2 \end{bmatrix}$$

Figure 3: Matrix A rank 3

In the examples above, the intention was to present data management in two-dimensional matrices. Although two-dimensional structures are essential for data management, it is necessary to exclude the possibility that all data is: (1) stored in square matrix where $m=n$; (2) low dimensional order; (3) relations are easily manageable. In addition to that, the authors introduced a standard singular value decomposition (SVD) model as one of the most universal and fundamental mathematical methods for dimensionality reduction and data management. Although some noted studies point out limitations for a particular field [21][5][16], authors consider the SVD model essential for understanding data management and manipulation, especially in this study format, as a straightforward introduction to raw data management.

3 SINGULAR VALUE DECOMPOSITION

Theoretical analysis and data experimentation suggested that the theory of matrix decomposition is one of the most beneficial ideas for data management. Therefore, it is not surprising that matrix decomposition is a fundamental discipline of linear algebra for various analytical problems within collected and stored data [27]. Dimensionality reduction aims to lower dimensionality space without significant loss of information [19]. With dimensionality reduction, practicing the matrix decomposition algorithm reduce the time complexity, memory usage and potentially increase accuracy of data analysis [16]. Although SVD is a well-known technique in various fields across computer science, machine learning, and more, social scientists are often very familiar with the value of observed results [15]. The equation for SVD of a given $m \times n$ matrix A with scalar values for structural rank r in $\boldsymbol{m \geq n}$ matrix structure is a factorization of three matrices [11]:

$$A = U \Sigma V^t \tag{1}$$

where diagonal $r \times r$ matrix $\sum$ contains singular values $\partial 1, \partial 2, \ldots, \partial n \geq 0$ valued from highest to lowest, matrix U contains left singular vectors in m dimension, and matrix V *transpose* contains right singular vectors in n dimension. If the observed matrix is a square, its factorized matrices will be orthogonal. An orthogonal matrix is a square matrix whose columns and rows values are mutually orthonormal containing eigenvectors for $A^t A$ and AA^t [26]. Calculated eigenvalues on diagonal of orthogonal matrix $\sum$ are singular values of matrix factorization for $\boldsymbol{m \neq n}$, and their index presents the structural rank of matrix A.

4 RESULTS AND DISCUSSION

In this section, the authors examined an available dataset to demonstrate matrix factorization on simple data matrix examples [14]. Out of available data attributes, the focus was on object categorization: *hotels*, *name of the object*, *username*, and *hotel rating*.

$$
\begin{array}{l}
 \\
\text{Barbara}\\ \text{Karen}\\ \text{Theresa}\\ \text{Judy}\\ \text{Erin}\\ \text{Diane}\\ \text{Tammy}\\ \text{Michele}
\end{array}
\begin{array}{c}
\begin{array}{cccccc}\text{Americas Best Value Inn Cheyenne} & \text{Bayside Resort Hotel West Yarmouth} & \text{Comfort Suites Southfield} & \text{Denver Warwick} & \text{Hotel Plaza and Casino Las Vegas} & \text{Palm Suites}\end{array}\\
\begin{bmatrix}
5 & 5 & 5 & 0 & 0 & 0\\
4 & 5 & 3 & 0 & 0 & 0\\
3 & 4 & 4 & 0 & 0 & 0\\
5 & 5 & 0 & 0 & 0 & 0\\
4 & 4 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 3 & 4 & 0\\
0 & 0 & 0 & 4 & 5 & 5\\
0 & 0 & 0 & 5 & 4 & 5
\end{bmatrix}\\
\text{A (m x n)}
\end{array}
\sim
\begin{array}{c}
\begin{bmatrix}
-.56 & -.70 & -.42 & 0 & 0 & 0\\
-.47 & .56 & -.08 & 0 & 0 & 0\\
-.41 & .44 & -.42 & 0 & 0 & 0\\
-.43 & -.07 & .63 & 0 & 0 & 0\\
-.35 & -.05 & .50 & 0 & 0 & 0\\
0 & 0 & 0 & -.34 & -.08 & -.94\\
0 & 0 & 0 & -.67 & .72 & .18\\
0 & 0 & 0 & -.66 & -.69 & .30
\end{bmatrix}\\
\text{U (m x r)}
\end{array}
\begin{array}{c}
\begin{bmatrix}
15.1 & 0 & 0 & 0 & 0 & 0\\
0 & 0.71 & 0 & 0 & 0 & 0\\
0 & 0 & 4.38 & 0 & 0 & 0\\
0 & 0 & 0 & 12.1 & 0 & 0\\
0 & 0 & 0 & 0 & 0.97 & 0\\
0 & 0 & 0 & 0 & 0 & 2.97
\end{bmatrix}\\
\Sigma\text{ (r x r)}
\end{array}
\begin{array}{c}
\begin{bmatrix}
-.62 & -.68 & -.39 & 0 & 0 & 0\\
-.71 & .70 & -.09 & 0 & 0 & 0\\
.33 & .22 & -.92 & 0 & 0 & 0\\
0 & 0 & 0 & -.58 & -.61 & -.55\\
0 & 0 & 0 & -.79 & .58 & .20\\
0 & 0 & 0 & -.19 & -.55 & .81
\end{bmatrix}\\
{}^{T}\text{V (n x r)}
\end{array}
$$

Figure 4: Singular Value Decomposition of matrix A

Important to state is that all null (*empty*) and false values in matrix A are assumed to be zero (0) valued. Zero is not an acceptable user rating for data attributes in the range 1 - 5, and so it displays replacement value. The obtained values on the diagonal of the $\sum$ matrix show the strength of the relationship between values of the matrix A attributes - singular vectors. Vector on coordinates $u_1 \partial_1 v_1 t$ contains the highest singular value equal to 15.11. The vector is called *the First Principal Component* [34] and indicates the line that best defines data observations of the matrix A (values have the lowest measured distance projection on component line) – contains the highest analytical value. The structural rank of the matrix represented with only one vector equals one (*see Figure 1*). In the example above (*Figure 4*), there are six positive singular values and question how many dimensions are possible to discard (remove singular values) without decreasing the analytical value of the matrix. A lower percentage of data retained by a combination of singular vectors is at least 90% of the sum of all squared singular values [18]. In our example, a sum of all squared singular values equals $15{,}11^2+12{,}13^2+4{,}38^2+2{,}97^2+0{,}97^2+0{,}71^2=$**405**. Removing singular values from the equation in ascending order results in: **404.50; 394.73; 375.59**. By keeping principal component lines written on coordinates $u_1 \partial_1 v_1 t$ and $u_4 \partial_4 v_4 t$ results in 92,74% of the sum of squared singular values (375,59/405*100), which is larger than the proposed minimum of 90%. Therefore, reducing the dimensionality of matrix A on rank two (2) (*see Figure 2*) caused a loss of 7,26% stored data – approximation of matrix A (*matrix A'*).

$$
\begin{bmatrix}
-.56 & -.42 & 0\\
-.47 & -.08 & 0\\
-.41 & -.42 & 0\\
-.43 & .63 & 0\\
-.35 & .50 & 0\\
0 & 0 & -.34\\
0 & 0 & -.67\\
0 & 0 & -.66
\end{bmatrix}
\begin{bmatrix}
15.1 & 0 & 0\\
0 & 4.38 & 0\\
0 & 0 & 12.1
\end{bmatrix}
\begin{bmatrix}
-.62 & -.68 & -.39 & 0 & 0 & 0\\
.33 & .22 & -.92 & 0 & 0 & 0\\
0 & 0 & 0 & -.58 & -.61 & -.55
\end{bmatrix}
\approx
\begin{array}{c}
\begin{bmatrix}
5{,}26/\mathbf{4.65} & 5{,}75/\mathbf{5.34} & 3{,}25/\mathbf{4.96} & 0 & 0 & 0\\
4{,}40/\mathbf{4.28} & 4{,}80/\mathbf{4.72} & 2{,}71/\mathbf{3.04} & 0 & 0 & 0\\
3{,}82/\mathbf{3.22} & 4{,}17/\mathbf{3.78} & 2{,}36/\mathbf{4.03} & 0 & 0 & 0\\
4{,}06/\mathbf{4.97} & 4{,}43/\mathbf{5.03} & 2{,}51/\mathbf{0.0} & 0 & 0 & 0\\
3{,}25/\mathbf{3.97} & 3{,}55/\mathbf{4.02} & 2{,}01/\mathbf{0.0} & 0 & 0 & 0\\
0/\mathbf{0} & 0/\mathbf{0} & 0/\mathbf{0} & 2{,}39 & 2{,}51 & 2{,}27\\
0/\mathbf{0} & 0/\mathbf{0} & 0/\mathbf{0} & 4{,}66 & 4{,}89 & 4{,}42\\
0/\mathbf{0} & 0/\mathbf{0} & 0/\mathbf{0} & 4{,}64 & 4{,}87 & 4{,}41
\end{bmatrix}\\
\text{A'}/\mathbf{A''}
\end{array}
$$

Figure 5: Approximation of matrix A (A' & A")

However, if we do an inverse calculation in the approximate values of matrix A, we can notice deviations in the data values of matrix A' compared to matrix A (*Figure 5*). Although the vectors $u_1 \partial_1 v_1 t$ and $u_4 \partial_4 v_4 t$ represent a large part of the values of matrix A, the vector $u_3 \partial_3 v_3 t$ is significantly related to its coordinated values. The reason is that the selected attributes from the sample are randomized, and although it may seem that there is a linear dependence between the elements, that cannot be viewed as a rule for all stored data. In other words, hotel rating values alone are not sufficient to describe possible attribute connections.

Additionally, adding the third singular value - 4.38 in an inverse calculation (matrix A"), combined with the previous singular values on the ∑ matrix diagonal, covers 97.46% of the sum of squared singular values (new rank of the matrix is equal to three 3; see *Figure 3*). By using the formula for the data compression ratio [26] and new structural rank of matrices A 'and A", it is possible to calculate the percentage of data reduction and approximately assume the analytical data value:

$$CR = \frac{m * n}{(m+n+1) * r} \tag{2}$$

where: m – rows; n – columns; r – singular values of new matrix. For matrix A' expression is: $CR(A^{'}) = (8*6)/((8+6+1)*2) = 6.4{:}\,1 \approx 15.63\%$ is a volume of compressed data which means that 92,74% of data can be retained by keeping the principal component lines written on coordinates $u_1\partial_1 v_1 t$ i $u_4\partial_4 v_4 t$ – rank 2. For matrix A" expression is: $CR(A^{''}) = (8*6)/((8+6+1)*3) = 1.067{:}\,1 = 93.72\%$ is volume of compressed data which means that 97,46% of data can be retained by keeping the principal component lines written on coordinates $u_1\partial_1 v_1 t$, $u_3\partial_3 v_3 t$ i $u_4\partial_4 v_4 t$ - rank 3. Due to the size of matrix A" rank 3, there is no significant contribution in data compression of matrix A. On the other hand, there is a significant data reduction of matrix A - rank 2, but also it brings analytical risks and possible misinterpretation due to the data loss on $u_3\partial_3 v_3 t$ coordinates.

5 CONCLUSION

Practical implications of data management address many issues such as predicting tourist demand, supporting demand level anticipation, enabling better decision making, managing knowledge flows with customers, and providing the best service more efficiently and effectively. The presented SVD method is one of the fundamental mathematical algorithms essential for analyzing large amounts of data. Although pointed benefits of data management using SVD arise from this and other studies, there are also several limitations. Firstly, it is vital to have the highest possible transparency within data attributes due to the potential clusters within data values with similar qualitative features. Hotel ratings in their numerical form don't reveal enough information to provide definite conclusions about existing connections within numerical data. That is visible from dimensionality reduction, where data on third component line have significant analytical value no matter its low volume. Additional descriptive and cluster analysis for hotel objects and users would contribute more insights about connections within ratings, which would prove or disapprove its significance to remaining data projected on first and second component lines. Additionally, with a higher number of attributes and observations, the risk of efficiency failure rises, especially if there is low data transparency. Finally, SVD is a reliable tool for dimensionality reduction and graph analysis, but on the other hand, its complex algorithm can be overwhelming. Thus, the paper aimed to demonstrate a few practical SVD possibilities and enhance understanding of its value throughout simplistic form for the application in the smart tourism domain as a data management tool. For that purpose, an open data source served well in the demonstrative purpose of the study.

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DEMONSTRATION POTENTIAL OF SIMULATION MODELLING IN THE URBAN MOBILITY DOMAIN

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Abstract: The study explores the potential of simulation modelling in one particular aspect of the presentation and problem-solving of urban mobility dilemmas. For that purpose, the case of a temporary bus station in Split (Croatia) was developed in preparation for a workshop attended by more than twenty graduates and future business analysts in April 2021. The participants expressed their attitudes on the (demonstration) potential of simulation modelling techniques for urban mobility solutions before and after the workshop, resulting in statistically significant and positive changes in their attitudes even after a short workshop intervention.

Keywords: simulation modelling, optimization, urban mobility, Arena Simulation

1 INTRODUCTION

Over the last several decades, simulation modelling techniques have become an essential planning tool in various disciplines, including sustainable urban development [6, 8, 12]. As the mobility sector is one of the most important fields of urban development [2, 18], and the relationship between transportation and environmental planning is essential for effective urban growth [19], simulation modelling is found to be suitable for managing various factors that affect the field of study [9]. Specifically, simulation modelling provides opportunities for predicting outcomes based on collected data about the observed system without affecting real-world processes [16]. System complexity, types of problems, and user requirements affect the selection of a modelling technique [5] from a wide range of prevalent ones under four main simulation modelling categories: discrete simulation modelling, system dynamics, agent-based modelling, and hybrid modelling, all with a potential for a specific contribution to the area of urban development and mobility [11, 13, 17]. An example of a contemporary topic within the urban development domain is Smart Cities, where "smart" technologies contribute to economic, social and environmental development [7]. Since mobility has a high impact on quality of life and urban development, Smart Mobility solutions within the Smart City concept are growing in popularity [1]. Simulation modelling is frequently used as a reliable mechanism for mobility management [4]. Correspondingly, this paper analyzes the potential of simulation modelling in diagnostics and problem-solving in the mobility sector using Arena Simulation software, proven valuable in particular in the academic environment [10] and real-world transportation systems [3, 14]. The paper first presents a case study explicitly prepared for a workshop with graduate students in Section 2. The results of surveying workshop participants' attitudes on the demonstration potential of simulation modelling techniques are presented in Section 3, followed by main conclusions in Section 4.

2 CASE STUDY: SIMULATION MODELLING OF A TEMPORARY BUS STATION

2.1 Problem definition

As mentioned, a workshop was planned with the objective to inspect the demonstration potential of simulation modelling in the urban mobility domain focusing on a present-day issue in one local community. Specifically, the local government proposed a temporary solution in Split (Croatia) within its Masterplan Construction Study for Urban Development – a temporary bus station. The idea of the project is to relocate the bus station from the east coast of the city to another area (Kopilica), which should reduce traffic overload in the city port and city centre during the tourist season. Although the motif for relocation is reasonable, the proposed solution was met with many arguments and disputed factors that slowed down the project and raised doubt about its success. The main problem of the proposed solution is the lack of supporting infrastructure capacity needed to meet the requirements and, on a general note, the low infrastructure potential of the new area because of its questionable possibility to deal with increased numbers of tourist arrivals. Ultimately the temporary solution could lead to traffic chaos at one of the busiest city entrances in a critical period. Due to the conflicting viewpoints of many legislators and practitioners, the proposed solution was assessed as optimal to be presented as a case study with many possible teaching lessons about the urban development issue and simulation modelling in general.

2.2 Modelling the system

As with other simulation models, the first goal of the one presented here was to identify critical points of the project, analyze its infrastructure requirements for specific situations and propose adequate changes.The elements and data used for simulation model development are: (1) the number of *parking exits* is 1, (2) the number of available *parking spaces* is 19, (3) estimated bus entrances in one day at the peak of the tourist season is 500, (4) the estimated average number of bus entrances during the tourist season equals 300 buses per day, (5) a possible number of *passengers* per single bus is 50 for single-decker buses, up to 70 for double-decker buses, (6) based on instructions for traffic management and parking charges, *parking spaces* occupancy is in time frame 10-15-60 minutes [min - mod - max] per bus, (7) the train line Split - Split Predgrađe - Split operates every 30 minutes according to an established schedule, (8) the number of available passenger train seats is 167 plus accessible space for standing, (9) run time is in the time frame 6 AM to 10 PM (working hours). An animation map in ARENA software was used for visualization of the traffic performance for easier monitoring. Entity groups/units of the simulation model are (1) *bus*, (2) *passenger*, (3) *train*, and (4) *car*. The infrastructure resources are: (1) *bus parking space*, (2) *parking exit*, (3) *train passenger seats*, and (4) *train station Split Predgrađe*. The entrance of an entity *bus* is a normal distribution with a mean of bus entrance in a model every 3.2 minutes and deviation intervals: 25% low and 75% upper interval limit - NORM [3.2,0.8,2.4]. By entering the model, the *bus* entity "decides" which free *parking space* resource it will occupy for a limited time. Decision rules for *parking space* engagement include: (1) the preferential values, (2) the resource availability, (3) interval occupation of resource determined by bus-entity settings. The entity's movement line towards *parking space* uses the DECIDE module with the expression: *N-WayCondition - If "ParkingSpace x" = 0* else *"ParkingSpace x+n"*; where "*n*" is the identification number of the next available preferential parking space. If there is no available free *parking space*, the entity will leave the model without engaging any *parking space* resource. *Bus* entity engagement of *parking space* defines its availability with the expression**:** SeizeDelayRelease/TRIA[10-15-60]min/unit where: (1) 10 - minimal assumed minutes needed for *passengers* to exit the *bus*, (2) 15 - *mod* assumed minutes needed for *passengers* to exit and boarding of the new passengers, (3) 60 is maximal assumed minutes available for resource occupation. After an entity releases an occupied resource and status is back to available, another entity can engage *parking space* if a preferential number is the highest of all other available resources. Infrastructure resource *parking exit* connects to a single traffic lane toward the city centre. Because of the inability to use a *bus* for waiting time calculation due to the present status of the temporary bus station, the authors instead used cars as a measuring basis for waiting time. Due to the larger size compared to a car, slower speed, and different preferential traffic orders, collected time values are slightly increased. Distribution expression is: SeizeDelayRelease/TRIA[1,3,6]min/unit where: (1) 1 - minimal assumed minutes needed for getting off the terminal, (2) 3 – *mod* value, (3) 6 - maximal assumed minutes needed. The relationship between *parking space* and *parking exit* negatively correlates because the less time the *bus* is on the *parking space*, the more pressure it will put on the *parking exit*. That could lead to traffic overload on the *parking exit* and bus station due to a large queue. If we consider a possible increase in time spent on *parking space*, there will be less pressure on the *parking exit.* That puts the station parking capacity under question due to a long-time occupation. The distribution of *passengers* is the same as the distribution of *buses* and in entity relation 1:1 where "one" *passenger* holds a maximum assumed value of 50 to 70 units, depending on the vehicle characteristics. Additionally, there is a delay needed for passengers to leave the bus, take their luggage and move on through the model expressed as a constant value of 8 minutes per one *passenger* entity (first creation: CONST [8]). With the *passengers entering the* model, a DECIDE module regulates further entity movement, and the possible choice expression is: (1) 50% chance to take a train, (2) 50% chance for another type of transport/walk. If the *passengers* decide to move toward the resource *train station*, they enter the queue - HOLD module - for the *train.* The type of the HOLD module is *Infinite Hold* which keeps the *passengers* at the *train station* until available capacity requirements are ready. The train capacity is equal to 4, representing the maximal possible number of passengers per ride multiplied by the proposed number of passenger units per one entity (4*(50 to 70) = 150 – 280 ≈ train capacity = 167 seats + standing spots). If the number of *passengers* in a queue is greater than 4, the *train* will take only its capable number of *passengers* while others stay queued for the next train to arrive (e.g., 5-4=1 in HOLD). This simple model is outlined in Figure 1.

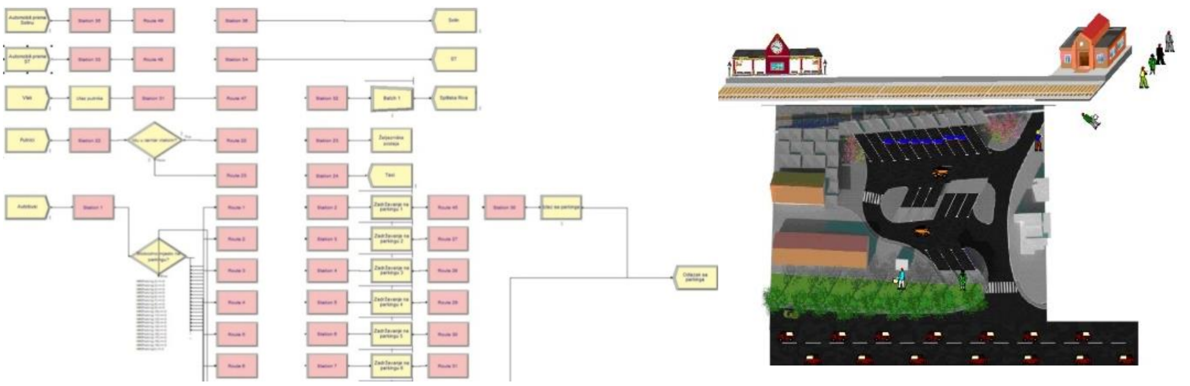

Figure 1: Simulation model in ARENA software

2.3 Scenario analysis

This simulation results (Table 1.) suggest that: (1) the number of available *parking spaces* for the daily number of 300 entries meet the criteria; (2) the number of *parking spaces* for the daily number of 500 entries do not meet the criteria - at least six entities have left the model without being able to stop due to the occupation of all available resources; (3) the number of the *parking exits* for the daily number of 300 entrances does not meet the criteria. The resource occupancy is present in 94.61% of the run time. The average waiting time in queue for 300 entrances is 15 minutes and 54 seconds. The highest single wait time was 34 minutes and 10 seconds. The average number of entities in the queue was 4.64, while the highest reached 12 *buses* at once. Thus, the two flaws of the solution are (1) the lack of parking space when the number of bus entrances approaches the expected number of 500 per day; (2) the low efficiency of the parking exit for the expected daily distribution of bus entrances.

ARENA Process Analyzer allows easier modelling optimization to review possible options for process upgrade and development. After the optimization results are: (1) adding extra *parking exit* results in average waiting time reduction from 15 minutes and 54 seconds to 32 seconds, (2) the average number of entities in the queue has decreased from 4.64 to 0.155; (3) parking exit occupation is reduced from 94.61% to 49.20% of the run time, (4) doubling the number of parking spaces for 500 entrances daily results meet the criteria. According to optimization results, the following changes are suggested: (1) increasing the number of *parking spaces* (Table 2.) and (2) introducing additional *parking exits*.

Table 1: Parking space occupancy for 300 and 500 entries

	N of entries = 300		***N of entries = 500***			***N of entries = 300***		***N of entries = 500***	
Parking	***%***	***Stop***	***%***	***Stop***	***Parking***	***%***	***Stop***	***%***	***Stop***
1	0.00	0	19.69	7	11	49.25	17	80.74	28
2	88.85	32	93.98	29	12	53.88	17	79.94	25
3	86.55	29	92.30	33	13	14.04	5	79.41	26
4	85.39	32	91.20	35	14	09.41	3	70.77	24
5	86.65	27	91.27	31	15	04.01	1	69.15	23
6	78.32	28	90.23	31	16	0	0	67.14	24
7	75.59	28	85.58	32	17	0	0	54.55	20
8	73.01	26	90.05	28	18	0	0	41.56	14
9	70.53	27	87.36	22	19	0	0	36.05	12
10	63.14	22	86.68	28					

Table 2: Parking space (*2) occupancy for 500 entries

N of entries = 500							
Parking * 2	***%***	***Parking * 2***	***%***	***Parking * 2***	***%***	***Parking * 2***	***%***
1 + 1a	0.00	6 + 6a	62.09	11 + 11a	49.42	16 + 16a	5.56
2 + 2a	69.54	7 + 7a	63.36	12 + 12a	38.84	17 + 17a	0.00
3 + 3a	66.88	8 + 8a	57.53	13 + 13a	27.99	18 + 18a	0.00
4 + 4a	69.69	9 + 9a	54.69	14 + 14a	14.78	19 + 19a	0.00
5 + 5a	60.17	10 + 10a	49.23	15 + 15a	3.35		

3 SURVEYING THE DEMONSTRATION POTENTIAL OF THE MODEL

Before the detailed presentation, the participants (N=24) completed a survey. It was followed by elaborating the simulation modelling terminology focusing on urban mobility dilemmas, full scenario presentation, including simulation elements and relationships between them, ARENA software properties, and interpreting the results. Participants were then asked to estimate the possibilities of the ARENA software for discrete event simulation (DES) of urban mobility issues again. A seven-point Likert scale with anchors ranging from strongly agree to disagree strongly was used. The encoded items with mean and standard deviation are: (1) Performance Analysis (AP) (U_AP, 5.50, 1.14; I_AP, 5.88, 0.992), (2) What-If Analysis (WIF) (U_WIF, 5.42, 1.80; I_WIF, 5.75, 0.99), (3) Quantitative and Qualitative Indicators (KKP) (U_KKP, 5.46, 1.29; I_KKP, 5.88, 0.95), (4) Analyst-Use (AUse) (U_AUSE, 5.58, 1.14, I_AUSE, 6.04, 0.86), (5) Users-Use (UUse) (U_UUSE, 4.71, 1.43, I_UUSE, 5.46, 1.22), (6) Operational Decision-Making (OD) (U_OD, 5.67, 1.09, I_OD, 5.88, 0.90), (7) Strategic Decision-Making (SD) (U_SD, 5.79, 1.29, I_SD, 5.96, 0.96), (8) As-Is Simulation System Modeling (SASIS) (U_SASIS, 5.92, 1.47, I_SASIS, 6.08, 1.06), (9) To-Be Simulation System Modeling (STOBE) (U_STOBE, 5.71, 1.12, I_STOBE, 6.33, 0.92), (10) Scenario Analysis (SA) (U_SA, 5.79, 1.18, I_SA, 6.25, 0.99), (11) Simulation and Process Design Analysis

(STR) (U_STR, 5.71, 1.08, I_STR, 6.04, 0.91). The results were analyzed using the Wilcox signed-rank test [15], a non-parametric test used to compare the two sets of scores taken by the same groups of participants (Table 3). It indicates a statistically significant change of participants' perception about the potential of simulation modelling in the presentation and problem-solving of mobility issues in six categories: What-If Analysis, Quantitative and Qualitative Indicators, Analyst-Use, Users-Use, To-Be Simulation System Modeling, and Scenario Analysis. Those participants who expressed no change in their perception are "tie" valued. For example, for the KKP category, a statistically significant change is observed (Asymp. Sig. 2-t = .032<.05), where three participants rated the category lower after the demonstration compared to ten participants who rated it higher. Comparison of Mean ranks shows a noticeable rank value increase (5.50<7.45), indicating a positive change in a participant's views, while eleven (Ties = 11) do not change their opinion.

Table 3: Ranks and Wilcoxon Signed Ranks Test (Z - Based on negative ranks), N=24

		N	***Mean Rank***	***Sum of Ranks***	***Z***	***Sig. (2-t)***
I_WIF - U_WIF Ties = 14	Negative Ranks[a]	2	4,50	9,00	-1,999	,046
	Positive Ranks[b]	8	5,75	46,00		
I_KKP - U_KKP Ties = 11	Negative Ranks	3	5,50	16,50	-2,140	,032
	Positive Ranks	10	7,45	74,50		
I_AUSE - U_AUSE Ties = 10	Negative Ranks	2	7,00	14,00	-2,668	,008
	Positive Ranks	12	7,58	91,00		
I_UUSE - U_UUSE Ties = 10	Negative Ranks	1	5,50	5,50	-3,082	,002
	Positive Ranks	13	7,65	99,50		
I_STOBE - U_STOBE Ties = 11	Negative Ranks	2	4,50	9,00	-2,627	,009
	Positive Ranks	11	7,45	82,00		
I_SA - U_SA Ties = 13	Negative Ranks	2	4,50	9,00	-2,230	,026
	Positive Ranks	9	6,33	57,00		

a. I_WIF< U_WIF; b. I_WIF> U_WIF

4 CONCLUSION

The study explored simulation modelling in the particular aspect of presentation and problem-solving of urban mobility dilemmas. A simulation case study of a temporary bus station in Split was developed and presented to future business analysts, roughly twenty graduate IT Management students. Essential information about the project, fundamental data for the modelling buildup, and possible outcomes of the described project ideas were presented with the results of simulation experiments and possible optimization solutions. A comparison between pre-demonstration and post-demonstration survey scores was made to investigate whether different scenarios, animations, and achieved results affected their attitudes on the potential of simulation modelling techniques for urban mobility solutions. Observed empirical results show slight but statistically significant positive changes in students' attitudes. This supports the findings of our previous studies in the context of using simulation modelling tools in academic teaching [10], where the benefits of using ARENA software have been confirmed in particular. As future analysts and decision-makers, they will have the right tools for presenting the limitations of solutions under scrutiny that can support problem-solving in their specific domains of interests. The case study demonstrated a high prospect of simulation modelling as an efficient solution for the urban mobility domain. Practical implications of the study refer to possible improvements in the use of urban resources and contribute to the exhaustive discussion about the temporary solution; simultaneously, the results emphasize the importance of the demonstration aspect of simulation modelling in changing peoples' attitudes. Future research on the demonstration potential of simulation modelling in the urban mobility domain would need to include a stronger theoretical background and empirical research on a more relevant and larger sample of respondents, thus addressing the limitations of this study.

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DEVELOPING SYSTEM DYNAMICS MODEL FOR WASTE MANAGEMENT IN TOURISM-ORIENTED SMART CITY

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Abstract: Understanding the complexity of the waste management system within smart cities is crucial for policymakers since urbanization carries new challenges regarding waste. Challenges are even more noticeable when it comes to tourist destinations. Since so far research has stressed the importance of taking a holistic view, which includes tourists, a real databased system dynamics model was developed to analyze waste management processes. Simulation scenarios indicated the necessity for waste management improvement. The system dynamics approach can provide the basis for a better understanding of waste management's dynamic processes and the basis for policymakers to achieve smart cities' long-term goals.

Keywords: smart city, system dynamics, waste management, tourist destination

1 INTRODUCTION

The UN Population Division (2019) forecasted that by the end of 2050 the urban population globally would reach over 70% of the total population. This predicted urbanization of the world raises major challenges related to sustainability [4]. By adopting the smart city concept, more likely are the chances that cities will be aligned with citizens' needs and that they will pursue sustainable development goals [1]. A city can be considered a smart city if it carries out services and traditional networking using information and communication technology [12]. One of the challenges arising from the urbanization growth is waste disposal since one of the ways (smart) city sustainability can be achieved is by minimizing waste [4]. Municipal Solid Waste (MSW) is defined as waste produced by the people and society in their everyday activities [22]. Waste management within the smart city concept is usually referred to as the Internet of Things (IoT) and route optimization improving the efficiency of the cleaning/collection process [2], [21]. However, big data obtained through IoT should be extracted and used to feed another, more holistic, model [29]. It is important to observe waste management systematically, as being a complex system consisting of different subsystems.

Tourism, in general, is considered an urban activity that transforms and impacts urban organization [1]. Facts are that the city is the physical place where both tourists' desires and inhabitants' needs intersect which further leads to compromised balance and citizens' life quality [24]. Another matter of city tourism is "overtourism" - intensified growth of the number of overnight stays concerning the number of citizens [23]. In this paper, tourist destinations characterized by overtourism are conceptualized as tourism-oriented cities. Both concepts, MSW and tourist destinations have a common characteristic: complexity - therefore it comes as no surprise that literature review confirms the use of System Dynamics (SD) as a method to understand the dynamic behavior of complex systems. However, the two mentioned concepts were mostly observed separately. Recent research has focused on using SD models to forecast MSW [18, 19, 27, 28], however to the best of our knowledge none of the researches included tourist perspective within the SD model. SD has been used for analyzing tourists' impact on urban infrastructure [3], and some authors highlight the limited availability of data and their importance for a holistic modeling approach [18].

The goal of this paper is to examine the potential of applying the SD approach in waste management, while considering a tourist dimension, with the tendency to provide a more holistic perspective. This paper addresses the research gap pointed out by authors who used SD for modeling the total amount of MSW generation but used only permanent residence population [28], also one of the future research recommendations was that the SD model should be based on the real data if possible [19], as some authors used fuzzy logic as a supplement tool [18]. Research questions are: *How can waste management be modeled with the purpose to support policymakers in waste management? To what extent is the tourist dimension important regarding waste management?* This paper consists of the introductory part and four other sections. The theoretical background is presented in Section 2. Section 3 introduces SD model development and presents the used methodology. Results of simulation are presented in Section 4 and, finally, conclusions are drawn in section 5, together with limitations and future research.

2 THEORETICAL BACKGROUND

Due to uprising challenges, smart cities need to reconfigure themselves more sustainably and efficiently [4, 28]. The problem of MSW is becoming more noticeable, obstructing the development of society [27]. As smart cities are gaining more and more attention, a growing number of cities are implementing smart waste management solutions to become more efficient [21]. MSW management system is reasonably complex and wide-ranging, relating to numerous aspects [28]. In this respect, smart city policymakers entail an advanced form of decision support, i.e. new forms of urban simulation models and prediction methods [4]. Furthermore, the outcome of a specific policy or strategic plan is largely dependent on whether the policymakers understand the inner interactions of the system [22]. For that purpose, SD can be used since its main goal is to understand how system components interact, how the changes in one component impact others, and how such changes affect the entire system [1]. SD has been applied in the field of waste management, i.e. authors [27] applied this approach to analyze the benefits of classification of MSW. Additionally, the authors used SD to examine four policy's impacts (economy, demography, sorting rate, and treatment methods) on MSW management [28]. The more narrow area was also examined, such as food waste [19] and hospital waste [13]. Besides waste management, SD has been used in various smart city aspects such as energy consumption [7], disaster management [16], and the development of digital services [25].

Since cities must face different demands by offering adequate services and facilities, the tourist load on the city can compromise its balance, affecting the quality of life [15], as well generation of waste. Furthermore, a smart city is changing in its nature in real-time, which is why a data-driven approach is essential for city progress [16, 25]. Hence, we propose the usage of the SD model as a potential quality basis for creating better public policy [21]: for a better understanding of waste management's dynamic processes, as well as the basis for policymakers to achieve smart cities' long term goals. SD model can use real data, takes into consideration system components' interactions, including how the changes in one component impact others, as well as how such changes affect the entire system [15]. Respectively, the City of Split is considered to be a smart city and is also facing the aforementioned challenges which are confirmed by the results from recent research showing that waste management has emerged as one of the top three priorities precisely for the smart city of Split [8]. City of Split faces additional challenges since it is a tourist destination, together with nearby cities, since it records significant tourist flows [17]. With the continuous rise of urbanization, as well as the acceleration of the number of tourists in Dalmatian county [9], waste management has become one of the main issues. In the next section, the development of the SD model is introduced in the case of the smart city of Split.

3 SYSTEM DYNAMICS MODEL DEVELOPMENT

Simulation models can be used to understand the basic processes in the original waste management system [18]. As mentioned before, MSW and tourist destinations are characterized as rather complex concepts, implying the necessity of implementation of a simulation model that observes complicated information feedback systems, such as SD [27]. SD, as an aspect of systems theory, is a method to understand the dynamic behavior of complex systems. SD can be described as the time-dependent behavior of managed systems, to describe the system, and to understand how information feedback governs [17]. SD uses both qualitative and quantitative analyses. The qualitative tools are mainly used to capture the model structure, while the quantitative methodologies focus on feedback loop analysis aiming to design an effective policy to adjust the system behavior, using causal loop diagrams [26], structure–behavior diagrams [10], and stock-flow diagrams [14]. SD methodology recognizes two main functions (variables): level variable and rate variable. Level variable, also known as accumulation variable, is mainly used to describe the cumulative effect of a variable. Rate variable is a variable representing the change rate of the level variable, thereby controlling the speed of change in the system [27]. Figure 1. presents the basic principle of SD applied to waste management: *Total waste* is a level variable that accumulates all changes of rate function *Waste generation* in time interval *dt.*

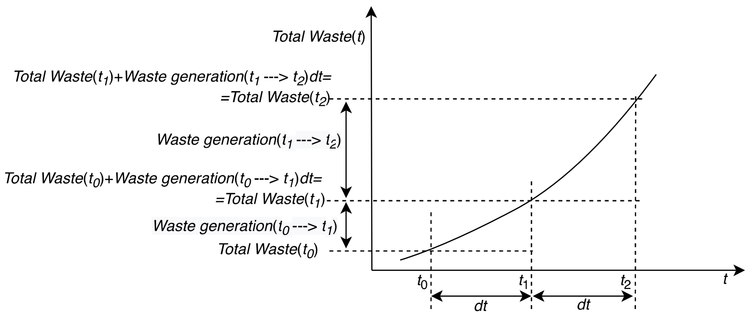


Figure 1: Basic principle of system dynamics calculation source: Adjusted to [17]

The structure of the system can be represented by a causal loop diagram. The causal loop diagram reflects the feedback relationship in the system [27]. The most commonly used variables for the waste management SD model are [18]: collected waste, recycling, regulations, treatment price, and environmental behavior. Some authors used a more generic approach to SD and used [11], [22]: total tonnes of waste generated, population, population growth, population decline, median household income, and total tonnes recycled. Destination's attractiveness, considering data availability, and Butler's [5] original idea will be presented with a number of tourist arrivals V for 18 local administrative units (LAU) that are tourism-oriented and that are using the same waste management. The data was obtained from Split-Dalmatia County statistical publications [9]. So, for making a waste policy, the forecasting model must include the effect of tourism and the local population. For this purpose, the starting point for describing the structure of the waste management model is the Tourism area life cycle (TALC). The TALC [5] has recently become one of the most cited models in tourism literature.

The main purpose of the TALC model [6] is to point out the dynamic nature of tourist destinations and to propose a generalized process of development and potential decline, which could be avoided with the appropriate interventions. SD aspect of TALC is in detail described in [17]. Data used for modeling is from the period 2016-2020. Local population data were obtained from Institute for Public Health [20] and the amount of waste data was obtained from the company officially managing waste landfills for the broader area of City of Split (in total 18 LAU, Split included). Considering the research recommendations [22] as well as the availability of real data, we developed a model that includes the following inflows: waste generation per person, local population (including changes in local population), number of arrivals (based on TALC model [17]) and length of stay. Outflow is total waste, defined by the rate of waste recycling. The causal loop diagram of the model is presented in Figure 2.

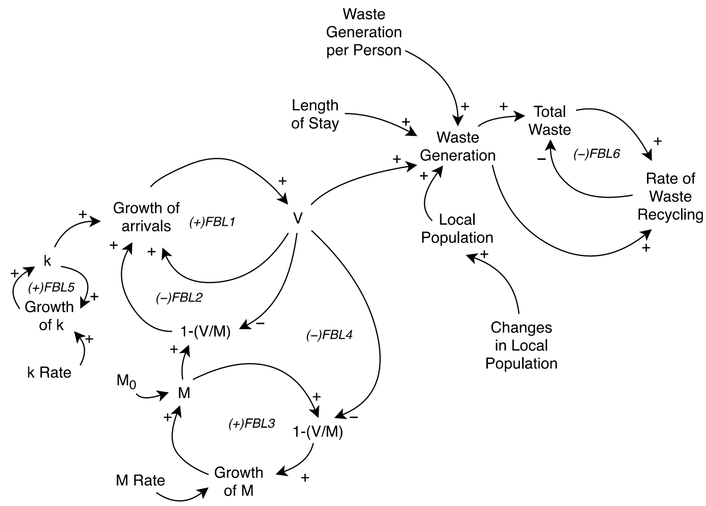


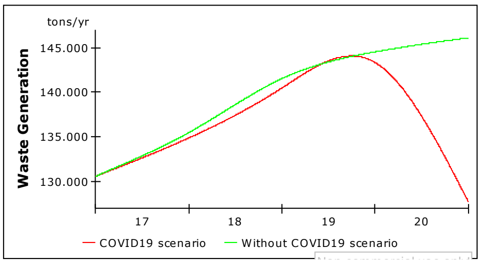
Figure 2: Causal loop diagram of the waste management system

According to Figure 2, six feedback loops can be recognized. Recognizing feedback loops is important because of their polarity and consequently pattern behavior of the modeled system. A feedback loop can be positive or negative, depending on several negative cause-consequence links between variables (functions) in a loop. A positive loop has an even number (zero included) of negative links and characterizes exponential pattern behavior. The negative loop has an odd number of negative links and characterizes goal-seeking pattern behavior. It means that negative loops have regulative character, thus they can be used for system regulation. Figure 2 shows three negative feedback loops. FBL2(–) has a self-regulation character, meaning that during the time, as *V* (number of arrivals) is approaching *M* (maximum expected number of visitors), the value of *Growth of arrivals* is becoming smaller. Similar behavior has FBL4(–). FBL6(–) is also a negative loop but it depends on the *Rate of Waste Recycling* which presents a managerial variable because it depends on policymakers' decisions regarding investment in recycling.

4 RESULTS AND DISCUSSION

Since simulation modeling helps visualize the real-life behavior by conducting virtual experiments and creating different scenarios [29], a developed SD model has been applied and two simulation scenarios have been created. So, after validation of the model (standard deviation used), two simulation scenarios were developed. Results of the "*COVID19 scenario*" showed a large decrease in waste generation in the year 2020 which could be influenced by the Covid-19 pandemic since the number of tourist visits has decreased dramatically [9]. "*Without*

Covid-19 scenario” shows that the waste generation in the observed area increased (see Figure 3). The difference between the two scenarios confirmed the importance of taking into consideration the tourist dimension, along with the effect of the local population in the waste management system.



Waste Generation (tons/yr)

Time	COVID19 scenario	Without COVID19 scenario
1. sij 2017.	130.524,70	130.524,70
1. sij 2018.	134.829,19	135.423,33
1. sij 2019.	140.441,05	141.497,99
1. sij 2020.	143.319,97	144.503,97
1. sij 2021.	127.697,24	146.072,79

Figure 3: Waste generation simulation scenarios created in Powersim software

This model points out the importance of the tourist dimension regarding the waste management system and the necessity of applying the proposed SD model, addressing mentioned smart city challenges. Due to the complexity of the waste management system, it is of utmost importance that the system is modeled properly, thus including all subsystems which influence waste generation. The significance of the proposed SD model has shown to be even more prominent in the smart city of Split since the city is in a very unenviable situation regarding the treatment of MSW [15]. Also, since it is expected that the near future will assume the implementation of IoT in waste management, such as sensors that could then feed the proposed SD model with real-time data, the existence of such an SD model should be considered as a prerequisite.

5 CONCLUSION

This paper aimed to show the potential of using the SD approach based on real data in waste management. SD model for waste management in tourism-oriented LAUs was developed using a holistic view since it included the effects of both local populations, as well as tourist attendance. The main potential of the proposed model is that it addresses the complexity of waste management systems. Moreover, prediction methods based on the proposed model could be used for creating different scenarios that can help policymakers in decision-making in tourism-oriented smart cities. Future research should be oriented towards investigating the effects of possible waste policies. Also, the introduced SD model tends to capture the waste management system, however, subsystems were not analyzed in a detailed manner, since each can be considered a distinct research field. Results have confirmed that applying a more holistic approach thus including the number of tourist arrivals is essential for tourist destinations, so future research should test the model in other tourism-oriented destinations.

Acknowledgment

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SELECTION OF IOT PLATFORMS IN SMART CITIES: MULTI-CRITERIA DECISION MAKING

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Abstract: Recently, increased interest in the smart city concept has opened up new research and business-like questions. When considering the implementation of Internet of Things (IoT) platform in smart cities it is important that it is chosen adequately. Thus, this paper identifies relevant criteria for IoT platform selection. End users and vendors have evaluated the importance of the proposed criteria. The selection procedure was demonstrated using the PROMETHEE method. Results accredit vendors to offer more suitable platforms, and enable end users and decision makers to better understand and improve the selection of IoT platforms according to smart city needs.

Keywords: Internet of Things, smart city, *MCDM, PROMETHEE*

1 INTRODUCTION

The concept of the Smart City has been intensively researched lately. According to Scopus database search done in May 2021, the number of papers has increased exponentially in the last six years. This suggests the need for further research and practical application of the abovementioned concept. According to European Commission, smart city is “a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business” [6]. Digital and telecommunication technologies cannot stand alone, as for a city to become smart, a high degree of information technology integration and a broad application of information resources should be accomplished [10].

The new emerging concept of Internet of Things (IoT) has become an important agenda when considering the future of information and communication technologies (ICT) [9]. It enables remote monitoring, managing and controling of devices, as well as creating knowledge from real-time data [1, 10, 13,]. IoT means installing and connecting sensors to the internet through specific protocols for information exchange to accomplish intelligent recognition, location, tracking, monitoring and management [9, 14]. Successful implementation of IoT platform could bring up significant benefits, e.g. efficiency, effectiveness, safety, security, and quality decision-making [9]. Because of filling the gap between device sensors and data networks, IoT platforms are considered the most significant component of the IoT concept. The platform connects the data to the sensor system and gives insights using back-end applications to get an impression of the large amount of data coming from different sensors [13].

As the demand for IoT platforms increases so is the number of service providers (vendors) growing. Furthermore, research company Gartner (2020) expects the global government IoT endpoint electronics and communications market to reach $17.4 billion in 2021. Relevant IoT end users (e.g. city administrators, managers, decision makers and policy planners) need to answer crucial questions related to the selection of the IoT platforms that are to be implemented in a city.

The motivation and goal of this paper lays in a practical and theoretical need to investigate whether commonly used criteria for the selection of technology in general are applicable for IoT platforms, as a part of the smart city concept. In addition, the presented study aims to investigate if there are differences in perceived importance between end users and vendors when it comes to IoT platforms' selection criteria. The literature shows the existence of few criteria and alternatives when selecting an IoT platform, where neither is dominant [5].

Interesting cognition arises when choosing the method to select the appropriate alternatives (in this case IoT platforms). Several MCDM methods exist, such as the analytical hierarchal process (AHP), the analytical network process (ANP), data envelopment analysis (DEA) or PROMETHEE. According to the literature MCDM method PROMETHEE has not been used when selecting IoT platforms so far, however, few authors considered it for future work [5]. With this paper, the authors fill the research gap by using PROMETHEE method to demonstrate the selection procedure of IoT platforms, as well as include non-IT experts in selecting the criteria. To the best of our knowledge, this approach has not been presented before.

Paper consists of 5 sections organised as follows. Section 2 gives a theoretical background on the IoT domain, IoT platform and criteria used. Section 3 shortly introduces the methodology used, while section 4 presents and discusses the results of MCDM analysis based on the selected and evaluated criteria. Section 5 concludes the paper with final remarks, listed limitations and avenues for future research.

2 THEORETICAL BACKGROUND

IoT assumes interconnecting the physical objects with telecommunication networks, merging real life with virtual space, and supporting the development of different digital services and applications. The IoT system consists of small sensors embedded in the objects such as electronic devices, alarm systems, cars, home appliances and industrial machines, which communicate with each other, as well as with their environment [13]. As the IoT domain is an even more novel area than the Smart City concept itself, the papers concerning the selection of criteria are mainly based on a review of the existing literature. For example, forces that have been traditionally investigated are technology, market, and regulations [3]. Other authors have presented multi-criteria approach using three main criteria for IoT applications [9]: (1) technological prospect, (2) market potential and (3) regulatory environment. From methodological perspective, their findings can be limited as they rely on respondents that are mainly experts with ICT background. Additionally, many authors have proposed detailed methodology to assess IoT, but the literature is lacking empirical research [14]. Literature review analysis confirmed that different criteria can be found depending on the type of technology (e.g. database, cloud, etc.). The list of criteria, information about IoT domain and authors who investigated the criteria are summed in Table 1.

Table 1: IoT selection criteria

Criteria	***IoT domain***	***Authors***
Reliability	IoT application; IoT platform	[9, 11]
Cost	IoT application; IoT cloud; IoT platform	[9, 15, 12]
Standardization	IoT application	[9]
Scalability	IoT platform	[12]

Market Longevity	IoT platform	[12]
Security (and safety);	IoT platform	[11,12]
Usability	IoT platform; IoT database	[1, 12]
Integration Flexibility	IoT platform	[11,12]
Availability	IoT platform; IoT cloud	[15, 12]
Security	IoT (in general); IoT application; IoT platform	[9, 16, 11, 12]
Legal regulations	IoT (in general)	[16]
Device management	IoT platform	[11]
Functionality	IoT platform	[11, 12]
Usefulness of visualization	IoT platform	[11]
Variety of data analytics	IoT platform	[11]
Portability	IoT database	[1]
Supportability	IoT database	[1]

Souce: Authors' analysis, 2021.

Criteria that were not considered as relevant (outside of the scope of an IoT platform) were excluded from further evaluation and the authors focused on the general ones only (e.g. market longevity). The following 15 criteria were extracted from the literature review: availability, security, price, reliability, device management, integration flexibility, manufacturer quality, portability, scalability, standardization, supportability, functionality, usability, usefulness of visualization, and variety of data analytics.

3 METHODOLOGY

Multi-criteria decision-making (MCDM) indicates the existence of limited number of alternatives, as well as decision making with conflicting criteria that share the following characteristics [2]: (1) multiplicity of criteria, (2) conflict among criteria, and (3) incomparable units of measure.

A decision-maker or multiple ones (e.g. experts) assess the importance of criteria in terms of priorities or weights. Assessments are possible through methods for group weight assessment (e.g. ranking, grading, pairwise comparisons, Delphi method), and methods for the single decision-maker (e.g. calculating eigenvector, weighted least squares and entropy method) [2]. For this study, group weight assessment has been done i.e. the grading method with experts, where grading was conducted by presenting the criteria to each expert who then awarded a grade for each criteria in an interval from number 0 to 100. The weight is determined as follows (1):

$$w_{jk} = \frac{p_{jk}}{\sum_{j=1}^{n} p_{jk}} \tag{1}$$

$$w_j = \frac{\sum_{k=1}^{l} w_{jk}}{\sum_{j=1}^{n} \sum_{k=1}^{l} w_{jk}} \tag{2}$$

where n signifies the number of alternatives, ρ_{jk} the grade from expert k to criteria j, w_{jk} signifies normalised weight calculated for criteria j from expert k, and w_j (2) stands as the total weight for criteria j.

In order to answer research questions, the research instrument was prepared. In accordance with the results of the literature review, the authors arranged the list containing the important criteria (N=15) when selecting IoT platform. IoT experts including vendors from Croatia, as well as smart city end users from Croatia were contacted and asked to evaluate the importance of each criterion with grades from 0 to 100. In addition, experts had an opportunity to list any additional criteria if found necessary.

The second part of the selection process concerns choosing the appropriate alternative. When looking for the available alternatives in the market, a new question arises concerning the method that should be used to support the selection of appropriate platforms from available alternatives. For illustrative purpose, two IoT platform alternatives were selected and PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) was used as method. It is an outranking method used when there is a finite set of alternative actions which need to be ranked and selected based on various criteria [2]. PROMETHEE supports transforming qualitative data using an ordinal scale [8]. One of six specific preference function should be used to define generalized criteria for each criterion f*j* [4]. Types of particular preference functions are: usual criterion, U-shape criterion, V-shape criterion, level criterion, V-shape with indifference criterion and Gaussian criterion. Additionally, some parameters need to be defined in advance, such as q – difference threshold, which defines the interval where the decision-maker is indifferent, p – strict preference threshold, which defines the value above there is a strict preference, s – parameter between q and p.

4 RESULTS AND DISCUSSION

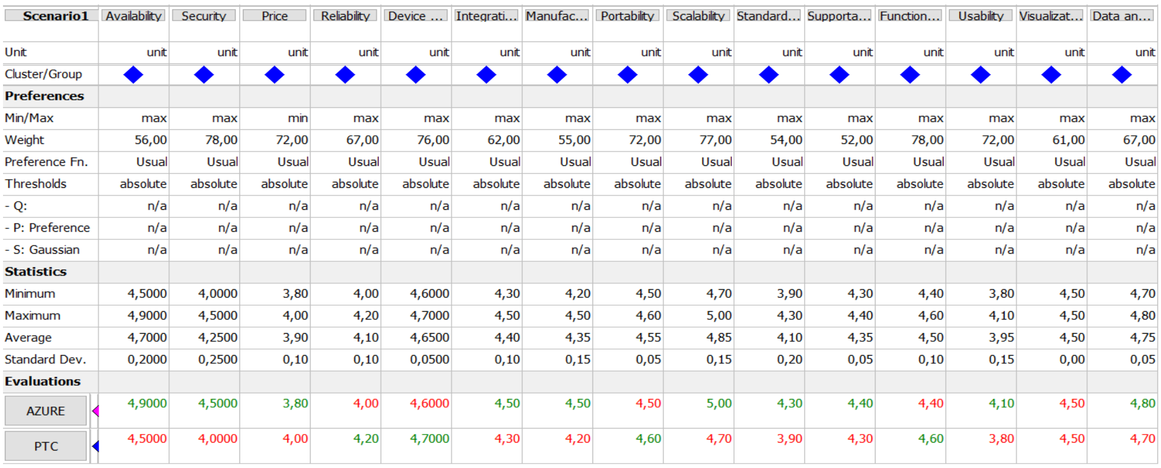
Total number of 8 experts participated in the evaluation, half of whom were end users (N=4) and half vendors (N=4). Results of experts' evaluation yielded additional three criteria: "customer support team", "intuitive user interface" and "privacy/data protection"; however all of them could be considered contained within the listed criteria (N=15). Criteria weights were calculated for each group of experts and sorted from the most rated criteria. Calculated weights are shown in Table 2.

Table 2: Criteria weights according to vendors and end users

Criteria	***Weight according to vendors***		***Criteria***	***Weight according to end users***
Device management	0.0791		Functionality	0.0798
Scalability	0.0790		Security	0.0780
Security	0.0786		Scalability	0.0754
Price	0.0781		Portability	0.0753
Functionality	0.0770		Device management	0.0735
Usability	0.0726		Usability	0.0713
Reliability	0.0698		Variety of data analytics	0.0687
Portability	0.0689		Price	0.0665
Variety of data analytics	0.0644		Reliability	0.0651
Usefulness of visualization	0.0599		Integration Flexibility	0.0646
Integration Flexibility	0.0587		Usefulness of visualization	0.0624
Availability	0.0556		Manufacturer quality	0.0576
Standardization	0.0554		Availability	0.0564
Manufacturer quality	0.0519		Supportability	0.0535
Supportability	0.0510		Standardization	0.0517

As seen from above, the most important criteria for end users while selecting the IoT platform is "functionally". It is interesting to point out that, except for criteria "price", every other criterion has been rated as more important by IoT vendors than it has been from end users. Unexpectedly, "price" is considered more important criteria by vendors than by end users.

For the second part of the selection process, two IoT platforms (alternatives) were chosen - Azure IoT Microsoft and ThingWorx PTC because these platforms were perceived as the most popular by end users [7]. Evaluation of set criteria (populating of decision matrix) was done based on published comparison, as well as qualitative reviews (ibid). Group criteria weights (including end users and vendors grading) were calculated and rounded W = {56; 78; 72; 67; 76; 62; 55; 72; 77; 54; 52; 78; 72; 61; 67}. Input data is shown in Figure 1.



Scenario1	Availability	Security	Price	Reliability	Device ...	Integrati...	Manufac...	Portability	Scalability	Standard...	Supporta...	Function...	Usability	Visualizat...	Data an...
Unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit
Cluster/Group															
Preferences															
Min/Max	max	max	min	max	max	max	max	max	max	max	max	max	max	max	max
Weight	56,00	78,00	72,00	67,00	76,00	62,00	55,00	72,00	77,00	54,00	52,00	78,00	72,00	61,00	67,00
Preference Fn.	Usual	Usual	Usual	Usual	Usual	Usual	Usual	Usual	Usual	Usual	Usual	Usual	Usual	Usual	Usual
Thresholds	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute
- Q:	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
- P: Preference	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics															
Minimum	4,5000	4,0000	3,80	4,00	4,6000	4,30	4,20	4,50	4,70	3,90	4,30	4,40	3,80	4,50	4,70
Maximum	4,9000	4,5000	4,00	4,20	4,7000	4,50	4,50	4,60	5,00	4,30	4,40	4,60	4,10	4,50	4,80
Average	4,7000	4,2500	3,90	4,10	4,6500	4,40	4,35	4,55	4,85	4,10	4,35	4,50	3,95	4,50	4,75
Standard Dev.	0,2000	0,2500	0,10	0,10	0,0500	0,10	0,15	0,05	0,15	0,20	0,05	0,10	0,15	0,00	0,05
Evaluations															
AZURE	4,9000	4,5000	3,80	4,00	4,6000	4,50	4,50	4,50	5,00	4,30	4,40	4,40	4,10	4,50	4,80
PTC	4,5000	4,0000	4,00	4,20	4,7000	4,30	4,20	4,60	4,70	3,90	4,30	4,60	3,80	4,50	4,70

Figure 1: Parameters and alternatives assessments in Visual PROMETHEE software

Ranking results of proposed alternatives are shown in Table 3. Ranking with PROMETHEE method is done based on Phi net flow which is the result of computing two preference flows, Phi+ and Phi- [2]. Interpreting the results, the best alternative is A1 (Azure) as has the highest leaving flow (0.6446) and at the same time the lowest entering flow (0.2942).

Table 3: Flow table

Rank	***Alternative***	***Phi***	***Phi+***	***Phi-***
1	AZURE	0,3504	0,6446	0,2942
2	PTC	-0,3504	0,2942	0,6446

In order to examine in more detail how sensitive the choice of alternative is to the change in the evaluation of the criteria functionality, Visual stability intervals in Visual PROMETHEE can be used. The stability interval for criterion functionality is 31.75%, which shows how much weight of this criterion could be increased for leading alternative to change its position. Visual representation of the analysis is shown in Figure 2.

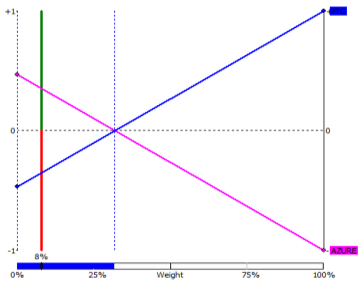


Figure 2: Visual stability intervals for criteria functionality in Visual PROMETHEE software.

5 CONCLUSION

The goal of this paper was to propose the most important criteria to be considered by relevant end users when selecting the IoT platform within the smart city concept. Thus, based on literature review this paper first identified IoT platform selection criteria. Next, the proposed criteria have been evaluated according to their importance by both, IoT vendors and smart city managers (end users). Results show that both vendors and end users assessed “Security” and “Scalability” as top three most important criteria. Results also show the existence of differences in the importance of selection criteria among vendors and end users (e.g. “functionality” and “price”). Results of this study can be used by both, IoT vendors to better tail the needs of the end users when designing future IoT platforms, and by smart city administrators, managers, and policy planners when selecting the IoT platforms for the smart cities.

The presented study suffers from some limitations, which can also serve as starting points for future research. As not being able to define selection criteria for specific cities, the authors used a rather generic approach. Hence, more IoT selection criteria could be included in the analysis. Next, the number and diversity of participants considered in the evaluation of the identified criteria should be expanded. It would also be beneficial to include some vendors and smart city managers in wider geographical regions, e.g. Slovenia, and compare the results. In this study, the authors used PROMETHEE method to select IoT alternative. In the future, other methods could be used to verify the results. In addition, a higher number of alternatives would be considered.

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GROUP METHOD OF DATA HANDLING FOR MODELING GNSS SITE-SPECIFIC QUALITY PARAMETERS

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Abstract: This paper proposes the use of group method of data handling (GMDH) model to predict site-specific time series of quality parameters by using global navigation satellite systems (GNSS). There are several local environmental factors that can interfere with GNSS position estimates. Prediction of multipath and carrier-to-noise ratio (CNR) based on satellite elevation angle is particularly important in urban street canyons where signal reflections lead to positioning errors. The aim of this work is to propose a soft computing approach for elevation-dependent modeling of site-specific parameters, which could be used as a reference for quality prediction in kinematic positioning, especially in adverse GNSS positioning situations. Prediction model was constructed based on GMDH and simulation results show a good agreement of the proposed model to the actual values. Thus, GMDH provides promising results for further investigation on its usability in real-time positioning.

Keywords: GNSS, satellite elevation, multipath, group method of data handling (GMDH)

1 INTRODUCTION

In GNSS positioning, quality parameter modeling is important to determine the influence of site-specific parameters on the final positioning results. New applications targeting users in urban areas, such as intelligent transportation systems (ITS), benefit significantly from accurate positioning capability in urban environments [1], [2]. However, there are site-specific environmental factors that can interfere with GNSS position estimation and degrade the final positioning results [3]. Continuously operating GNSS reference stations (CORS) allow us to study the site-specific effects over a longer period of time to estimate their periodicity, which may be due to seasonally varying environmental factors. Based on the findings from static CORS measurements, site-specific models can be determined and further used for kinematic positioning in urban environments. The prediction of the carrier-to-noise ratio based on the satellite elevation angle is particularly important in urban street canyons where signal reflections lead to multipath errors [4]–[6]. The aim of this paper is to propose a group data processing method for elevation-based GNSS influence modeling that can be used as a reference for kinematic positioning in adverse GNSS positioning situations.

Current GNSS positioning accuracy is adequate for most civilian users. However, a number of applications, including autonomous navigation, require centimetre-level positioning. GNSS positioning techniques are very efficient in an open-sky environment with good satellite geometry, few cycle slips and low multipath. The environmental factors that most affect the quality of kinematic positioning are:

- multipath effects, which are very high on pseudo-range and carrier phase,
- cycle slips are common,
- carrier-phase availability in really bad conditions is low, and
- the satellite geometry is weak.

The statistical properties of signal reception conditions vary greatly in different types of positioning scenarios, which differ up to the local environment and surrounding objects, as well as local interference conditions [7], [8]. It depends on a GNSS receiver to detect local obstacles for proper positioning algorithms. In order to characterize different environmental influences, it is necessary to distinguish several factors, namely: signal attenuation, multipath, blocking and interference. GNSS multipath is caused by the reception of signals that not only come directly from satellites, but are also reflected or diffracted by the local objects. Multipath causes an error in the pseudorange measurement and thus affects the positioning accuracy, since the multipath signal takes a longer path than the direct signal (Fig. 1). To effectively reduce the influence of multipath interference, the multipath mitigation strategy focuses on three aspects: the observation environment, the receiver hardware, and the data processing software. The predicted model can be a valuable information for real-time positioning.

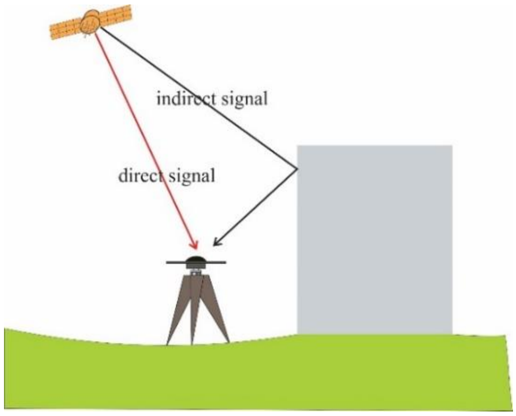

Figure 1: Multipath in urban canyons.

The general quality assessment of GNSS observations under different conditions could be easily described by the dilution of precision values (DOP). When satellites are relatively close to each other, the overlap range of position uncertainty is larger and vice versa. DOP is the relationship between coordinates and measurement accuracy. When the DOP values increase, both the horizontal and vertical precision of the point position decreases [9]. Define (x, y, z) and (X_i, Y_i, Z_i) for the position of the receiver and the i^{th} satellite positions, respectively. The approximate position of the receiver is (x^0, y^0, z^0), while $(\hat{x}, \hat{y}, \hat{z})$ is determined according to the least squares' adjustment of the redundancy pseudoranges. The geometric DOP, GDOP refers to the geometry matrix H:

$$\mathrm{GDOP} = \sqrt{trace(H^T H)^{-1}} \tag{1}$$

$$H = \begin{bmatrix} e_{11} & e_{12} & e_{13} & 1 \\ e_{21} & e_{22} & e_{23} & 1 \\ \vdots & \vdots & \vdots & \vdots \\ e_{n1} & e_{n1} & e_{n1} & 1 \end{bmatrix}$$

$$e_{i1} = \frac{\hat{x} - X_i}{\hat{r}_i}, \quad e_{i2} = \frac{\hat{y} - Y_i}{\hat{r}_i}, \quad e_{i3} = \frac{\hat{z} - Z_i}{\hat{r}_i}, \text{ and } \hat{r}_i = \sqrt{(\hat{x} - X_i)^2 + (\hat{y} - Y_i)^2 + (\hat{z} - Z_i)^2}.$$

Multipath can be detected using Melbourne-Wübbena (MW) linear combination, which is free of geometry, troposphere, and ionosphere, and is affected only by noise from code or carrier-phase measurements, including multipath. It is composed of carrieer-phase (wide-lange – W) and code (narrow-lane – N) measurements and expressed as follows [10]:

$$L_{MW} = (f_1 P_1 + f_2 P_2)/(f_1 + f_2) - (f_1 L_1 - f_2 L_2)/(f_1 - f_2), \tag{2}$$

where P and L represent the code and carrier-phase measurements in meters and f is the frequency (subscripts denote the frequency numbers). Because of its computational simplicity, this approach is often used to evaluate the total multipath in GNSS.

The main objective of the current research can be stated as follows: to investigate and test the GMDH technique to acquire the prediction model based on periodic time series of elevation dependent GNSS parameters to be further used in GNSS signal quality detection for optimal positioning.

2 TIME SERIES MODELING WITH GMDH

Time series prediction can be viewed as a special case of nonlinear regression and function approximation. Therefore, nonlinear regression approaches, such as artificial neural networks (ANNs), can be used to perform time series forecasting problems. GMDH, first proposed by Alexey Grigorevich Ivakhnenko in 1968 [11], is a modeling technique that provides an effective approach for identifying higher order linear systems. GDMH, similar to ANN, constructs the mapping of input data to the output data based on human knowledge and is based on its architecture. Since the accuracy of ANN depends on the selection of the architecture, the idea of GMDH is to replace such a complex model with structure consisting of sub-models [12]. Sub-models are placed into a linear, nonlinear and dynamical sets [13].

A GDMH is a multilayer neural network consisting of a set of higher-order polynomial neurons arranged in a special structure to map a given set of training feature vectors into their corresponding response variables. Therefore, it automatically learns the relationships in the system, especially the relationships that dominate the system variables during the training/learning process. GMDH has the following advantages in term of ANN [14]:

- GMDH models allow us to obtain explicit expressions as well, while in ANN only implicit expressions are available,
- it provides adaptive network representations, while the design of the ANN topology is a trial-and-error process, and
- GMDH is a self-organized model and the structure of the models is self-optimized according to the available data.

System modeling allows us to design and analyze processes for nonlinear systems in situations where explicit mathematical expression is not always possible. In such an approach, the use of pattern recognition from input-output data pairs provides promising modeling results for understanding system behavior. Several strategies can be used for modeling time series, including different types of artificial neural networks, i.e., radial basis networks (RBFNs), wavelet neural networks (WNNs) [15] lead us to promising results. The fundamental difference between RBFNs and WNNs compared to GMDHs is the architecture of the network. While the first two are based on only one hidden layer, the latter follows a multi-hidden layer architecture. The GMDH approach has its advantages because the number of hidden layers and neurons in each specific layer and the model structure are automatically optimized and determined with respect to the complexity and noise level of the data sample.

Finally, a stopping condition is needed to prevent the network from growing to infinity. At least two stopping conditions are available, namely the minimum estimation error and the maximum number of layers [16].

2.1 Group method of data handling

The GMDH network is a fast learning machine based on the principle of heuristic self-organization that can be used for system modeling and prediction as well as system optimization. In principle, a GMDH is a kind of multilayer feedforward neural network consisting of high-order polynomials Kolmogorov-Gabor [17]. GMDH uses a multilayer network of n-th order polynomials. Very often, second-order polynomials (quadratic neurons) are used to characterize the complex nonlinear relationships between the given inputs and outputs of a system. Each quadratic neuron has two inputs and a single output expressed by the equation:

$$g(x_1, x_2, \dots) = w_0 + w_1 x_1 + w_2 x_2 + w_3 x_1 x_2 + w_4 x_1^2 + w_5 x_2^2 \tag{3}$$

In the above equation, w_i $(i = 0, \dots, 5)$ represent the weights of the quadratic neuron. GMDH models consist of three parts, namely: (a) input variables, (b) internal criteria, and (c) external criteria. Internal criteria are used to estimate the coefficients, i.e., weights w, in Equation 1.

Usually, least square principle is used as the internal criterion. Internal criteria do not use any additional information, but in contrast, external criteria are used for model selection. There are several external criteria to choose from depending on the nature of the problem. Among the available external criteria, the regularity criterion is commonly used. Also, the selected candidate models are adopted for the next layer. Once the self-organizing model satisfies the requirements, the learning of the model is terminated.

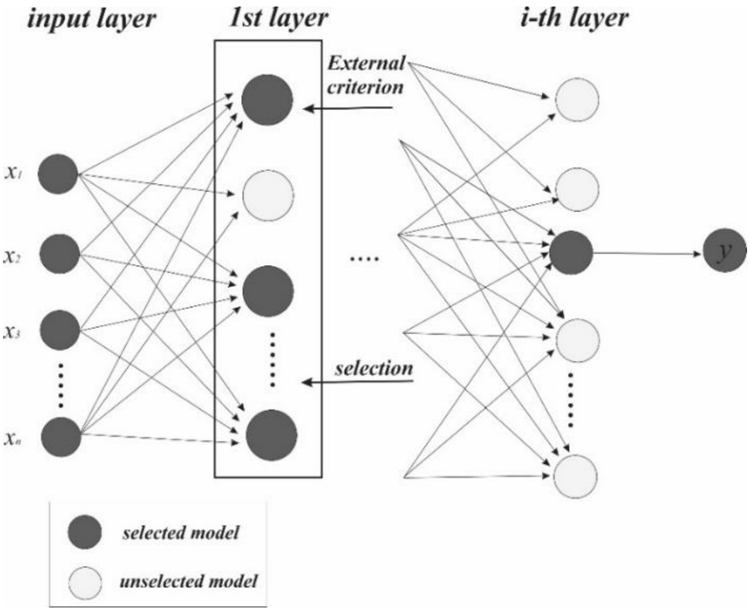

Figure 2: GMDH (group method of data handling) model.

GMDH models consist from the following steps [14]:

- Step 1: The data of n input variables ($x_1, x_2, \dots, x_1$) are divided into two parts, namely training and test groups. The training group is used to estimate the coefficients of the model, while the second is used for validation to separate the embedded information into useful or harmful.
- Step 2: Input variables are the nodes in the input layer; also, all combinations of nodes in the current layer are defined: ($C_n^2 = n(n-1)/2$).
- Step 3: Mean candidates are generated from all node combinations using Eq. 3. The coefficients (weights) are estimated during training using internal criteria such as ordinary least squares. The value of external criterion (EC) is computed for the middle candidate models for the test data set.
- Step 4: The middle candidate models are ranked in the current layer with respect to their external criterion value. Only certain nodes are selected as inputs for the next layer (grey nodes in Fig. 2).
- Step 5: if the minimum explicit criterion value in the current layer is the minimum external criterion of middle candidate models: $\varepsilon^l = \min(\mathrm{EC})$.
- Step 6: if the condition $\varepsilon^{l-1} > \varepsilon^l$, then go to the next layer ($l = l + 1$) and repeat the steps from 2 to 6, otherwise go to step 7.
- Step 7: set the middle candidate model with minimum external criterion value as the optimal complexity model, in the next process, the explicit expression of this model can be obtained iteratively.

3 GMDH APPLICATION FOR GNSS OBSERVATION QUALITY MODELING

In this study, GNSS observations were tested for use with GMDH for two quality parameters, namely: carrier-to-noise ratio (CNR) (Fig. 3) and multipath (Fig. 4). Observations were of the time span of four hours from the Slovenian continuously operating reference station (CORS) network, SIGNAL, namely KOPE, located in the south-western part of the network. The main feature of this point is that it is located on the coast, near the sea, at the same location as the tide gauge. GMDH was applied for modelling and prediction of most affected parameters from the environment, CNR and multipath; they both depend upon geometry of satellites (presented with DOPs) and satellites' elevation.

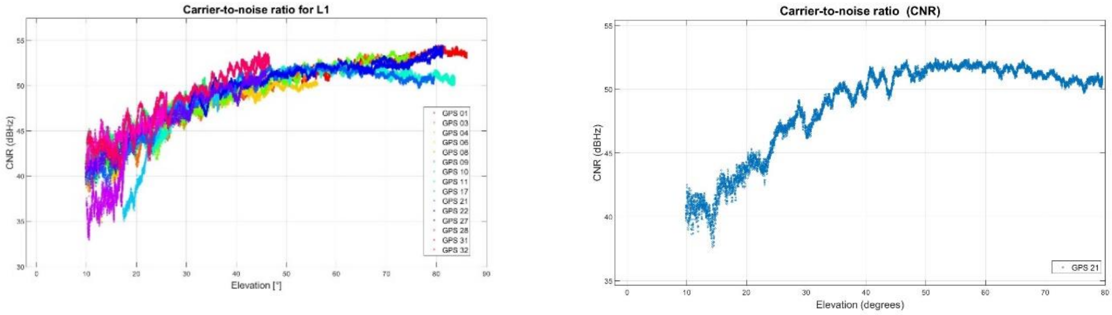

Figure 3: Time series of CNR for: (a) all GPS satellites in view; (b) for GPS satellite No. 21.

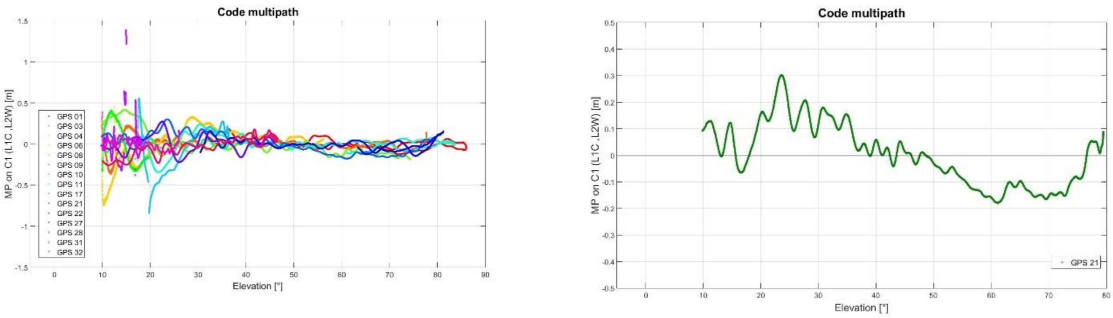

Figure 4: Time series of multipath for: (a) all GPS satellites in view; (b) for GPS satellite No. 21.

The GMDH models for prediction differed in time of delays; we set up a shift register of delays (D), from which we retained successive values of our time series. Each past value was then treated as an additional dimension in the inputs to our predictor. Different delay scenarios were evaluated by comparing its testing to the measured values, namely 2, 3, 5, 10 and 20 epochs of delay. A comparison of fitting error, forecast errors of combination models and the individual models is shown in Tab. 1. Tab. 1 reports the forecast of CNR and Tab. 2 the forecast of multipath according to different sets of prediction data, RMSE and regression coefficient (R) for the training and testing data sets and for all of them. Data was divided into 70% for the training phase and 30% for the validation. Each layer of GMDH structure consisted from maximum 20 neurons and we set maximum of five hidden layers.

Table 1: Prediction results for CNR by using GMDH.

Delay	RMSE (all data) [dBHz]	R (train)	R (test)	R (all)
2	0.506	0.98684	0.98113	0.98619
3	0.494	0.98753	0.98118	0.98678
5	0.487	0.98782	0.98119	0.98701
10	0.449	0.99030	0.98191	0.98896
20	0.433	0.99009	0.98233	0.98859

Table 2: Prediction results for multipath by using GMDH.

Delay	RMSE (all data) [m]	R (train)	R (test)	R (all)
2	0.088	0.93765	0.90184	0.93455
3	0.089	0.93847	0.89268	0.93440
5	0.083	0.94712	0.89654	0.94265
10	0.081	0.94892	0.89853	0.94512
20	0.081	0.94921	0.89835	0.94467

The forecast performance shows a good agreement between training and testing data for both, CNR (Tab. 1) and multipath (Tab. 2) time series. Based on RMSE and regression coefficients it is clear that the GMDH forecast leads to satisfying results, so further analyses are quite substantiated and meaningful for GNSS. For multipath better results were obtained for short time prediction, that may be due to the fact that multipath in kinematic positioning changes rapidly.

4 CONCLUSIONS

This paper proposes GMDH approach for modeling of site-specific quality parameters, which could be used in real-time quality assessment and prediction for parameters used for quality GNSS positioning estimation. GMDH modeling results were validated on testing data samples for different delays.

As seen from the results delay of ten data gives promising results for CNR and delay of five data for multipath. The experimental analysis shows that GMDH is feasible and brings different aspect of solution of time-series modelling in GNSS quality-parameter positioning with promising results. However, further research and new tests by using different quality as well as bigger sample size of data might be used in further experiments to check the robustness of the method.

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Special Session 2:

Computational Mathematical Optimization

MIXED INTEGER LINEAR PROGRAMMING FORMULATION FOR K-MEANS CLUSTER PROBLEM

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Abstract: The minimum sum of clustering is the most used clustering method. The minimum sum of clustering is usually solved by the heuristic K-means algorithm which converges to a local optimum. Much effort was put into solving such kind of problem, but a mixed integer linear programming formulation (MILP) is still missing. In this paper, we formulate MILP models and solve them up to sample size 100. The advantage of MILP formulation is that users can extend the original problem with arbitrary linear constraints.

Keywords: Clustering, LP formulation, K-means

1 INTRODUCTION

Clustering is one of the most used methods in data science. Inside this area, K-means clustering is the most used approach which aims to minimize the within cluster sum of squares of distances. K-means clustering algorithm is a very fast method, but it is a heuristic algorithm without any guarantee for global optimum. In data science, it is said that the K-means algorithm is sensitive to the initial cluster centers, in optimization terminology the K-means algorithm converges to a local optimum. This phenomenon is well known, however, this method is implemented in most used statistical and data science softwares till nowadays, contrary to the fact that exact algorithms are known (see for instant du Merle et al. (1999), Peng and Wei (2007)).

Solving clustering problem using linear programming appeared early in the literature, see Vinod (1969), Rao (1971). Later, different types of clustering problems were solved using LP, see for instance Cornuejols et al. (1980), Kulkarni and Fathi (2007), Dorndorf and Pesch (1994), Gilpin et al. (2013), but the most frequently used minimum sum of squares clustering was less investigated. Du Merle at al. (1999) proposed an exact algorithm to solve the minimum sum of squares clustering problem, but this approach did not appear in statistical packages, probably due to the fact that it is a quite complicated algorithm.

We can also form the minimum sum of squares clustering problem as Semidefinite Programming (SDP) problem (see Peng and Wei (2007)). The drawback of this possibility is that SDP problems can be solved only for moderate size problems.

In this paper, we present Mixed Integer LP formulations for the minimum sum of squares problem. These formulations can be extended to problems with many types of constraints (for instance lower bound on the cardinality of clusters or must-link constraints: Bradley et al. (2000), Davidson and Ravi (2007)). The presented MILP model is based on formulation appeared in Awasthi et al. (2015).

2 MILP FORMULATION FOR MINIMUM SUM OF SQUARES CLUSTERING PROBLEM

We have N points in the n-dimensional space: $\mathcal{A} = \{a_1, \dots, a_N\} \subset \mathbb{R}^n$. Our aim is to group these points into K clusters in a way that we minimize the within cluster sum of squared distances. Clusters of points are denoted by $\mathcal{A}_k$, $k = 1 \dots K$. These sets form a partition of $\mathcal{A}$, since $\mathcal{A}_k \cap \mathcal{A}_\ell = \emptyset$, $\cup_{k=1}^K \mathcal{A}_k = \mathcal{A}$ and $\mathcal{A}_k \neq \emptyset$ for all $k = 1, \dots, K$. Let $\mathcal{P}_\mathcal{A}$ denote the set of partitions of $\mathcal{A}$ into eaxctly K non-empty subsets. The center of cluster $\mathcal{A}_k$ is denoted by c_k, which is defined as the multidimensional mean. Sum of squared distances within the cluster $\mathcal{A}_k$ is given by the formula: $\sum_{a_i \in \mathcal{A}_k} d(a_i, c_k)^2$, where $d(a, b)$ is the Euclidean distance between points a and b (also called ℓ_2 norm). We can reformulate this sum of squares formula as $\frac{1}{|\mathcal{A}_k|} \sum_{a_i, a_j \in \mathcal{A}_k} d(a_i, a_j)^2$ (see du Merle et al. (1999), Awasthi et al. (2015)). The *minimum sum of squares clustering problem* is the following:

$$\min_{(\mathcal{A}_1, \mathcal{A}_2, \dots, \mathcal{A}_k) \in \mathcal{P}_\mathcal{A}} \sum_{k=1}^K \sum_{a_i, a_j \in \mathcal{A}_k} \frac{d(a_i, a_j)^2}{|\mathcal{A}_k|} \; .$$

In Awasthi et al. (2015), we can find a promising formulation:

$$\sum_{i,j} d(a_i, a_j)^2 \, z_{ij} \to \min \tag{1}$$

s.t.

$$\sum_{j=1}^N z_{ij} = 1 \qquad \forall\, i \in [N] \tag{2}$$

$$z_{ij} \le z_{ii} \qquad \forall\, i, j \in [N] \tag{3}$$

$$\sum_{i=1}^N z_{ii} = K \tag{4}$$

$$z_{ij} \ge 0 \qquad \forall\, i, j \in [N] \tag{5}$$

$$z_{ij} \in \{0, 1/|\mathcal{A}_{t(j)}|\} \qquad \forall\, i, j \in [N]$$

where $\mathcal{A}_{t(j)}$ is the cluster which contains a_j, $|\mathcal{A}|$ is the cardinality of the set $\mathcal{A}$ and $[L] := \{1, \dots, L\}$. Except for the last constraint, this is a linear model with nonnegative decision variables z_{ij} which indicates whether element i and j belongs to the same cluster or not. There are several problems with the last constraint, we do not know apriori the value of $t(j)$ and the cardinality of cluster $\mathcal{A}_{t(j)}$. However, it can be reformulated as $z_{ij}(z_{ij} - z_{ii}) = 0$, but it is still not a linear constraint.

Unfortunately (but not surprisingly), the optimal solution of the problem minimizing (1) subject to (2)-(5) does not give a 'legal' clustering. To ensure this, we need further constraints.

It is worth prescribing the symmetry of the variables z_{ij}, that is,

$$z_{ij} = z_{ji} \qquad \forall\, i,j \in [N] \ . \tag{6}$$

Another possible linear constraint is the 'triangle inequality':

$$z_{ij} + z_{i\ell} - z_{j\ell} \leq z_{ii} \qquad \forall\, i,j,\ell \in [N] \ . \tag{7}$$

Indeed, if both variables z_{ij} and $z_{i\ell}$ take positive value (meaning elements i and j are in the same cluster and also elements i and ℓ are in the same cluster), then variable $z_{j\ell}$ has to take positive value, and in this case, the values of all of the three variables have to equal variable z_{ii}. If both variables z_{ij} and $z_{i\ell}$ are 0, then the value of variable $z_{j\ell}$ is not constrained.

We refer to the model minimizing (1) subject to (2)-(7) as *MSSR: Minimum Sum of Squares Relaxation*. It still does not surely result in a 'legal' clustering structure, but as the numerical tests show, we already get an optimal clustering with this model in most of the cases. To get an exact model, we use binary variables. It can be done in different ways, we will discuss two of them.

First we introduce binary variable ζ_{ij}, which takes value 1, if elements i and j are in the same cluster, otherwise it takes value 0:

$$\zeta_{ij} \in \{0,1\} \qquad \forall\, i,j \in [N] \ . \tag{8}$$

Values of variables z_{ij} and ζ_{ij} are not independent, hence we need constraints to ensure the relationship between them:

$$z_{ij} \leq \zeta_{ij} \qquad \forall\, i,j \in [N] \ . \tag{9}$$

$$z_{ii} - z_{ij} \leq 1 - \zeta_{ij} \qquad \forall\, i,j \in [N] \ . \tag{10}$$

Now the problem minimizing (1) subject to (2)-(10) gives an exact model for the K-means problem. However, we can add further constraints (cuts) to help the MILP solver to find an optimal solution faster. Two possibilities are considering the following constraints

$$(N-K+1) z_{ij} \geq \zeta_{ij} \qquad \forall\, i,j \in [N] \ . \tag{11}$$

$$(N-K+1)(z_{ii} - z_{ij}) \geq 1 - \zeta_{ij} \qquad \forall\, i,j \in [N] \ . \tag{12}$$

We reach the *MSS formulation*: minimizing (1) subject to (2)-(12). It is easy to see that if an optimal solution of MSSR is a 'legal' clustering, then all binary variables ζ_{ij} take integer values, i.e. branch and bound tree will only contain the root node.

In MSS formulation the number of binary variables can be quite large, its number increase quadratically as the number of elements increases. We tried another formulation, in which the number of binary variables is significantly less. Let γ_{ik} denote the binary variable which indicates if element i is assigned to cluster k:

$$\gamma_{ik} \in \{0,1\} \qquad \forall\, i \in [N], k \in [K] \ . \tag{13}$$

Since every element belongs to exactly one cluster

$$\sum_{k=1}^{K} \gamma_{ik} = 1 \qquad \forall\, i \in [N] \;, \tag{14}$$

furthermore every cluster contains at least one element:

$$\sum_{i=1}^{N} \gamma_{ik} \geq 1 \qquad \forall\, k \in [K] \;. \tag{15}$$

We need to connect variables γ_{ik} to variables z_{ij}. If elements i and j are in different clusters, then z_{ij} has to be zero, therefore

$$z_{ij} \leq 1 + \gamma_{ik} - \gamma_{jk} \qquad \forall\, i \neq j \in [N] \;. \tag{16}$$

Now the problem minimizing (1) subject to (2)-(5) and (13)-(16) gives an exact model for the K-means problem. We call it *AMSS (Assignment-type Minimum Sum of Squares)* formulation. Let us again show some further constraints that can help the MILP solver. One possibility is to enforce i and j into different clusters if $z_{ij} = 0$:

$$\gamma_{ik} + \gamma_{jk} \leq 1 + (N - K + 1) z_{ij} \qquad \forall\, i, j \in [N], k \in [K] \;. \tag{17}$$

Furthermore, in a clustering problem, the essential result is a grouping, meaning which elements are in the same cluster and which are in different ones. The 'label' of the cluster is irrelevant. If we have K clusters the labels can be assigned in $K!$ way. We can break this symmetry by prescribing that the first element belongs to the first cluster:

$$\gamma_{1,1} = 1 \;. \tag{18}$$

We could go further. If the second element belongs to the same cluster as the first element, it will be assigned to cluster 1 as well. Otherwise, let it be in the second cluster, so we have $\gamma_{2,k} = 0$, for $k \geq 3$. Similarly for the third element, $\gamma_{3,k} = 0$ for $k \geq 4$. Surprisingly, these constraints also slow down the process, it is not worth using all of them.

AMSS has signficantly less binary variables than MSS ($N \times K$ vs. $(N-1) \times (N-1)$). A further advantage of AMSS formulation is that more constraints can be formulated with the help of variables γ_{ik} than with the help of ζ_{ij}. On the other hand, it is not true that if the optimal solution of MSSR formulation gives a legal clustering, then all binary variables in the relaxation of AMSS take integer values.

3 NUMERICAL RESULTS

In order to test the above formulations, we generated uniformly distributed random points in the unit square. On these instances, we tested the MSSR, MSS and AMSS formulations. We used a desktop computer with 3.60 GHz Intel Pentium processor and 8 GB RAM. Operating system is Windows 10 Enterprise. We used Gurobi 9.1.1 solver with the default parameter settings for solving MILP problems.

instance (N,K)	#var. (bin.)	#conns.	# nonzero	#iter.	time (sec)	o.f. value
(50,2)	2,500 (0)	62,526	245,100	44,891	5.41	8.7706
(75,2)	5,625 (0)	210,976	832,650	47,323	29.55	14.4857
(100,2)	10,000 (0)	500,051	1,980,200	113,292	146.49	18.8850
(50,3)	2,500 (0)	62,526	245,100	32,493	2.30	4.8643
(75,3)	5,625 (0)	210,976	832,650	112,711	17.09	8.6184
(100,3)	10,000 (0)	500,051	1,980,200	271,365	110.24	11.8003
(50,5)	2,500 (0)	62,526	245,100	21,525	1.40	2.7192
(75,5)	5,625 (0)	210,976	832,650	74,264	9.46	4.3356
(100,5)	10,000 (0)	500,051	1,980,200	134,661	68.26	6.0120

Table 1: Essential information about MSSR formulation

instance (N,K)	#var. (bin.)	#const.	# nonzero	#iter.	time (sec)	o.f. value
(50,2)	3,725 (1,225)	67,426	257,350	13,057	4.86	8.7706
(75,2)	8,400 (2,775)	222,076	860,400	85,215	69.00	14.4857
(100,2)	14,950 (4,950)	519,851	2,029,700	199,582	547.48	18.8850
(50,3)	3,725 (1,225)	67,426	257,350	7,231	3.53	4.8643
(75,3)	8,400 (2,775)	222,076	860,400	51,086	45.91	8.6184
(100,3)	14,950 (4,950)	519,851	2,029,700	122,879	345.28	11.8003
(50,5)	3,725 (1,225)	67,426	257,350	8,950	3.58	2.7192
(75,5)	8,400 (2,775)	222,076	860,400	42,963	38.07	4.3356
(100,5)	14,950 (4,950)	519,851	2,029,700	199,143	1,064.93	6.0156

Table 2: Essential information about MSS formulation

instance (N,K)	#var. (bin.)	#const.	# nonzero	#iter.	time (sec)	o.f. value
(50,2)	2,600 (100)	70,029	267,451	559,853	306.13	8.7706
(75,2)	5,775 (150)	227,854	883,201	64,316	45.55	14.4857
(100,2)	10,200 (200)	530,054	2,070,101	155,495	270.05	18.8850
(50,3)	2,650 (150)	73,755	278,776	211,463	88.09	4.8643
(75,3)	5,850 (225)	236,255	908,476	81,300	56.23	8.6184
(100,3)	10,300 (300)	545,005	2,115,051	205,222	312.18	11.8003
(50,5)	2,750 (250)	81,207	301,226	182,144	72.10	2.7192
(75,5)	6,000 (375)	253,057	959,026	73,654	56.49	4.3356
(100,5)	10,500 (500)	574,907	2,204,951	766,669	16,128.02	6.0156

Table 3: Essential information about AMSS formulation

Some important statistics about the size of LP problems and some information about the solution process can be found in Table 1, Table 2 and Table 3.

As we can see in Table 1, 2 and 3, except the instance (100,5), the optimum solution of MSSR will result in a legal clustering structure, actually we do not need the integer variables. For all presented instances, the running times are less than 2.5 minutes for MSSR formulation. Not surprisingly, running times for MSS and AMSS formulations are higher, but still tolerable (except for the instance (100,5)). There is not a strict dominance between

MSS and AMSS formulations, MSS seems to have slightly better performance (mostly for instance (100,5)).

4 CONCLUSION

In this paper we investigated MILP formulations for the minimum sum of squares clustering problem. These formulations have higher running times than the well-known K-means algorithm, however for sample size at most 100 still tolerable. If in some application it is crucial to work with global optimum these formulations give a possibility for it. Furthermore, we are able to insert further (linear) constraints in the model.

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COMPARISON OF AN ITERATIVE HEURISTIC AND JOINT OPTIMIZATION IN THE OPTIMIZATION OF BONUS-MALUS SYSTEMS

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Abstract: Bonus-malus system (BMS) is a risk managing method primarily used in liability insurances. In a BMS there are finitely many classes, each having a different premium. At the start of the contract each policyholder is assigned to the 'initial class'. In each period, the policyholders are reclassified based on the number of claims. In Ágoston and Gyetvai (2020) we introduced a MILP model for the joint optimization of premiums and transition rules. The computational time of the model can be very long with realistic parameters. However, we may approximate the optimal solution by iteratively optimizing the premiums and then the transition rules. In this paper, we compare the computation of the MILP model and the iterative heuristic.

Keywords: Adverse Selection, Bonus-Malus system, Integer programming

1 INTRODUCTION

Bonus-malus systems (BMS) are used in Motor-third party liability insurances. The BMS is applied to distinguish the risky drivers from the less risky ones and incentivize drivers to be more careful.

In a BMS there are finitely many classes. For each period of the insurance, the policyholders are classified into one of these classes. Each class has a premium, so the policyholder's payment depends on the class where he/she is classified. At the beginning of the contract, each policyholder is classified into the so-called initial class. Then the classification depends on the previous period's classification and the number of claims reported in the present period. Suppose the policyholder has a claim in a period. In that case, he/she moves to a worse class with a higher premium. On the other hand, if he/she does not have a claim in the period, then he/she moves to a better class. Hence his/her premium will be lower. Therefore, the riskier policyholders will be in a worse class after several periods, and they pay more in general. The less risky policyholders will pay less in total.

Designing a BMS requires choosing the transition rules, the number of classes, the scale of premiums, and the initial class. The objective is to form a BMS that sorts policyholders as best as possible. There are many papers about the optimization of BMSs (e.g., Cooper and Hayes (1987); Lemaire (1995); Denuit et al. (2007); Heras et al. (2004); Brouhns et al. (2003); Denuit and Dhaene (2001); Mert and Saykan (2005); Najafabadi and Sakizadeh (2017)). The premium scale is the variable in these studies, and the number of classes, the initial class, and transition rules are parameters. The most relevant article for our studies is Heras et al. (2004). In this study, the authors introduce an LP model for the optimization of premiums. In Gyetvai and Ágoston (2018), we introduced a MILP model to find the optimal transition rules with a fixed premium scale. We presented a modification of this model for the joint optimization of the premiums and transition rules in Ágoston and Gyetvai (2020).

2 OPTIMIZATION MODELS

Let us assume that we can distinguish I risk-groups (types) among the policyholders. Each type has a different risk that does not change over time. In practice, transition rules are based only on claim numbers, without the consideration of the claim amount.

Let $M > 0$ be the highest number of possible claims in a period and let λ_m^i be the probability of m claims in a period for the policyholders of type i ($i = 1, \ldots, I$, $\sum_{m=0}^{M} \lambda_m^i = 1$). We denote the risk-parameters (expected claim amount) for risk-group i with λ^i, ($\lambda^i = \sum_{m=0}^{M} m\lambda_m^i$). ϕ^i denotes the proportion of the type i policyholders among all of the policyholders ($\sum_{i=1}^{I} \phi^i = 1$). The BMS has $K+1$ classes indexed from 0 to K.

The classification of a policyholder only depends on the previous period classification and the number of claims of the current period. This is called the Markov property. Hence the classification of the policyholders is a regular Markov chain. Therefore exists a unique stationary probability distribution (Kemeny and Snell (1976)) that we use in the optimization. Let c_k^i denote the stationary probability of the type i policyholders is classified into class k. For the optimization of the premiums, we use an LP model (the idea appeared in Heras et al. (2004)) to minimize the difference between the expected payment and the expected claims. We denote the premium of class k by π_k. Also, let g_k^i denote the absolute deviation between the expected payment and claims for a type i policyholder in class k. Then the model is written as follows:

$$\min \sum_{i=1}^{I} \sum_{k=0}^{K} \phi^i g_k^i \tag{1}$$

Subject to

$$\pi_k c_k^i + g_k^i \geq \lambda^i c_k^i \qquad \forall i, k \tag{2}$$

$$\pi_k c_k^i - g_k^i \leq \lambda^i c_k^i \qquad \forall i, k \tag{3}$$

$$\pi_{k-1} \geq \pi_k \qquad k = 1, \ldots, K \tag{4}$$

$$\pi_k \geq 0 \qquad \forall k$$

$$g_k^i \geq 0 \qquad \forall k, i$$

In Gyetvai and Ágoston (2018) we introduced a MILP model, where the transition rules are in the scope of the optimization and the premiums are considered as parameters.

Here we only give a brief description of the model. For a more detailed description, see Gyetvai and Ágoston (2018), and Ágoston and Gyetvai (2020).

Let $T_{j,m}$ denote binary variables for each possible step (j) and claim ($m = 0, 1, \ldots, M$). Hence if $T_{j,m} = 1$, then the policyholders with m claims move j classes upward (downward if $j < 0$) in the following period. Index j can be 0 as well, which means that they stay in the same class in the subsequent period. The domain of j is by $[-K : K]$. In this model the c_k^i stationary probabilities are variables that are determined by the optimal $T_{j,m}$ transition rules.

$$\min \sum_{i=1}^{I} \sum_{k=0}^{K} \phi^i g_k^i \tag{5}$$

Subject to

$$\sum_{j=\underline{J}}^{\overline{J}} T_{j,m} = 1 \qquad \forall m \tag{6}$$

$$\sum_{j=1}^{\overline{J}} T_{j,0} = 1 \tag{7}$$

$$\sum_{j=\underline{J}}^{-1} T_{j,M} = 1 \tag{8}$$

$$\sum_{l=j}^{\overline{J}} T_{l,m} \geq T_{j,m+1} \qquad \forall j, m = 0, \ldots M-1 \tag{9}$$

$$\sum_{k=0}^{K} c_k^i = 1 \qquad \forall i \tag{10}$$

$$d_{k,j,m}^i \geq \lambda_m^i c_k^i - (1 - T_{j,m}) \qquad \forall i, k, j, m \tag{11}$$

$$c_k^i = \sum_{j=\max(\underline{J}, -(K-k))}^{\min(\overline{J}, k)} \sum_{m=0}^{M} d_{k-j,j,m}^i \qquad k = 1, \ldots, K-1, \forall i \tag{12}$$

$$c_k^i = \sum_{j=0}^{\overline{J}} \sum_{\ell=0}^{j} \sum_{m=0}^{M} d_{k-\ell,j,m}^i \qquad k = K, \forall i \tag{13}$$

$$c_k^i = \sum_{j=\underline{J}}^{0} \sum_{\ell=j}^{0} \sum_{m=0}^{M} d_{k-\ell,j,m}^i \qquad k = 0, \forall i \tag{14}$$

$$\pi_k c_k^i + g_k^i \geq \lambda^i c_k^i \quad \forall i, k \tag{15}$$

$$\pi_k c_k^i - g_k^i \leq \lambda^i c_k^i \quad \forall i, k \tag{16}$$

Constraints (6)-(9) are needed for defining reasonable transition rules. Constraints (10)-(14) are for the calculation of the stationary probabilities c_k^i. And constraints (15)-(16) are for the absolute deviation of the objective function, similarily to the the premium optimization model.

In Ágoston and Gyetvai (2020) we presented another MILP model, where both premiums and transition rules can be optimized jointly. The presentation of this model would exceed the scope of this article. Hence we only describe the basic idea of the model. In this model, we start with default premiums for each class. We introduce binary variables O_k^ℓ for each class k and layer ℓ to change the default premium. Hence if $O_k^\ell = 1$, then the default premium of class k is increased with a value that the ℓth layer represented. We may consider several layers in the model, but it may increase the computational time significantly.

When realistic parameters are considered in this model, there are a considerable number of binary variables. Hence the running time can be extremely long. Separately the optimization models for the premiums and the transition rules can be calculated much faster than the joint optimization model. Hence we may use an iterative method to approximate the optimal solution. First, we calculate the optimal transition rules with a fixed premium. Then we find the optimal premiums to these transition rules, which we now consider as parameters. Then we use the optimal premiums of this model as parameters and re-optimize the transition rules. We continue it until we cannot improve the objective function further. The solution of this heuristic greatly depends on the initial model. In the initial model of transition rules optimization the premiums are outer parameters. We may also start with the premium optimization and then proceed with the optimization of the transition rules. In this case, the transition rules are outer parameters in the first model. In the comparison, we considered four types of initial premiums:

- Proportional (prop): We introduce own-classes for each risk-groups, which means the premium of these classes equals the risk-groups' expected claim. The risk-groups have that many own-classes that are proportional to their percentage of all policyholders.
- Linear (lin): We take the lowest and highest risk-groups' expected claim for the lowest and highest premium and set the classes' premium linearly.
- Minimal (min): The premium equals the highest expected claim in the worst class. In all other classes, it equals the lowest one.
- Maximal (max): In this case, only one class premium equals the minimal expected claim and each other to the highest one.

We also considered two types of initial transition rules:

- TRK: In case of any claim, the policyholders move into the worst class. Without a claim, the policyholders move one class upward.

- TR1: In case of any claim, the policyholders move one class downward. Without a claim, the policyholders move one class upward.

3 NUMERICAL RESULTS

We considered BMSs with 15 classes in the comparison of the joint optimization model to the iterative heuristic. We randomly chose their risk-groups' claim probability to test the heuristic in as many setups as possible. Hence we considered 100 randomized setups. In each setup we considered five equally sized risk-groups.

Two cases were examined: a realistic one, in which the risk parameters are generated from a 0.01 to 0.1 interval. And a not-so-realistic higher-risk setup, in which the risks are chosen from the [0.1 : 0.3] interval. In each model, the maximal number of claims per period can be up most 2. For the claim probabilities we considered Poisson distribution. We compared the iterative heuristic with six different initial solutions to the joint optimization model. We highlight the difference between the optimal solution and the running time. Figure 1 presents the relative deviation from the MILP model in both cases.

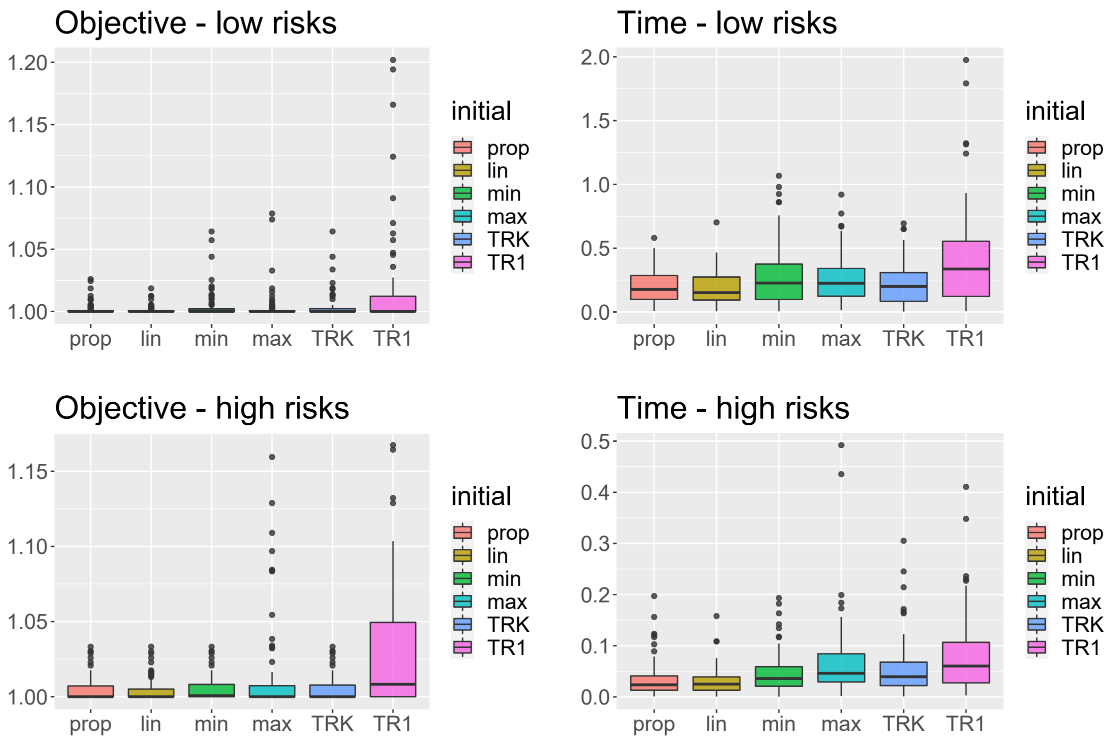

Figure 1: Objective and time change to the joint optimization model

On the left side of the figure, the objective increase to the joint model is presented. The top row shows the low-risk case and the bottom presents the high-risk case. When the risks are low, the results are similar to the objective of the joint model. The *TR1* resulted in the highest difference in average. However, even in this case, the average increase was only 1.4%. When the risks are higher, the difference between the joint model and the heuristic is higher as well. The *TR1* resulted in the highest increase in average in this case as well. The average increase was 2.9% for the *TR1* and the next in the line was the *max* with 1.1%

The running time of the iterative heuristic, in general, was much faster than the joint optimization model with each initial solution. Again, the *TR1* seems to be the worst. But even in this case, the average running time is less than half of the joint model in both setups (40% in the low and 8% in the high).

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COMPUTING INTERNATIONAL KIDNEY EXCHANGE SCHEMES[1]

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Abstract: In kidney exchange, patients may swap their donors to solve incompatibility issues. In international kidney exchange, countries merge their national patient-donor pools. We consider a recently introduced credit system where in each round, countries are given an initial kidney transplant allocation which is adjusted by a credit function yielding a target allocation. The goal is to find a solution in the patient-donor compatibility graph that approaches the target allocation as closely as possible, to ensure long-term stability of the international pool.

Our aim is to perform, for the first time, a computational study for a *large* number of countries using *sophisticated* methods. We therefore focus on the case where the kidney exchanges must form a maximum matching. As solutions, we use maximum matchings that lexicographically minimize the country deviations from the target allocation. The *theoretical* contribution of the paper is a polynomial-time algorithm for computing such matchings. For the initial allocations we use, in addition to easy-to-compute solution concepts, two classical solution concepts, namely the Shapley value and nucleolus. These solution concepts are hard to compute but we show that by using state-of-the-art software combined with our new polynomial-time matching algorithm, they are now within reach for international kidney exchange programs of up to fifteen countries.

Our experiments show that using lexicographically minimal maximum matchings instead of ones that minimize the largest deviation only makes an international kidney exchange scheme up to 56% more balanced.

Keywords: kidney exchange, cooperative games

[1]We dedicate this paper to the memory of Walter Kern, who recently passed away.

Simulations for measuring efficiency of international kidney exchange programmes

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Abstract: In this paper we present simulations for international kidney exchange programmes (KEPs). KEPs are organised in more than ten countries in Europe, the largest ones in the UK, in the Netherland and Spain, to facilitate the exchanges of immunologically incompatible donors. The matching runs are typically conducted in every three months for finding optimal exchanges using hierarchical optimisation with integer programming techniques. In recent years several European countries have started to collaborate to organise international exchanges using different collaboration policies. In this paper we conduct simulations for estimating the benefits of such collaborations with a simulator developed in a European COST Action project, called ENCKEP.

Keywords: kidney exchange, integer programming, hierarchical optimisation

1 INTRODUCTION

Patients with end-stage renal disease can be treated by dialysis, but their quality of life is poor and their life expectation is short. The only long-term solution according to our knowledge is transplantation. One can get a kidney from a deceased donor, but the demand is very high and waiting lists are long even in the developed world (over 100,000 patients are on the US waiting list, with an average waiting time of 8-10 years). Therefore living donation became a common practice, also due to the longer graft survival rates. However, if someone has a willing, but immunologically incompatible donor then transplantation is not possible. To resolve this issue, kidney exchange programmes (KEP) have been established in many countries to facilitate the exchanges of the donors. Due to the simultaneity of the exchanges the length of the exchange cycles is limited. For example, only 2- and 3-way exchanges are allowed in the UK and Spain, whilst four-way exchanges are also possible in the Netherlands. The goal of the KEPs is to find and arrange optimal exchanges for the pool of registered patient-donor pairs in the regular matching runs. The European practices have been surveyed in [1] and the optimisation aspects of the European KEPs were described in [2], as the results of a COST Action called European Network for Collaboration on Kidney Exchange Programmes (ENCKEP).

International kidney exchanges have been conducted first in between Vienna and Prague in 2016 [3], followed by the collaboration of Spain, Portugal and Italy. In the recent Handbook [6] of Working Group 3 and 4 of the ENCKEP COST Action has studied the practice of international KEPs, the modelling possibilities including results from [5] and [7], and the description of a simulation and evaluation tool developed by these working groups. In this paper we will illustrate the usage of the simulator tool by a case study with generated data for three countries, UK, Netherlands and Spain.

Optimisation policies used in the European Kidney Exchange Programmes (KEPs) consist of multiple optimisation criteria, which they use for finding the optimal solution in each matching run. These policies specify a priority order for the criteria, which is called the lexicographic order. Using this means, that there will be an optimisation run for each level of the order, and each lower level will get a constraint for the objective value of all the criteria above.

At the lowest level of the priority order, often there are multiple criteria used for weighted optimisation in practice. The weights are given according to the settings of the criteria, either on the cycle-level (e.g. maximisation of the number of cycles selected) or on the transplant-level (e.g. prioritisation of highly sensitised recipients). For a recent paper on sophisticated integer programming techniques for hierarchical optimisation for KEPs see [4].

2 COMPUTER SIMULATIONS

To simulate the operation of national and international KEPs, we used the ENCKEP Simulator tool [6]. This simulator is based on a standard technique of generating historical dataset for a period of time (e.g. five years) and conducting matching runs in regular time intervals (e.g. in every three months). For a survey on KEP simulators, see [8].

In order to conduct a simulation with this software, we have to provide input files, which will contain data about the pool, virtual compatibility graph, arc and pair failures, as well as the collaboration and optimisation policies we would like to use.

After the simulation has finished, the tool produces detailed output data about the simulation in 4 output files for further analysis. These files contain information about the cycles selected, matching runs, pool of donors and recipients, and the implemented arcs subject to the simulation. In the following chapters, we present the results of analysing these output files.

2.1 Simulations for individual countries

In the first part we will describe simulation results for national KEPs, namely for the UK, the Netherlands and Spain.

2.1.1 UK

In the KEP of the UK, they conduct matching runs every 3 months, and set the length upper bounds for both exchange cycles and chains to 3. We used the same settings, and allowed internal recourse in the simulation in order to search for embedded cycles to implement in cycles with either arc or node failure. As for the optimisation policy, we used the following set of criteria (see [6] for details).

Lexicographic:

1. Maximise the number of effective 2-cycles
2. Maximise the size of solution
3. Maximise the number of cycles selected
4. Maximise the number of back-arcs

Weighted:

- Priority for waiting time in KEP (linear function with score 50)
- Priority for highly sensitised recipients (linear function with score 50)
- Minimise the donor-donor age differences (threshold function with score 3 and threshold 20 years)

This optimisation policy is almost identical to the one used in real practice, but since we cannot generate HLA-data yet, we did not use the maximisation of HLA-matching optimisation criterion. However, the software is capable of using this as well, provided the HLA-data is available (e.g. in case of real historical datasets). The scores given for the weighted optimisation criteria during the simulation are depicted in Figure 1.

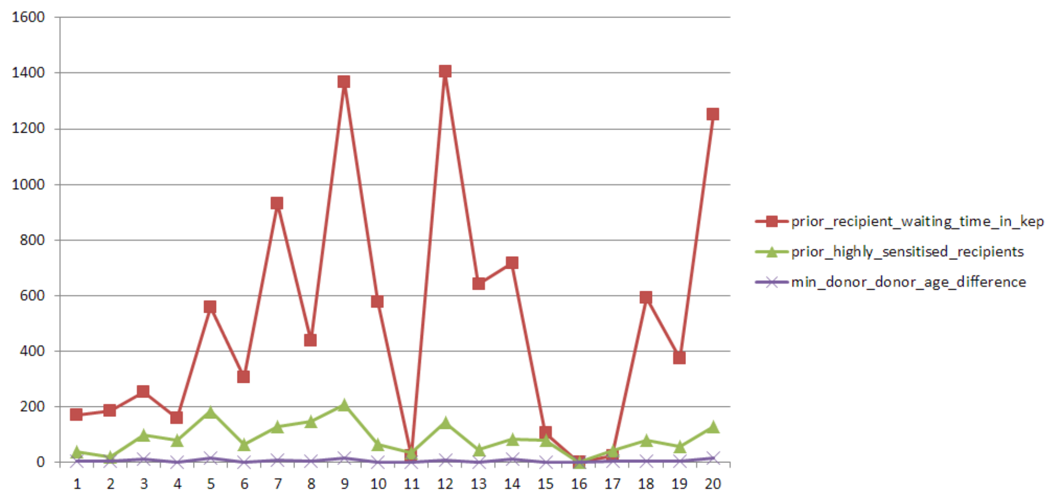

Figure 1: Weights given for the weighted criteria in each matching run for UK

The figure shows that in every matching run, the most influential weighted criterion was the prioritisation of waiting time in KEP. This was to be expected, since for this criterion, the UK policy gives 50 points for each matching run based on the waiting time of the recipient.

2.1.2 Spain

The KEP operating in Spain, sets the limit for maximum length of exchange cycles to 3. They do not use length constraint on chains, but since we have to set an upper bound for this in the simulation, which should be reasonable to limit run-time, we used 4. Also, we allowed internal recourse in the simulation. The optimisation policy we used consists of the following set of criteria (see [6] for details).

Lexicographic:

1. Maximise the size of solution
2. Maximise the number of cycles selected
3. Maximise the number of back-arcs
4. Priority for highly sensitised recipients (reciprocal function with score 5)

Weighted:

- Minimise the age-differences between donors and recipients (threshold function with score 15 and threshold 10 years)
- Priority for recipients with low matching probability (linear function with score 30)
- Priority for waiting time in KEP (threshold function with score 30 and threshold 1 year)
- Priority for same blood-group transplants (30 points)

This is very similar to the real policy, the difference is that we left out three criteria from the weighted optimisation. Priority for paediatric recipients was not used, because the generated pool contained only adult patients. Priority for time on dialysis and priority for donor-patients in the same region were left out also. Scores given for each weighted optimisation criteria are depicted on Figure 2.

To mimic practice, we tried to use realistic relative pool sizes, which meant that the Spanish pool was set to be smaller than the pool of the UK. As shown on the Figures 1 and 2, this

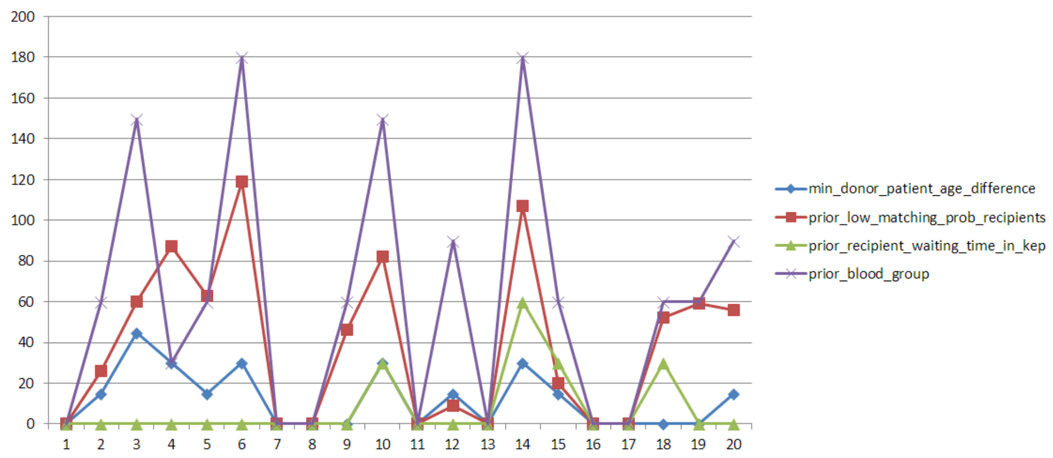

Figure 2: Weights given for the weighted criteria in each matching run for Spain

resulted in an increased number of matching runs where there were no available cycles in the virtual compatibility graph. In case of the UK, there was only one such matching run, while we had six in the Spanish simulation.

2.1.3 Netherlands

In the Netherlands, they use 4 as upper length limit for both exchange cycles and chains. Internal recourse was enabled here as well. The optimisation policy we used in the simulation was the following (see [6] for details).

Lexicographic:

1. Maximise the size of solution
2. Priority for same blood-group transplants
3. Priority for recipients with low matching probability (using reciprocal function with score 5)
4. Minimise the lengths of cycles selected

In practice, they only use lexicographically ordered criteria, so we did the same in the simulations. The policy is similar to the real one, the difference is that we left out the 5th and 6th criteria, which are the maximisation of the number of transplant centres in long cycles and priority for time on dialysis respectively. Since only lexicographic order is used here, it might be important to know that which levels of the hierarchy are usually not considered to find the final solution. To study this, we analysed the number of matching runs that stopped on the given priority level, because a unique solution was reached. The result is shown on Figure 3.

The pool size was approximately the same as the one used in the Spanish KEP simulation, but here were only had 2 matching runs, where no cycles were detected. The solution became final on the last (4th) level 6 times, and this number applies to the 3rd and 2nd levels as well.

2.2 Simulations for international exchanges

The software can simulate three different collaboration policies.

- Individual policy: Each participating pool will have its own matching run separately.

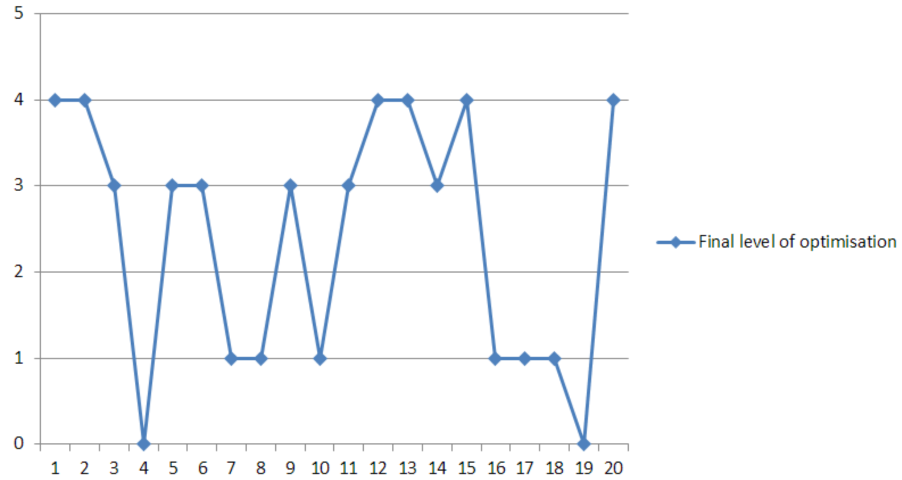

Figure 3: Level on which the solution became unique in each matching run for Netherland

- Consecutive policy: First, in each matching run, there will be an optimisation run for every pool separately. Then, the pairs who are still in the pools after that, will be merged into one joint pool, and there will be an optimisation run for this as well.
- Joint policy: All the participating pools will be merged into one pool, this will be used in the matching runs.

Each pool can have a different optimisation policy in the simulations for separate pools, just as in practice, so we used the corresponding settings. For the merged pools, we used the optimisation policy of the UK. The results are depicted on Figure 4.

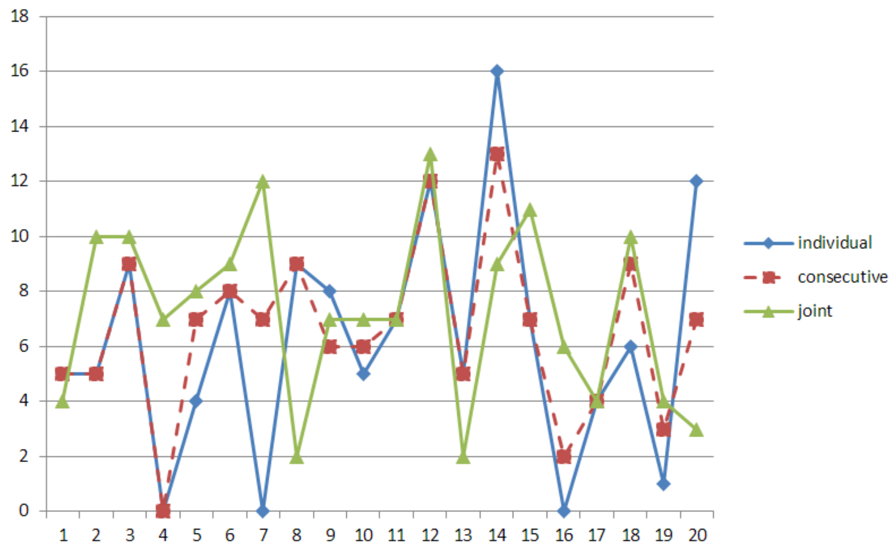

Figure 4: Number of transplants in each matching run with different collaboration policies

In some matching runs, the joint policy resulted in less transplantation than the individual policy, which should not happen in general. But it is reasonable here, because we set the upper bound for cycle and chain lengths to 3 for the joint pools, and we left them at 4 for the Netherlands to mimic real practice. Also, in these cases, often many of the selected cycles were cancelled in the joint collaboration, and with no embedded cycles to implement with internal recourse, these were cancelled completely.

	individual	consecutive	joint	total
UK	52	53	57	162
ES	23	28	40	91
NL	48	50	48	146
total	123	131	145	399

Figure 5: Number of total transplants by pools and collaboration policies

As depicted on Figure 5 the total number of transplants for the individual, consecutive and joint collaboration policies were 123, 131, 145 respectively. According to our simulation result, the total number of transplants can be increased by initiating a collaboration between the countries, where the joint policy seems to be the best approach.

Acknowledgements

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HEURISTICS FOR COMBINATORIAL AUCTION-BASED CHANNEL ALLOCATION APPROACHES IN MULTI-CONNECTIVE WIRELESS ENVIRONMENTS

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Abstract: In this paper we discuss the applicability of combinatorial auction-based channel allocation approaches in multi-connective environments, where tenants place bids for the subsets of channels. Two heuristical approaches are defined in order to reduce the computational requirements of the channel allocation algorithms. Each heuristics is based on the limitation of the bid set of tenants to avoid the combinatorial explosion, which arises if all subsets of the channels is considered in the process. The first proposed method narrows down the bid set based on the distance of the relevant base stations, while the second proposed method uses a many-to-many matching algorithm to pre-allocated the channels to tenants. In the combinatorial auction, tenants place bids only for the subsets of the pre-allocated channels. We compare the performance of the two proposed approach via simulation.

Keywords: combinatorial auction, resource allocation, multi-connectivity, wireless networks

1 INTRODUCTION

Ultra-reliable low latency communications (URLLC) is identified as one of the essential use cases of emerging fifth generation (5G) mobile wireless communications systems [2]. URLLC requirements are highly relevant in emerging applications as industrial automation and vehicular communications. One possible concept for enabling URLLC is multi-connectivity [6], i.e. using multiple communication paths at once. In this case, the redundancy of communication channels increases the reliability of the communication architecture. In the current paper we are focussing on channel allocation problems, where the channels (representing the communication paths) are considered as indivisible goods, which have to be allocated to objects (e.g. mobile industrial robots or similar entities) called *tenants* in our context. As one channel may be allocated to one tenant, while one tenant may receive multiple channels, the task boils down to a combinatorial optimization problem, where we look for the optimal allocation, according to a certain measure (e.g. the total capacity of the system) [5].

As each bundle (subset) of the available channels implies a different outcome for each tenant, the combinatorial auction (CA) method [7] seems a reasonable candidate to serve as the principle of the allocation algorithm. In real-life applications however, the number of objects (channels) to be allocated often exceeds the limit, which can be handled computationally by this approach. In this paper we introduce problem-specific heuristics to define two channel allocation algorithms in an assumed industrial environment, and compare their efficiency in the terms of the total allocated capacity and required computational time, based on simulations. In both of the proposed algorithms, we will suppose that tenants, who will be acting like bidders of the CA, will consider only a subset of the available channels. This assumption allows to significantly reduce the number of bids considered in the CA process.

2 MODEL

In this section we describe the computational framework used for the description of multi-connective communications.

2.1 General framework

In the current paper, we will assume that the available channels are served by base stations (BSs) to the tenants. Let us denote the the number of tenants by n_T, and the number of base stations by n_{BS}. In addition, the vector $n_{ch} \in \mathbb{R}^{n_{BS}}$ describes the number of channels at the individual base stations. The set of all channels is denoted by CH. We assume furthermore, that different channels of any BS exhibit the same properties.

The connectivity function of tenant k, denoted by $\rho_k : 2^{CH} \to \mathcal{R}$, describes the maximal achievable rate of communication for tenant k, if any subset of CH is allocated to tenant k. We assume that $\rho_k(S_1) \leq \rho_k(S_2)$ if $S_1 \subseteq S_2$.

For the exact determination of the connectivity function, in this paper we use the URLLC multi-connectivity model described in [3], with the path loss model

$$PL(d) = PL(d_0) + 10\delta log_{10}\left(\frac{d}{d_0}\right) \tag{1}$$

and parameters summarized in Table 1.

parameter	notation	value	unit
Rician factor	K	14.1	dBm
channel bandwidth	B	20	MHz
reference distance	d_0	15	m
reference PL	$PL(d_0)$	70.28	dB
PL exponent	δ	2	-
outage probability threshold	ϵ	10^{-9}	-
transmit power	P^T	15-25	dBm
interference power	P^I	-50	dBm

Table 1: Model parameters. The value of P^T was considered as a random variable for each BS in the simulations, with uniform distribution between 15 and 25.

We consider a 100m x 50m factory area, with 8 BSs, located on the factory walls (with random positions). We assume that each BS offers 1-3 channels, but the total channel number is no more than 20. In addition, we assumed 6 tenants with random positions.

To give an impression about the connectivity function in the case of this modelling framework and parameters, let us consider a tenant at the position (8.47,11.52) and two BSs, at the positions (0,0) and (100,13) respectively, both with 2 channels available. We assume the transmit power values $P_1^T = 23$ for BS 1 and $P_2^T = 16$ for BS 2 respectively.

If a single channel of BS 1 is assigned to the tenant, its resulting capacity will be 0.054 Mbps. If we assign one channel of BS 2 to the tenant (BS 2 is more far from the tenant) this value is 0.0037. In the case of two channels from BS 1, the result is 16.042, while in the case of two channels from BS 2 this value is 1.4595. Considering one channel from BS 1 and one from BS 2, the resulting capacity is 4.4016. In general, any number of channels may be assigned to a single tenant. If e.g. both channels of BS 1 and both channels of BS 2 is assigned to the tenant, the resulting capacity will be 20.5995. Based on the formulas described in [3], and on the parameters summarized in Table 1, the resulting capacity for all possible channel combinations may be calculated for the tenant (and for any other tenants in different positions). The principle behind the calculations is the reliability-based approach. In the URLLC framework, the communication fails if all of the assigned channels are down, and these events are considered independent. This explains, why an additional channel beyond the first significantly enhances the performance (redundancy arises), while additional channels after e.g. 3 or 4 already assigned channels do not bring too much additional benefit.

2.2 Assignment algorithms

The following assignment algorithms have been considered in the study.

2.2.1 Random assignment (RA)

This algorithm was used as a reference case. In this case, the available channels are randomly assigned to tenants, considering only $\bar{n}_{ch} = 4$ as a limiting factor, which describes that no tenant may receive more than 4 channels.

2.2.2 Distance-based semi-random assignment (DbsRA)

This algorithm is similar to the RA method, but in this case, to increase efficiency, each channel is allocated with higher probability to closer tenants. The probability weighting used is inversely proportional to the distance of tenants.

2.2.3 Distance-based Combinatorial auction (DbCA)

The input of the CA algorithm [7] is the set of bids. Each participant or player (here the tenants) submits a finite number of bids, where each bid corresponds to the value of a certain bundle of the available goods (in this case the channels). In this model, the value of a certain bundle of channels is determined by ρ_k for tenant k. The next step of the CA algorithm is to solve an integer optimization problem, which maximizes the value of the accepted bids, under the constraints that (I) for each player maximum one of its bids may be accepted, and (II) one item may be assigned maximum to one player.

If we consider all subsets of the available channels for all tenants, the principle of the CA boils down to brute-force optimization, and leads to a computationally infeasible problem (for 20 channels, every tenant would submit $2^{20} - 1$ bids). In the case of the DbCA, we use a very simple principle to reduce the cardinality of the bid sets: Every tenant considers only the channels of the two closest BS (thus maximum 6 channels in the case of the current parametrization). This way, the number of bids submitted for each tenant is $< 2^6$.

It may however happen, that according to this 'pre-assignment' of channels, channels of one or more BSs will not appear in the bids (if there are BSs present, which are relatively far from every tenant compared to other BSs). Not assigning a channel would significantly decrease the overall performance of the system (unused resource), thus in this case, we randomly assign these channels to tenants to complete the pre-assignment process. In the next step, all tenants evaluate all possible subsets of the pre-assigned channels, and thus determine the bids of the CA process.

2.2.4 Gale-Shapley based Combinatorial auction (GSbCA)

In the case of this method, the pre-assignment of channels is performed differently compared to the DbCA method. In this case, for the first step of the pre-assignment, we use the many-to-many matching version of the Gale-Shapley algorithm [1]. To do this, first we have to set up preferences for the tenants over the channels and vice versa. In this case this is done by simply considering the tenant-BS distances (for each channel we consider the relevant BS), in the sense that closer entities prefer each other to more far alternatives. In addition we have to define quotas for both the tenants and the channels (denoted by q_T and q_{ch} respectively).

In this case we assumed $q_T = q_{ch} = 6$, implying that to each tenant maximum 6 channels are allocated in the pre-assignment process, and any channel is allocated to maximum 6 tenants.

This method does not guarantees either that all channels will be pre-assigned to, thus again, we assign the potentially remaining channels at random to tenants. After the pre-assignment is done, the further steps of the algorithm are the same as in the case of the DbCA method.

3 RESULTS AND DISCUSSION

We evaluated the proposed assignment algorithms via simulation. The algorithms have been performed in the case of 1000 scenarios. In each scenario, the following variables have been randomized:

- The positions of the BSs at the boundary of the simulation area.
- The positions of the tenants in the simulation area.
- The number of channels per BS (1-3) with a total maximum of 20.
- The transmit power of BSs (15-25 units).

The results of the simulations in the context of the total assigned capacity are depicted in Fig. 1.

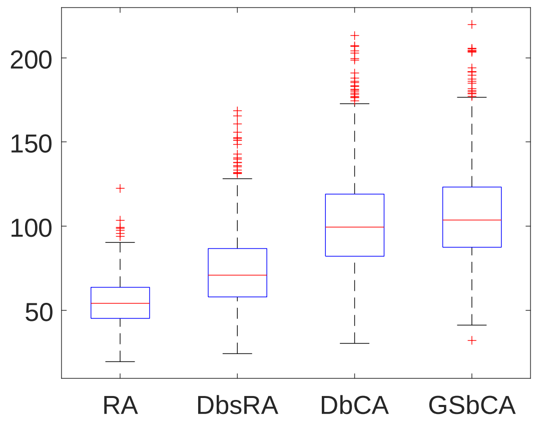

Figure 1: Total capacity in MBps in the case of the various assignment algorithms. In the box plot, the central mark is the median, while the edges of the box are the 25th and 75th percentiles respectively. The whiskers extend to the most extreme data points which are considered not to be outliers, and the outliers are plotted individually with red crosses. The median vales are respectively 54.18, 70.87, 99.38 and 103.63 for the four algorithms.

In the case of the RA and DbsRA, due to the highly indeterministic nature of the algorithms, 10 runs were performed for each scenario, and the average values were considered as the result for the actual scenario. As it can be seen in Fig. 1, the DbCA algorithm implies a 83.42 % improvement in the total system capacity, compared to the RA. One may argue that the RA includes extremely contra-intuitive assignments as well (as it is possible that every channel is assigned to more distant tenants). If we compare the improvement to the DbsRA, this improvement of the DbCA is 40.23 %. These values are 91.27 % and 46.22 % in the case of the GSbCA.

The results of the simulations in the context of computational time are depicted in Fig. 2.

The results depicted in Fig. 2 show that the CA-based algorithms require significantly more time compared to the very simple reference scenarios (RA and DbsRA), but typically they may

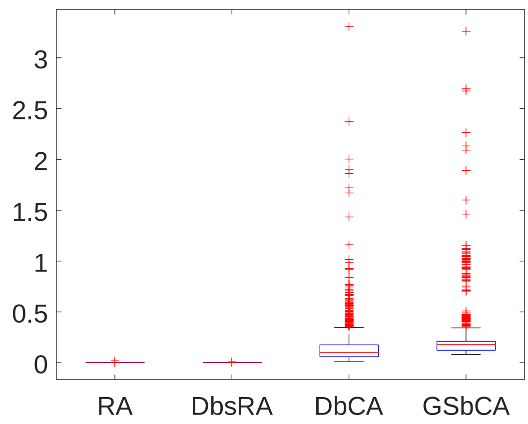

Figure 2: Computational time in s in the case of the various assignment algorithms. The median vales are respectively 0.0008, 0.0011, 0.1007 and 0.1782 for the four algorithms. The simulations were run on a standard desktop PC (Intel core i5 @ 2.9 GHz, 16 GB RAM, 64 bit OS, MATLAB environment).

be performed in 1 sec, or in a few seconds worst case. Considering movement-induced reconfiguration in the case of industry-automation applications (as e.g. mobile industrial robots), this seems to be an acceptable value.

3.1 Discussion

One additional aspect, which may be considered as a measure of channel assignment algorithms is fairness. In this context, fairness usually translates to the capacity value of the tenant with minimal capacity in a particular scenario. In this paper, it was not among our aims to include any fairness guarantees in the assignment algorithms, but for the sake of completeness, results in this context may be depicted as well. The minimal assigned capacity values are depicted in Fig. 3.

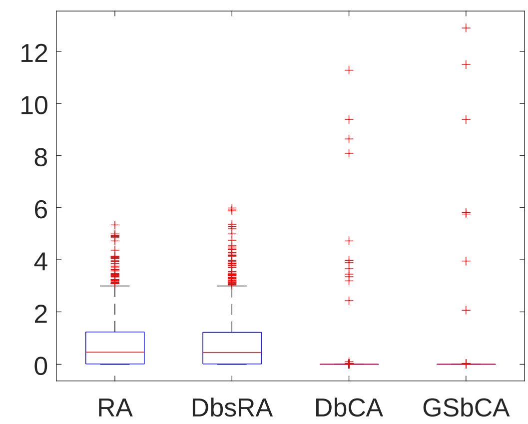

Figure 3: Fairness: Minimal capacity in MBps in the case of the various assignment algorithms. The median vales are respectively 0.46, 0.44, 0 and 0 for the four algorithms.

As it may be seen in Figs. 3 and 1 as well, there is usually a tradeoff between fairness and efficiency. More efficient algorithms in general tend to allocate every channel to tenants, for which the greatest resulting capacity may be provided, thus potentially leaving some tenants without any resources. There are algorithms, as e.g. the 'weakest selects' algorithm [4], which aim to optimize not the total efficiency, but the fairness of the resulting allocation. The framework of the CA algorithm however allows the inclusion of constraints corresponding to the minimal resulting value (capacity) of participants, thus this issue may be explicitly addressed in the future.

In addition, let us note that although the number of channels per BS was randomized in the simulations, the range of this parameter was assumed to be low (1-3), while the number of BSs was relatively high compared to the number of tenants (8 vs 6). To determine if the results are valid for qualitatively different configurations as well (few BSs, each with high number of channels), further studies are necessary.

4 CONCLUSIONS AND FUTURE WORK

In this paper we proposed two CA-based allocation algorithms for channel allocation in multi-connective wireless environments. Based on simulations we have shown that the considered algorithms are efficiently allocating the resources in the analyzed setups, while their computational requirements also remain on an acceptable level. The next step will be to compare the performance of the algorithms and their potential future adjusted versions (let us consider e.g. the inclusion of constraints allowing minimum allocated capacity for each tenant) with other allocation schemes used in the multi-connective context, like the Gale-Shapley algorithm used [3], according to various measures, including fairness as well.

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A FAMILY OF LONG-STEP INTERIOR POINT ALGORITHMS FOR LINEAR PROGRAMMING

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Abstract: Ai and Zhang (2005) closed the gap between the practice and theory of interior point methods (IPM) for LP. They proposed a large-update IPM with the same complexity as the best short-step methods. We combine their main ideas with the algebraic equivalent transformation technique introduced by Darvay (2003). Using different transformation functions gives different search directions. Therefore we present sufficient properties of the function to keep the complexity of the proposed large-update algorithm $O(\sqrt{n}L)$.

Keywords: Linear optimization, interior point algorithms, algebraic equivalent transformation, long-step algorithm

A NUMERICAL COMPARISON OF LONG-STEP INTERIOR POINT ALGORITHMS FOR LINEAR OPTIMIZATION

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Abstract: This paper introduces a general algorithmic framework and presents the numerical comparison of six long-step interior point methods for linear programming problems. The algorithms are based on the approach of Ai and Zhang and obtained by using the algebraic equivalent transformation method of Darvay with different functions.

Keywords: Linear optimization, interior point algorithms, algebraic equivalent transformation

1 INTRODUCTION

Since Karmarkar introduced the first interior point method for linear optimization in 1984 [7], this algorithm type became one of the most widely used solution methods, not just for linear programming problems but also for many other problem classes.

According to the choice of step-length, interior point methods can be divided into two main groups, short-step and long-step algorithms. Even though long-step methods perform better in practice, short-step variants have the best-known theoretical complexity, i.e., there was a gap between theory and practice for many years.

In their groundbreaking paper of 2005, Ai and Zhang introduced a new long-step interior point algorithm for monotone linear complementarity problems. They proved that their method has the best-known iteration complexity of short-step variants [1]. Since then, many papers have been published based on their approach for different problem classes.

In 2002, Darvay developed a new method for finding search directions in interior point algorithms for linear optimization [2]. In his analysis, he applied a strictly increasing and continuously differentiable function to the central path problem and then determined the new directions using Newton's method. Since then, various authors have published numerous studies that generalize Darvay's method, using different functions, algorithm types, or problem classes.

Our general framework combines the two above-mentioned methods. We introduce an Ai-Zhang type general framework based on the algebraic equivalent transformation technique.

2 PRELIMINARIES

Let us consider the linear programming problem in standard form:

$$\left.\begin{aligned} \min\ \mathbf{c}^T\mathbf{x} \\ A\mathbf{x}=\mathbf{b} \\ \mathbf{x}\geq\mathbf{0} \end{aligned}\right\} \qquad \left.\begin{aligned} \max\ \mathbf{b}^T\mathbf{y} \\ A^T\mathbf{y}+\mathbf{s}=\mathbf{c} \\ \mathbf{s}\geq\mathbf{0} \end{aligned}\right\} \tag{1}$$

where $A \in \mathbb{R}^{m\times n}$, $\mathbf{b} \in \mathbb{R}^m$ and $\mathbf{c} \in \mathbb{R}^n$ are given, and $\operatorname{rank}(A) = m$.

System (2) describes the optimality criteria of the primal-dual pair. To be able to introduce interior point algorithms, we consider a relaxed version of (2), the central path problem (3), where $\nu > 0$ is a given parameter.

$$\left.\begin{aligned} A\mathbf{x}=\mathbf{b},\ \mathbf{x}\geq\mathbf{0} \\ A^T\mathbf{y}+\mathbf{s}=\mathbf{c},\ \ \mathbf{s}\geq\mathbf{0} \\ \mathbf{x}\mathbf{s}=\mathbf{0} \end{aligned}\right\} \quad (2) \qquad\qquad \left.\begin{aligned} A\mathbf{x}=\mathbf{b},\mathbf{x}\geq\mathbf{0} \\ A^T\mathbf{y}+\mathbf{s}=\mathbf{c},\mathbf{s}\geq\mathbf{0} \\ \mathbf{x}\mathbf{s}=\nu\mathbf{e} \end{aligned}\right\} \quad (3)$$

Let us introduce the following notations:

$$\mathcal{F} = \{(\mathbf{x},\mathbf{y},\mathbf{s}):\ A\mathbf{x}=\mathbf{b},\ A^T\mathbf{y}+\mathbf{s}=\mathbf{c},\ \mathbf{x}\geq\mathbf{0},\ \mathbf{s}\geq\mathbf{0}\},$$

$$\mathcal{F}_+ = \{(\mathbf{x},\mathbf{y},\mathbf{s})\in\mathcal{F}:\ \mathbf{x}>\mathbf{0},\ \mathbf{s}>\mathbf{0}\},$$

where $\mathcal{F}$ is the set of feasible solutions, and $\mathcal{F}_+$ is the set of strictly positive feasible solutions.

According to the well-known result of Sonnevend, if $\mathcal{F}_+ \neq \emptyset$, then for each $\nu > 0$ system (3) has a unique solution [8]. As ν tends to 0, the solutions of (3) converge to the solutions of system (2).

Let φ be a continuously differentiable function,

$$\varphi : (\xi,\infty) \to \mathbb{R}, \quad \varphi'(t) > 0 \text{ for all } t \in (\xi,\infty),\ \xi \in [0,1).$$

According to the algebraic equivalent transformation method of Darvay, we can determine new search directions by applying φ to the central path problem in the following way:

$$\left.\begin{aligned} A\mathbf{x}=\mathbf{b},\quad \mathbf{x}\geq\mathbf{0} \\ A^T\mathbf{y}+\mathbf{s}=\mathbf{c},\quad \mathbf{s}\geq\mathbf{0} \\ \varphi\left(\frac{\mathbf{x}\mathbf{s}}{\nu}\right)=\varphi\left(\mathbf{e}\right). \end{aligned}\right\} \tag{4}$$

If we apply Newton's method to system (4), we get the following for the search directions:

$$\begin{aligned} A\Delta\mathbf{x} &= \mathbf{0} \\ A^T\Delta\mathbf{y}+\Delta\mathbf{s} &= \mathbf{0} \\ \mathbf{s}\Delta\mathbf{x}+\mathbf{x}\Delta\mathbf{s} &= \nu\frac{\varphi(\mathbf{e})-\varphi\left(\frac{\mathbf{x}\mathbf{s}}{\nu}\right)}{\varphi'\left(\frac{\mathbf{x}\mathbf{s}}{\nu}\right)}. \end{aligned} \tag{5}$$

The right-hand side of the previous system depends on the function φ, therefore we can introduce different new methods, depending on the choice of the function φ.

If we consider a scaled version of (5), in most cases the analysis of interior point methods can be carried out easier. Let

$$\mathbf{v} = \sqrt{\frac{\mathbf{x}\mathbf{s}}{\nu}}, \quad \mathbf{d_x} = \frac{\mathbf{v}\Delta\mathbf{x}}{\mathbf{x}}, \quad \mathbf{d_s} = \frac{\mathbf{v}\Delta\mathbf{s}}{\mathbf{s}}, \text{ and } \bar{A} = A \text{ diag}\left(\frac{\mathbf{v}}{\mathbf{s}}\right).$$

With the new notations, the scaled Newton-system can be formulated as follows:

$$\begin{aligned} \bar{A}\mathbf{d_x} &= \mathbf{0} \\ \bar{A}^T\Delta\mathbf{y} + \mathbf{d_s} &= \mathbf{0} \\ \mathbf{d_x} + \mathbf{d_s} = \mathbf{p_v} &= \frac{\varphi(\mathbf{e}) - \varphi(\mathbf{v}^2)}{\mathbf{v}\varphi'(\mathbf{v}^2)}. \end{aligned}$$

The better complexity results of Ai and Zhang are based on two main ideas: the decomposition of the Newton-directions and a new wide neighbourhood.

They considered the following two systems and assigned different step-lengths to the positive and negative components:

$$\left.\begin{aligned} A\Delta\mathbf{x}_+ &= \mathbf{0} \\ A^T\Delta\mathbf{y}_+ + \Delta\mathbf{s}_+ &= \mathbf{0} \\ \mathbf{s}\Delta\mathbf{x}_+ + \mathbf{x}\Delta\mathbf{s}_+ &= \nu\mathbf{v}\mathbf{p}_\mathbf{v}^+ \end{aligned}\right\} \qquad \left.\begin{aligned} A\Delta\mathbf{x}_- &= \mathbf{0} \\ A^T\Delta\mathbf{y}_- + \Delta\mathbf{s}_- &= \mathbf{0} \\ \mathbf{s}\Delta\mathbf{x}_- + \mathbf{x}\Delta\mathbf{s}_- &= \nu\mathbf{v}\mathbf{p}_\mathbf{v}^-, \end{aligned}\right\} \tag{6}$$

where ${\mathbf{p_v}}^+$ and ${\mathbf{p_v}}^-$ denote the positive and negative part of vector $\mathbf{p_v}$, i.e.,

$${\mathbf{p_v}}^+ = \max\{\mathbf{p_v}, \mathbf{0}\} \in \mathbb{R}^n \text{ and } \mathbf{p}_\mathbf{v}^- = \min\{\mathbf{p_v}, \mathbf{0}\} \in \mathbb{R}^n,$$

the maximum and minimum are taken componentwise.

The method of Ai and Zhang works in the following wide neighbourhood, where $\beta, \tau \in (0, 1)$ are given parameters, $\nu = \tau\mu$ and $\mu = \frac{\mathbf{x}^T\mathbf{s}}{n}$:

$$\widetilde{\mathcal{W}}(\tau, \beta) = \left\{(\mathbf{x}, \mathbf{y}, \mathbf{s}) \in \mathcal{F}_+ : \|\mathbf{v}\mathbf{p}_\mathbf{v}^+\| = \left\|\frac{1}{\nu}\mathbf{a}_\varphi^+\right\| \leq \beta\right\}.$$

3 A NEW CLASS OF LONG-STEP INTERIOR POINT ALGORITHMS

In the original algorithm of Ai and Zhang, the central path problem is not transformed, therefore it can be considered a special case of the algebraic equivalent transformation method with the identity map, i.e., $\varphi(t) = t$. In 2018, Darvay and Rigó presented an Ai-Zhang type long-step interior point algorithm by applying the function $\varphi(t) = \sqrt{t}$ [3].

Recently, we introduced a new Ai-Zhang type method, using the algebraic equivalent transformation method with the function $\varphi(t) = t - \sqrt{t}$ [4].

For all three methods, the convergence and $O(\sqrt{n}L)$ complexity can be guaranteed. After comparing the analysis of these algorithms, we became interested in whether it is possible to introduce a general Ai-Zhang type algorithmic framework and find a function class for which the convergence and desired complexity can be achieved.

For our analysis, we introduced the following Ai-Zhang type wide neighbourhood:

$$\mathcal{W}(\tau, \beta) = \left\{(\mathbf{x}, \mathbf{y}, \mathbf{s}) \in \mathcal{F}_+ : \|\mathbf{p}_\mathbf{v}^+\| \leq \beta \text{ and } \mathbf{v} > \xi \mathbf{e}\right\},$$

where $\beta, \tau \in (0, 1)$ are given parameters. To make sure that the algorithm is well-defined for different φ functions, we included the condition $\mathbf{v} > \xi \mathbf{e}$.

Our general algorithmic framework can be described as follows:

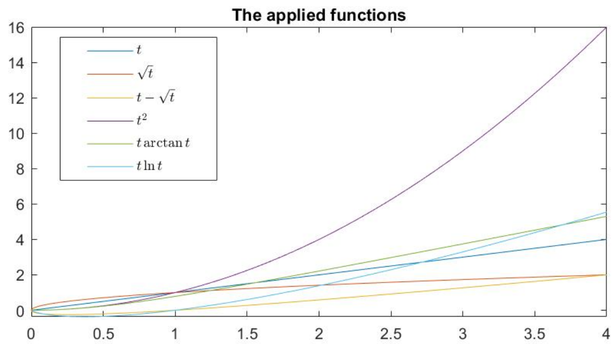
Input: $A \in \mathbb{R}^{m \times n}$, $\mathbf{b} \in \mathbb{R}^m$, $\mathbf{c} \in \mathbb{R}^n$
Parameters $0 < \tau < 1$, $0 < \beta < 1$, proximity parameter $\varepsilon > 0$
$(\mathbf{x}_0, \mathbf{y}_0, \mathbf{s_0}) \in \mathcal{W}(\tau, \beta)$, $\mu_0 = \frac{\mathbf{x}_0^T \mathbf{s}_0}{n}$
$\mathbf{x} := \mathbf{x}_0$, $\mathbf{y} := \mathbf{y}_0$, $\mathbf{s} := \mathbf{s}_0$, $\mu := \mu_0$ and $\nu := \tau \mu$
while $\mathbf{x}^T \mathbf{s} > \epsilon$ **do**
Determine $\Delta \mathbf{x}_+, \Delta \mathbf{s}_+, \Delta \mathbf{y}_+$ and $\Delta \mathbf{x}_-, \Delta \mathbf{s}_-, \Delta \mathbf{y}_-$ by solving (6);
$(\alpha_1, \alpha_2) := \operatorname{argmin}\{\mu(\alpha) : (\mathbf{x}(\alpha), \mathbf{y}(\alpha), \mathbf{s}(\alpha)) \in \mathcal{W}(\tau, \beta)\}$, where
$\mathbf{x}(\alpha) = \mathbf{x} + \alpha_1 \Delta \mathbf{x}_- + \alpha_2 \Delta \mathbf{x}_+$, $\mathbf{y}(\alpha) = \mathbf{y} + \alpha_1 \Delta \mathbf{y}_- + \alpha_2 \Delta \mathbf{y}_+$ and
$\mathbf{s}(\alpha) = \mathbf{s} + \alpha_1 \Delta \mathbf{s}_- + \alpha_2 \Delta \mathbf{s}_+$;
$\mathbf{x} := \mathbf{x}(\alpha)$;
$\mathbf{y} := \mathbf{y}(\alpha)$;
$\mathbf{s} := \mathbf{s}(\alpha)$;
$\mu := \frac{\mathbf{x}^T \mathbf{s}}{n}$;
$\nu := \tau \mu$;
end

Algorithm 1: General algorithmic framework

We identified a function class for which Algorithm 1 is convergent and finds an ε-optimal solution to system (2) in $O(\sqrt{n}L)$ iterations [5].

4 NUMERICAL RESULTS

The most frequently applied functions in the literature of the algebraic equivalent transformation are $\varphi(t) = t$, $\varphi(t) = \sqrt{t}$, $\varphi(t) = t - \sqrt{t}$ and $\varphi(t) = \frac{\sqrt{t}}{2(1+\sqrt{t})}$. In [5], we showed that the first three of these functions are included in our new function class. Furthermore, we identified three new functions that satisfy the properties of the new function class, and, to our best knowledge, have not been used in this context in the literature before, namely $\varphi(t) = t^2$, $\varphi(t) = t \arctan t$ and $\varphi(t) = t \ln t$.



The algorithm based on the first function ($\varphi(t) = t$) can be viewed as the original method of Ai and Zhang, with a slightly modified wide neighbourhood definition. The algorithm variant based on the function $\varphi(t) = \sqrt{t}$ corresponds to the method of Darvay and Rigó [3].

We implemented Algorithm 1 in Matlab and compared the results for the above listed six functions for 32 linear programming problems from the Netlib library [6]. To determine strictly feasible starting points in the neighbourhood $\mathcal{W}(\tau, \beta)$, we applied the self-dual embedding technique [9].

For the parameter settings, we used $\beta = 0.125$, $\tau = 0.125$ and $\varepsilon = 10^{-6}$. For the sake of simplicity, we fixed the value of α_2 as 1 and calculated the largest α_1 value for which the new iterate $(\mathbf{x}(\alpha), \mathbf{y}(\alpha), \mathbf{s}(\alpha))$ remains in the neighbourhood $\mathcal{W}(\tau, \beta)$. The number of iterations and the running time (in seconds) required to find an ε-optimal solution for the different algorithm variants are shown in Table 4. The shortest running time for each test problem is highlighted with bold numbers.

			t		$\sqrt{t}$		$t-\sqrt{t}$		t^2		$t\arctan t$		$t\ln t$	
	m	**n**	**Iter.**	**Time**	**Iter.**	**Time**	**Iter.**	**Time**	**Iter.**	**Time**	**Iter.**	**Time**	**Iter.**	**Time**
adlittle	189	378	11	0.2992	11	**0.2953**	11	0.3059	12	0.3489	11	0.3042	11	0.3115
afiro	62	124	7	**0.0161**	7	0.0184	7	0.0192	7	0.0251	7	0.0244	7	0.0215
agg	933	1866	10	34.4089	11	41.9497	10	38.3429	10	30.8876	10	29.9413	10	**29.8912**
agg2	1276	2552	14	98.6336	15	105.4592	15	**85.5975**	15	85.9759	15	102.9358	15	96.4848
agg3	1276	2552	15	122.1428	15	124.0588	15	119.5863	15	126.3768	15	106.5304	15	**104.7470**
bandm	717	1434	9	12.9590	10	14.7513	9	**12.7925**	9	13.2567	9	13.9785	9	13.1588
beaconfd	342	684	9	**1.7000**	9	2.0108	9	1.7186	8	1.7025	9	1.7823	9	1.8244
blend	89	178	8	**0.0707**	9	0.0744	9	0.0756	8	0.0859	9	0.1076	9	0.0826
bnl1	1724	3448	10	**175.0822**	11	190.3188	10	175.6311	10	176.7987	10	195.6307	10	223.0791
brandy	419	838	8	3.8622	9	3.8483	8	3.6551	8	3.5135	8	3.5178	8	**3.4606**
e226	612	1224	9	**10.4281**	10	12.0397	9	10.7507	10	10.9956	9	10.8357	9	11.1550
etamacro	938	1876	11	42.3508	11	43.6106	11	43.0326	10	**38.9137**	11	43.6564	11	42.6810
fffff800	1026	2052	10	50.9550	10	50.5345	10	51.4154	9	**46.6445**	10	50.9074	10	50.0788
finnis	1483	2966	12	169.7703	12	158.8282	12	133.3033	11	**123.5786**	12	134.4181	12	133.5724
grow7	1003	2006	8	30.6104	10	36.9307	9	33.7950	8	30.5303	8	30.7118	8	**30.1929**
israel	492	984	8	4.3200	9	4.6514	9	4.7011	8	4.3001	9	4.6263	8	**4.1894**
kb2	86	172	7	0.0603	7	**0.0580**	7	0.0602	6	0.0671	7	0.0816	7	0.0745
lotfi	379	758	11	2.8526	11	2.7601	11	2.9339	9	**2.3150**	11	2.9942	11	2.7733
recipe	254	508	7	**0.6225**	8	0.8660	7	0.8372	7	0.7679	7	0.7709	7	0.7303
sc105	150	300	7	0.1840	8	0.1922	7	**0.1799**	7	0.2026	7	0.2014	7	0.1881
sc205	285	570	7	0.9589	8	1.1714	7	**0.9256**	7	1.1280	7	0.9684	7	0.9624
sc50a	75	150	7	**0.0477**	7	0.0523	7	0.0490	7	0.0624	7	0.0588	7	0.0503
sc50b	73	146	7	0.0496	7	**0.0425**	7	0.0471	7	0.0607	7	0.0655	7	0.0575
scagr25	895	1790	9	24.2466	9	24.4921	9	25.0989	8	**21.8548**	9	24.3432	9	24.2294
scagr7	211	422	8	0.4958	8	0.5319	8	0.4754	7	0.4810	8	0.5369	8	**0.4648**
scfxm1	773	1546	10	17.8367	10	18.0917	10	17.8247	10	18.1064	10	19.2260	10	**17.8192**
scrs8	954	1908	8	26.8143	9	29.9578	8	**26.3165**	8	26.3358	8	32.4648	8	26.7485
sctap1	310	620	6	0.7804	6	0.8450	6	0.8038	5	**0.6456**	6	0.7781	6	0.8297
scsd1	839	1678	19	**43.2631**	18	48.0288	18	45.1233	19	58.6922	18	54.7086	18	51.2099
scsd6	1499	2998	20	241.3395	20	230.0351	20	211.9853	20	**190.3297**	20	214.7360	20	218.8522
share2b	256	512	8	**0.5477**	9	0.6963	8	0.7354	8	0.7179	8	0.6717	8	0.7242
stocfor1	236	472	7	0.4705	8	0.5692	7	0.4741	7	0.4954	7	0.4659	7	**0.4581**
		Average	9.5938	34.9431	10.0625	35.8678	9.6875	32.7685	9.3750	31.7561	9.6563	33.8431	9.6250	34.0970

Table 1: Numerical comparison of the six long-step algorithms

As it can be seen from Table 4, there is no significant difference between the six algorithm variants for linear programming problems. The average running times and average number of iterations are shown in the last row of Table 4. From these results, we can observe that in terms of running time, the algorithms based on the functions $\varphi(t) = t^2$ and $\varphi(t) = t - \sqrt{t}$ perform slightly better than the other variants.

5 CONCLUSION

We presented a new general algorithmic framework for Ai-Zhang type long-step interior point algorithms, based on the algebraic equivalent transformation method of Darvay.

We implemented the general method and compared the results for six special cases. As it can be observed from our results, there is no significant difference between the six variants, although, in terms of average running time, two of them perform slightly better.

One of our important goals is to generalize this framework to linear complementarity problems. We expect that in this case, the effectiveness of the algorithm variants will be significantly different.

ACKNOWLEDGEMENT

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Power and preferences

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Abstract: We study the power of voters that are symmetrical except for their position in a policy space. We find that contrary to corresponding results in a one-dimensional spectrum of voters, where the median voter has a key role, voters with a

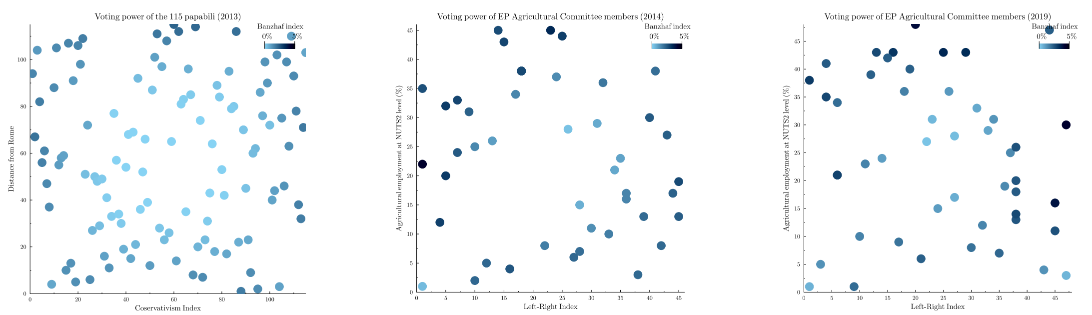
Keywords: keyword, keyword, keyword,

1 Abstract

The analysis of voting situations focuses on weighted voting with the objective to link voting weights and the ability to influence decisions. The literature of a priori power measures starts with the assumption that nothing is known about the issues to be voted on or the voters' preferences and therefore any coalition of players is possible.

In practice, this assumption is often violated: some coalitions are simply not likely or possible. We consider convex voting games, players are located on a policy space and their positions do put restrictions on the coalitions that may emerge. A proposal without a majority support may get new "yes" votes by inviting nearby voters – naturally, their support comes at a price: the proposal must be changed slightly to gain their support.

Kóczy and Sziklai [2] and Fertő et al. [1] consider convexity coordinate-wise in a two-dimensional policy space so that strictly internal voters of the rectangles spanned coalitions are necessarily members. On the other hand, those on the borderline of the rectangles are free to join or leave. Power is drawn from the ability to turn a losing coalition into a winning one. We consider the model where players are symmetric except for their position on the policy space. Abstracting away from abstentions [1] one finds a surprisingly uniform pattern. To see this we first transform the policy space into a discrete grid, where each coordinate is replaced by its rank among the corresponding coordinates among the voters. Such a transformation keeps the rectangles where a player may be critical for majority: if a rectangle spanned by some of the voters was such, the rectangle spanned by the transformed images of those voters covers the same voters including the one in question.



(a) Concalve, 2013 (b) COMAGRI, 2014-19 (c) COMAGRI, 2019-24

Figure 1: Examples of power distributions with ranked coordinates. Calculations are based on Kóczy and Sziklai [2] and Fertő et al. [1].

In Figure 1 we see examples of such gridplots and one may immediately notice that (1) voters near the centre are weak and (2) voters around the four corners are weak. One may wonder if this is a general property.

We present both simulation and analytical results. We have generated random voters and for these, we calculated the voting power of each voter and then we have taken the average power of the players whenever that particular grid point has been selected. With n players, the chance of being selected is $1/n$, so with already fairly small numbers of n we can have a smooth surface. The randomization made sure that no two points are on the same gridlines – an assumption we kept also for the analytical formula. The latter calculates the expected probability that a grid point is on the borderline of a rectangle of minimal winning size. The calculation is a simple enumeration of such rectangles. Our preliminary model sorts possible rectangles in 6 types each with 4 subtypes facing different directions. When we talk about proper voting games, that is, the quota requires a majority, or course only some of these rectangles may exist. For each case we consider rectangles of different sizes separately. We first calculate the number of ways the spanning voters can be located, then the ways internal points can be arranged then the rest.

What we find is that central voters have little power and so do voters in extreme positions; voters with central in one and extreme in the other coordinate have the highest power.

Our results suggest a number of things:

- Since the one-dimensional version of our model would be a horizontal line with a dip at the median voter, our model suggests that the opening up of political issues in two dimensions may lead to a raise in extremism. Preliminary findings suggest that as the correlation between the two coordinates increases, the relative importance of taking extreme positions diminishes.

- Certainly, such power distribution may lead to a race to extremism: even the same moderate party would delegate a representative who takes an extreme position in one of the aspects.

- Interestingly, voters with totally extreme positions are marginal, although not as much central voters. This may suggest that radical voters may benefit from taking mainstream positions on some issues.

2 Acknowledgements

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ALGEBRAIC EQUIVALENT TRANSFORMATION TECHNIQUE IN CASE OF SUFFICIENT LINEAR COMPLEMENTARITY PROBLEMS

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Abstract:

We introduce a new predictor-corrector interior-point algorithm for solving sufficient linear complementarity problems. The presented algorithm uses a new type of algebraic equivalent transformation on the nonlinear equations of the system defining the central path. This technique was proposed by Darvay and Takács [1] for linear optimization. We use the square function in this new approach in order to determine the search directions. We show that the predictor-corrector algorithm has the same complexity as the best known interior-point algorithms for solving sufficient linear complementarity problems. To the best of our knowledge, this is the first predictor-corrector interior-point algorithm for solving sufficient linear complementarity problems which is based on this search direction.

Keywords: sufficient linear complementarity problems; predictor-corrector interior-point algorithm; algebraic equivalent transformation technique

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SENSITIVITY OF FAIR PRICES IN ASSIGNMENT MARKETS

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Abstract: In assignment markets, as proved by Shapley and Shubik (1972), the set of competitive equilibrium payoffs coincides with the core of the related assignment game, and there are two special core allocations: one is simultaneously the best for all buyers, the other is simultaneously the best for all sellers. If prices are set by a market mechanism that is known to determine the minimum equilibrium prices with respect to agents' stated valuations, the buyers have no incentive to falsify their true values. The sellers, however, can manipulate the mechanism to their benefits.

We investigate the sensitivity of the two special core allocations and that of their average, called the 'fair' allocation. We show that if an agent unilaterally falsifies all of his stated valuations by the same amount, his payoff in the 'fair' allocation cannot decrease, but can increase by at most half of that amount. Our proof basically relies on a new characterization of the buyer-optimal and seller-optimal allocations in terms of the lengths of longest paths in an acyclic directed network constructed from the valuations stated by the agents.

Keywords: two-sided market, assignment game, minimum equilibrium price

BOUNDED POOLING PROBLEM

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Abstract: Up to our best knowledge, the first operations research model for blending chemical substances were formulated by Dantzig and his co-authors in the late 1950s.

From an operations research perspective, the standard pooling problem involves decision variables associated with *unknown quantities* and *qualities*. In the models of the pooling problem, bilinear equations (or inequalities) are typically used in addition to linear conditions. The feasible solution set of the pooling problem is not convex and sometimes not even connected. Thus, solving the pooling problem leads to a global optimization problem. In the original problem formulation, raw materials of different qualities from different sources are mixed and the mixed materials must meet quality constraints in each terminal. One of the first important results on pooling problems in networks comes from Haverly, but in the last 20 years there has been a substantial literature on the subject and practical methods for solving it. In the *standard pooling problem* (SPP), the lower bound on the flows is 0 on each edge, so there is always a feasible solution, the all-zero flow. Experience shows that this is not the case in practice. Each source must produce and deliver a positive amount of the raw material and blend it with others to produce final blend at each terminal. This gives, naturally, a positive lower bound on the flow value at each terminal, in addition to upper bounds. In the literature, there are 14 small-scale and 20 large-scale examples of SPPs. All these test problems are defined with 0 lower bound.

Our goal is to create more realistic test problems, namely such that at the terminal vertices a required positive flow bounds the flow from below. In this talk, we show our efforts to build such more realistic test problems and analyse the resulted new set of test problems.

Keywords: Pooling problem; bilinear optimization; global optimization

IMPLEMENTATION OF PRIMAL-DUAL INTERIOR-POINT ALGORITHM FOR SOLVING SUFFICIENT LINEAR COMPLEMENTARITY PROBLEMS[1]

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Abstract: A primal-dual interior-point algorithm (PD IPA) for solving $P_*(\kappa)$-linear complementarity problems (LCP) has been implemented and tested. The technique of algebraic equivalent transformation (AET) of the central path system allows us to incorporate into our implementation the most frequently used AET functions, namely $\varphi(t) = t$, $\varphi(t) = \sqrt{t}$ and $\varphi(t) = t - \sqrt{t}$.

Keywords: primal-dual Newton barrier interior-point algorithm; sufficient linear complementarity problems; algebraic equivalent transformation technique

1 INTRODUCTION

The main focus of this paper is on the computer implementation of a PD IPA [3] with different AET functions for $P_*(\kappa)$-LCPs with $\mathcal{O}\left((1+\kappa)\sqrt{n}\log\left(\frac{(\mathbf{x}^0)^T\mathbf{s}^0}{\epsilon}\right)\right)$ iteration complexity. During the implementation we have faced some numerical difficulties that will be discussed. It is important to mention that there are various applications of LCPs in numerous fields like in business and economics, engineering, etc [1]. For example, the Fischer- and Arrow-Debreu competitive market equilibrium problem leads to LCP [13]. However, in most of the applications the matrix does not possess properties that would ensure the effective (polynomial) solvability of the LCP. We show the practical efficiency of the algorithms by providing numerical results and compare those with the ones presented in [3].

2 LINEAR COMPLEMENTARITY PROBLEMS (LCPs)

First we define the (general) LCP as

$$-M\mathbf{x} + \mathbf{s} = \mathbf{q} \quad \mathbf{x}, \mathbf{s} \geq \mathbf{0}, \quad \mathbf{x}\mathbf{s} = \mathbf{0}, \tag{LCP}$$

where $M \in \mathbb{R}^{n\times n}$. The set $\mathcal{F}$ denotes the feasible solutions of LCP, $\mathcal{F}^+$ interior points, while $\mathcal{F}^*$ contains the solutions of LCP. LCPs with *skew symmetric*, *positive semidefinite*, *positive definite* matrices can be solved in polynomial number of iterations up to ε-optimality.[2] The largest class of matrices for which IPAs have theoretical guarantees on efficiency is the class of *sufficient matrices* [6, 7], $P_*(\kappa) - matrices$ (or $P_* - matrices$) [7, 10], where $\kappa \geq 0$. Illés et

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[2]A feasible solution $(\mathbf{x}, \mathbf{s})$ of a given LCP is called ε-optimal solution, if $\mathbf{x}^T\mathbf{s} \leq \varepsilon$, where $\varepsilon > 0$, see for instance [7].

al. [7] showed that from an ε-optimal solution with properly selected ε, exact solution can be computed with a strongly polynomial *rounding procedure*.

Interestingly enough, Kojima et al.[10], Guu and Cottle [6], and Väliaho [12] proved that the sufficient- and P_*-matrix classes are equivalent.

We use P_* to denote the set of all P_*-matrices. The handicap of the matrix M is defined as follows:

$$\hat{\kappa}(M) := \min\{\kappa : \kappa \geq 0, M \in \mathcal{P}_*(\kappa)\}.$$

Throughout the paper we will assume that M is $P_*(\kappa)$-matrix. We also suppose that $\mathcal{F}^+ \neq \emptyset$. The system which defines the *central path problem* is

$$-M\mathbf{x} + \mathbf{s} = \mathbf{q}, \quad \mathbf{x}, \mathbf{s} > \mathbf{0}, \quad \mathbf{xs} = \mu\mathbf{e}, \tag{CPP}$$

where $\mu > 0$ and $\mathbf{e}$ is the n-dimensional all-one vector. If M is a $P_*(\kappa)$-matrix, then the central path system has unique solution [10].

The *algebraically equivalent transformation (AET)* is a method to determine the search directions introduced by Zs. Darvay in 2003 [2]. Let $\varphi : (\xi^2, \infty) \to \mathbb{R}$ be a continuously differentiable and invertible function for which $\varphi'(t) > 0$, for each $t \geq \xi^2$, where $\xi \in [0,1)$. Applying the function φ componentwisely on the nonlinear equation of the (CPP), we get

$$-M\mathbf{x} + \mathbf{s} = \mathbf{q}, \qquad \varphi\left(\frac{\mathbf{xs}}{\mu}\right) = \varphi(\mathbf{e}), \qquad \mathbf{x}, \mathbf{s} > \mathbf{0}. \tag{CPP_φ}$$

After some calculations, see for instance [3–5], we get the general form of the Newton system:

$$\begin{aligned} -M\Delta\mathbf{x} + \Delta\mathbf{s} &= \mathbf{0} \\ S\Delta\mathbf{x} + X\Delta\mathbf{s} &= \mathbf{a}_\varphi, \end{aligned} \tag{1}$$

where

$$\mathbf{a}_\varphi = \mu \frac{\varphi(\mathbf{e}) - \varphi\left(\frac{\mathbf{xs}}{\mu}\right)}{\varphi'\left(\frac{\mathbf{xs}}{\mu}\right)}$$

and $X = diag(\mathbf{x})$, $S = diag(\mathbf{s})$. In the following section we present the implemented version of the PD IPA.

3 NUMERICAL SOLUTIONS

Firstly, we consider the matrix form of (1):

$$\begin{bmatrix} -M & I \\ S & X \end{bmatrix} \begin{pmatrix} \Delta\mathbf{x} \\ \Delta\mathbf{s} \end{pmatrix} = \begin{pmatrix} \mathbf{0} \\ \mathbf{a}_\varphi \end{pmatrix}. \tag{2}$$

In theory, the solution of the system (1) is $\Delta\mathbf{x} = (S + XM)^{-1}\mathbf{a}_\varphi$ and $\Delta\mathbf{s} = M\Delta\mathbf{x}$. However, in practice, calculating matrix inverse causes a lot of numerical errors.

Cholesky-decomposition only works on positive semidefinite matrices, thus we have to choose different factorization (LU, QR) for sufficient matrices. Important ingredient of any optimization algorithm implementation is the computational linear algebra package. We choose ALGLIB C++ library for solving systems of linear equations.

In order to get the Newton directions, first of all we use some notations:

$$M' = \begin{bmatrix} -M & I \\ S & X \end{bmatrix}, \mathbf{q}' = \begin{pmatrix} \mathbf{0} \\ \mathbf{a}_\varphi \end{pmatrix} \text{ and } \mathbf{x}' = \begin{pmatrix} \Delta\mathbf{x} \\ \Delta\mathbf{s} \end{pmatrix}.$$

We calculate $M'\mathbf{x}' = LU\mathbf{x}' = \mathbf{q}'$, then we solve equation $L\mathbf{y} = \mathbf{q}'$ on $\mathbf{y}$ and then $U\mathbf{x}' = \mathbf{y}$ on $\mathbf{x}'$. From computational tests, it turned out that solving this form

$$(X^{-1}S + M)\,\Delta\mathbf{x} = X^{-1}\mathbf{a}_\varphi$$

of the Newton system leads to a most stable numerical solution. Therefore, the matrix $X^{-1}S + M$ is decomposed into L and U matrices and then the

$$LU\,\Delta\mathbf{x} = X^{-1}\mathbf{a}_\varphi$$

is solved numerically, and after that $\Delta\mathbf{s} = M\Delta\mathbf{x}$ is computed.

Algorithm 1 shows the implemented version of the IPA .

Algorithm 1: Implemented primal-dual Newton barrier interior-point method

Input:
precision parameter: $\varepsilon = 10^{-5}$;
barrier update parameter: $\theta = 0.999$; proximity parameter: $\tau = 1$;
steplength decreasing parameter: $\sigma = 0.95$; strictly feasible starting points $(\mathbf{x}^0, \mathbf{s}^0)$, $\mu^0 > 0$, such that $\delta(\mathbf{x}^0, \mathbf{s}^0; \mu^0) \leq \tau$; $M \in \mathbb{R}^{n\times n}$ sufficient matrix; $\mathbf{q} \in \mathbb{R}^n$ right hand vector.

begin
- $\mathbf{x} := \mathbf{x}^0$, $\mathbf{s} := \mathbf{s}^0$, $\mu := \mu^0$;
- **while** $n\mu \geq \varepsilon$ **do**
  - $\mu := (1-\theta)\mu$;
  - Calculate $\Delta\mathbf{x}$ and $\Delta\mathbf{s}$ by solving (1) numerically using LU decomposition (rmatrixlu(),rmatrixsolve());
  - Calculate local κ for $\Delta\mathbf{x}$;
  - $\alpha_{x_h} := \{-\frac{x_i}{\Delta x_i} : \Delta x_i < 0\}$ and $\alpha_{s_h} := \{-\frac{s_i}{\Delta s_i} : \Delta s_i < 0\}$;
  - $\alpha_h := \sigma \cdot \min\{\alpha_{x_h}, \alpha_{s_h}\}$;
  - $\alpha := \min\{\alpha_h, 1\}$;
  - $\mathbf{x}^+ := \mathbf{x} + \alpha\Delta\mathbf{x}$ and $\mathbf{s}^+ := \mathbf{s} + \alpha\Delta\mathbf{s}$;
  - $\|r\|_\infty := \|-M\mathbf{x}^+ + \mathbf{s}^+ - \mathbf{q}\|_\infty$;
  - $\delta(\mathbf{x}^+, \mathbf{s}^+; \mu) := \left\| \frac{\mathbf{a}_\varphi^+}{2\sqrt{\mu\mathbf{x}^+\mathbf{s}^+}} \right\|_2$, where $\mathbf{a}_\varphi^+ = \mu \frac{\varphi(\mathbf{e}) - \varphi\left(\frac{\mathbf{x}^+\mathbf{s}^+}{\mu}\right)}{\varphi'\left(\frac{\mathbf{x}^+\mathbf{s}^+}{\mu}\right)}$;
  - **if** $\delta(\boldsymbol{x}^+, \boldsymbol{s}^+; \mu) > \tau$ **then**
    - "Not in τ neighbourhood"
  - **else**
    - **if** $\delta(\boldsymbol{x}^+, \boldsymbol{s}^+; \mu^+) > 2\cdot\tau$ **then**
      - "Not in its own τ neighbourhood"
  - $\mu^+ := \frac{(\mathbf{x}^+)^T\mathbf{s}^+}{n}$;
  - $\mu := \mu^+$;

Output: $(\mathbf{x}, \mathbf{s})$: $n\mu < \varepsilon$

4 NUMERICAL RESULTS

The solver was tested on the following LCPs. One of the used test problems is based on matrices generated by T. Illés and S. Morapitiye (ITMS) [8]. They generated sufficient matrices of sizes 10×10, 20×20, 50×50, 100×100, 200×200 and 500×500, 10 examples from each. Beside this, they also presented a 700×700 matrix. M. E.-Nagy (ENM) generated sufficient matrices [11] of different sizes from $n = 3,\dots,10$, 10 examples from each. A matrix with exponential κ was generated by Zs. Csizmadia (CsZs) [9] which has 1 in every position of the diagonal, under the diagonal -1, above the diagonal 0.

All of the test problems were generated in the following way: $\mathbf{q} := -M\mathbf{e}+\mathbf{e}$. We considered $\mathbf{x}^0 = \mathbf{e}$ and $\mathbf{s}^0 = \mathbf{e}$ as starting points for the implemented PD IPA.

In general, we used the $2n\times 2n$ Newton system for getting the solution. In case of CsZs matrices we made some changes, we used the system $X^{-1}S+M$ to compute the corresponding Newton directions. If the initial value of κ used in the PD IPA, differs significantly from the true value κ of the Csizmadia-matrix, then the experience has shown that more iterations are required to solve the LCP. The theoretical step length of the PD IPA is $\alpha = 1$. However, in practice, especially during the first few steps, the allowable step length is strictly smaller than 1. We computed in each iteration $\kappa(\Delta\mathbf{x})$ in the following way:

$$\kappa = -\frac{1}{4}\frac{\Delta\mathbf{x}^T M\Delta\mathbf{x}}{\sum_{i\in\mathcal{I}_+(\Delta\mathbf{x})}\Delta\mathbf{x}_i(M\Delta\mathbf{x})_i}.$$

The maximum of $\kappa(\Delta\mathbf{x})$ was used to approximate the handicap of the matrix for further use in the implementation.

$\varphi(t)$	t	$\sqrt{t}$	$t-\sqrt{t}$	t	$\sqrt{t}$	$t-\sqrt{t}$
n	Iter.	Iter.	Iter.	Time (s)	Time (s)	Time (s)
10	14	14	14	0.142	0.241	0.183
20	18	18	18	0.408	0.330	0.343
50	29	29	29	2.190	2.030	2.491
100	48	48	48	12.772	10.793	11.345
200	84	85	85	77.582	75.361	97.842
250	103	103	103	115.257	146.432	183.927
300	121	121	122	233.219	252.023	336.329
400	158	158	158	557.695	607.319	713.061
450	-	-	-	-	-	-

Table 1: TR LCP solver on CsZs-matrices

The step length was computed as $\alpha = \min\{\sigma\,\alpha_{\text{best}}, 1\}$, where $\sigma = 0.95$ is a parameter which guarantees that the new iterate stays strictly feasible and $\alpha_{\text{best}} = \min\left\{\max_{\Delta\mathbf{x}_i<0} -\frac{x_i}{\Delta\mathbf{x}_i}, \max_{\Delta\mathbf{s}_i<0} -\frac{s_i}{\Delta\mathbf{s}_i}\right\}$.

We tested the performance of the implemented PD IPA with $\alpha = \sigma\,\alpha_{\text{best}}$ as well. If too many times happened that $\alpha > 1$ occurred, instead of accelerating the computation, the new iterates moved away from the central path and finally, the number of necessary iterations needed to reach ε-optimal solution increased. During our test computations with different versions of our implementation, we observed a very sensitive balance between having locally larger step length than 1 and overall good performance of the algorithm.

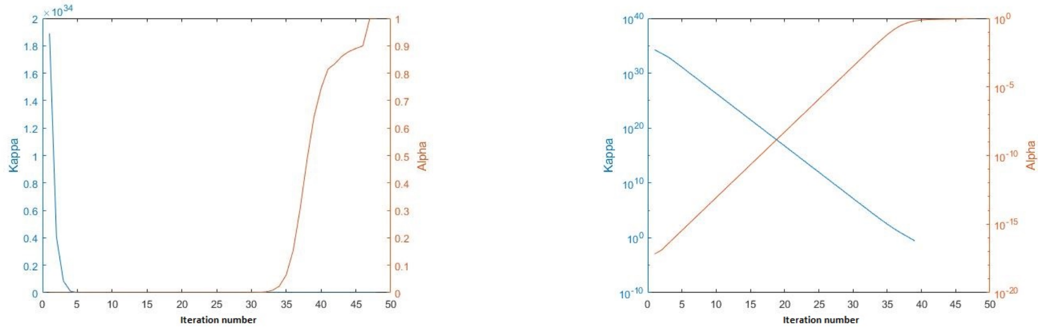

Figure 1: Connection between the local κ and the step length, tested on the size of 100×100 CsZs matrix (on the right hand side plotted with logarithmic scale)

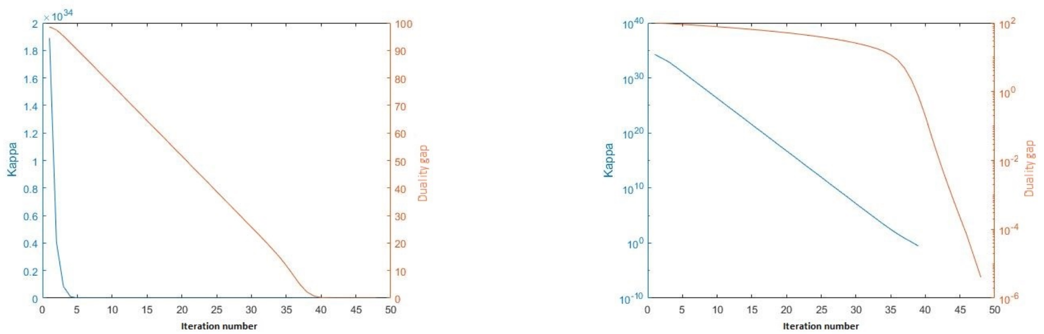

Figure 2: Connection between the local κ and the duality gap, tested on the size of 100×100 CsZs matrix (on the right hand side plotted with logarithmic scale)

In the following we show the numerical results of the implemented algorithm. In Table 1, 2 and 3 we present the average of iteration numbers and CPU times in seconds in case of CsZs matrices, ENM matrices and ITMS matrices. We compared our results with the ones provided in [3]. It can be seen that on both CsZs and ITMS matrices the iteration numbers in our solver results and in [3] are close to each other, however on CsZs matrices we could get better results and on ITMS worse results.

$\varphi(t)$	t	$\sqrt{t}$	$t-\sqrt{t}$	t	$\sqrt{t}$	$t-\sqrt{t}$
n	Iter.	Iter.	Iter.	Time (s)	Time (s)	Time (s)
3	4.89	6.67	5.11	0.0460	0.0593	0.0494
4	4.78	6.67	4.67	0.0410	0.0652	0.0499
5	5.2	7	5.2	0.0495	0.0709	0.0585
6	5.1	7.1	5.1	0.0475	0.0819	0.0754
7	5.7	7.2	5.7	0.0682	0.0777	0.0897
8	5.625	7.5	5.375	0.0758	0.1053	0.0721
9	5.375	7.375	5.375	0.0756	0.1309	0.0793
10	6.125	7.714	6.125	0.1046	0.1224	0.1120

Table 2: TR LCP solver on ENM matrices

Figure 1 shows that until $\kappa(\mathbf{\Delta x}) > 10^5$, for the step length we have $\alpha < 10^{-3}$. Namely, $\kappa(\mathbf{\Delta x})$ and the corresponding α are inversely proportional. Figure 2 shows that the duality gap decreases very slow until $\kappa(\mathbf{\Delta x})$ is large, as we expected from the observation shown on Figure 1.

5 CONCLUSION

In this paper we presented the numerical results of the implementation of PD IPA for solving sufficient LCPs, which uses the AET technique. In this numerical study we considered the mostly used AET functions, namely $\varphi(t) = t$, $\varphi(t) = \sqrt{t}$ and $\varphi(t) = t - \sqrt{t}$. In practice, the implemented PD IPA largely outperforms the predicted theoretical iteration numbers.

$\varphi(t)$	t	$\sqrt{t}$	$t-\sqrt{t}$	t	$\sqrt{t}$	$t-\sqrt{t}$
n	Iter.	Iter.	Iter.	Time (s)	Time (s)	Time (s)
10	8.0	9.0	8.0	0.0778	0.0952	0.0682
20	7.2	9.0	7.2	0.1730	0.2580	0.1742
50	5.4	8.0	5.2	0.6876	1.2836	0.6832
100	7	8.8	6.8	3.8494	5.069	3.896
200	7.2	9.4	7.2	12.9252	20.1886	13.7776
500	9.0	10.4	8.4	106.664	115.2506	89.2294
700	9.0	11.0	9.0	190.3930	251.7430	197.179

Table 3: TR LCP solver on ITMS matrices

	LCPs with CsZs matrices			LCPs with ITMS matrices		
$\varphi(t)$	t	$\sqrt{t}$	$t-\sqrt{t}$	t	$\sqrt{t}$	$t-\sqrt{t}$
n	Iter.	Iter.	Iter.	Avg. Iter.	Avg. Iter.	Avg. Iter.
20	15	15	15	7.2	7.1	7.4
50	25	25	25	5.2	5.1	5.3
100	43	42	43	5.6	5.5	6
200	78	78	78	6	6	6
500	184	184	184	6.7	6.9	6.7

Table 4: Numerical results given in [3]

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MAKING THE NEXT STEP IN FINDING THE BEST ROUTE

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Abstract: Because the Vehicle Routing Problem (VRP) is very complex, with practical cases being too large to obtain the optimal solutions, heuristic approaches need to be used. Since high performance computing (HPC) can provide large computing power, it seems to be a great fit for this problem. In this paper we describe two methods, namely Multi-seed computation and Step method and test their performance on real VRP example from a logistic company. Since logistic companies need to have a good result fast, we were mainly interested in finding the best possible solution in given short time.

Keywords: Step method, multi-seed computation, VRP, HPC

1 INTRODUCTION

This paper describes the project HPC logistics along with its results. The main focus of the project was to determine whether a high performance computer could significantly improve the behaviour of the optimization engine, developed for solving vehicle routing problems of different difficulties and discover ways for which the benefits are highest.

The optimization engine used in this project is based on the open source project jsprit [1] with many additional features added. jsprit is a java based, open source toolkit for solving rich Traveling Salesman Problems and VRPs [2,3]. The meta-heuristic used was developed by Schrimpf et al. [4] who formulated the *ruin-and-recreate* principle - a large neighborhood search that combines elements of simulated annealing and threshold-accepting algorithms. Essentially, it works as follows: starting with an initial solution, each subsequent iteration consists of disintegrating parts of the solution leading to (I.) a set of jobs that are not served by a vehicle anymore and to (II.) a partial solution containing all other jobs. Thus, this is called the *ruin* principle. Based on the partial solution (II.) all jobs from (I.) are re-integrated again, which is therefore referred to as *recreation* [5] yielding to a new solution. If the new solution has a certain quality, it is accepted as the new best solution, whereupon a new *ruin-and-recreate* iteration starts. These steps are repeated over and over again until a certain termination criterion is met (e.g. computation time, number of iterations, etc.). One such iteration takes a relatively constant amount of time to compute for a certain problem (on a particular machine with its specifications), but this time differs greatly between problems of different sizes and difficulty.

Even though the optimization engine employs state-of-the-art search strategies, obtaining good results is still very time consuming, also depending on the size of the problem and number of constraints of the VRP (for example, the more vehicle capacity dimensions there are, the slower the algorithm). The cost of the solution decreases fast in the beginning, but after that more and more time is needed to obtain an improvement, if it exists. This means that for larger logistics companies with several hundred vehicles in their fleet, getting a good solution could take many hours, which might be too much to be useful.

The process starts with an initial solution, which can be given, or generated with a heuristic method. The optimization process is then steered by a random seed. Different seeds have different convergence speeds. A certain seed may lead us closer to the optimal result faster, but we can't determine which seeds are better for specific problems. Also, some seeds may perform better in the beginning of the process, while others perform better later on. So, it seems that the best way forward is to use as many different seeds as possible, in order to increase the chance of finding "the right one" (getting us as close to the optimum in a very short time) as much as possible.

2 EMPLOYING HPC

The aim of this project was to explore the options to speed up obtaining a good solution with a high performance computer. For this purpose, we planned two speed-up techniques:

1. **Multi-seed computation**: We have simply run several threads, each one with its own, different seed. This random seed impacts the rate with which a better solution is found. It is impossible to anticipate which random seed will give us better results for which problem. Using several processes with different seeds we have increased our chance to find a good solution within a given time.
2. **Step method**: We have tried to take advantage of the fact that some seeds were more "efficient" than the others, their convergence was faster. Our idea was to use the currently best solution as an initial solution for the rest of the process. The process goes as follows:
    a. Run the algorithm with multiple seeds as above.
    b. Stop the algorithm after a certain number of iterations and find the best (cheapest) solution found so far among all the random seeds.
    c. Select this solution, set it as the initial solution (starting point) for all the random seeds, and continue with the next step.
    d. Repeat until the termination criterion is met.

Multi-seed computation is a special case of the Step method where the number of iterations for each step equals the number of iterations after which the algorithm should terminate, so we only have one step.

The idea for our Step method arose from existing approaches:

- Gradient descent - we are using the best solution as a start for the next step. The difference is that we are not able to analytically determine the best "direction" for continuation, but have to heuristically search the neighbourhood, using several threads with different seeds.
- Genetic algorithms - a single step produces a "population", and the best representatives of the population are used for the next step. The difference is that we have used only one best solution for the next step. We could potentially also use all non-dominated solutions, or something similar, but would have to determine which new thread gets which initial solution. This might be feasible, but would need some additional mental effort.

3 RESULTS

For the tests we used a real VRP example from a logistic company. Tests were run on a problem with cargo and vehicle capacities with three dimensions, time windows and shipments with both pickup and delivery locations specified. We chose a problem for which we knew there existed a plan with no unassigned shipments (even though sometimes the initial solutions could not deliver all shipments), but was difficult enough that the algorithm could run for many thousand iterations and still obtain better solutions. The problem contained 556 shipments and 15 available vehicles.

3.1 Initial testing and Multi-seed computation

We first ran the algorithm on HPC using 6 random seeds separately and calculated an average cost across all 6 seeds. We let the algorithm run for 200 minutes. Then we repeated these calculations using 24 seeds. Results can be found in Table 1. We see from Table 1 that the best solution cost is lower for calculations using 24 seeds, where average time to obtain this cost is comparable with the one obtained from calculations using 6 seeds. Also all other average times shown in Table 1 seem to be either comparable between calculations done with different numbers of seeds or they follow no rule. These variations in average times show that not all random seeds are good, but choosing multiple of them will increase the chances for one of them to be good for a given problem. We can also see that not all seeds were successful enough to get a solution within 1% or 5% of the best solution, which also shows that some seeds were not suitable for solving the problem. On the other hand, best times are all significantly lower for calculations using a higher number of seeds. This shows that calculations run with a higher number of seeds can obtain better solutions significantly faster, but it is crucial to try out multiple different seeds.

Table 1: Results of the multi-seed computation.

Nr of seeds	***Average best solution cost***	***Best solution cost***	***Average time needed for best solution [s]***	***Best time to break cost of 70 000 [s]***	***Average time to break cost of 70000 [s]***	***Best time to get within 5% of best solution ever [s]***	***Average time to get within 5% of best solution ever [s]***	***Nr of seeds that got a solution within 5% of best ever***
6	66947	66073	5631	190	524.0	284	1268	6
24	67009	65790	5628	116	1018	208	2002	22

To check that claim more thoroughly we also ran calculations using 1, 3 and 12 seeds and plotted the best solution cost progression through time for each of these calculations (including the ones run with 6 and 24 seeds). Results are shown in Figure 1. We can see from Figure 1 that calculations run with a higher number of seeds overall converged to solutions with lower costs than calculations that were run with lower number of seeds. Where, again, a choice of random seeds seems to affect the calculation process, since the solution cost for 12 seeds is lower than the one for 24 seeds.

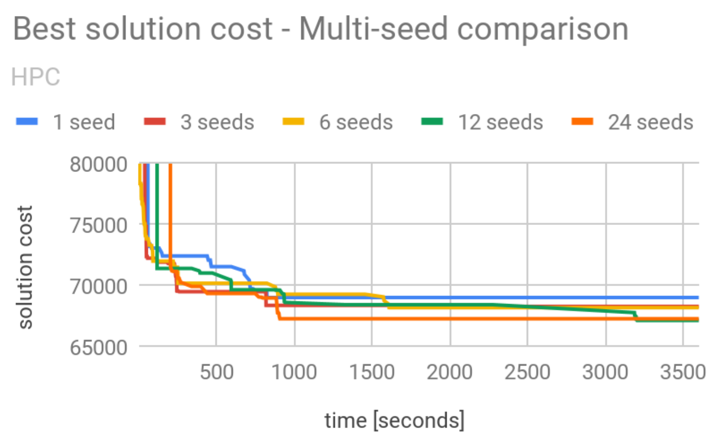

Figure 1: Best solution cost progressions for different numbers of seeds.

3.2 Step method

For the step method, we needed to set the number of iterations within each step and the number of steps. We tried calculations on HPC, where we set the total number of iterations to 1000 and each step to 100 iterations (10 steps). We ran the tests on HPC with 6 and 24 different seeds. Using 24 seeds we also tried a faster calculation, where we set the total number of iterations to 1000 and each step to 10 iterations (100 steps) and a slower one where we set the total number of iterations to 10 000 and each step to 1000 iterations (10 steps). Results and comparisons can be found in Figure 2 and in Table 2.

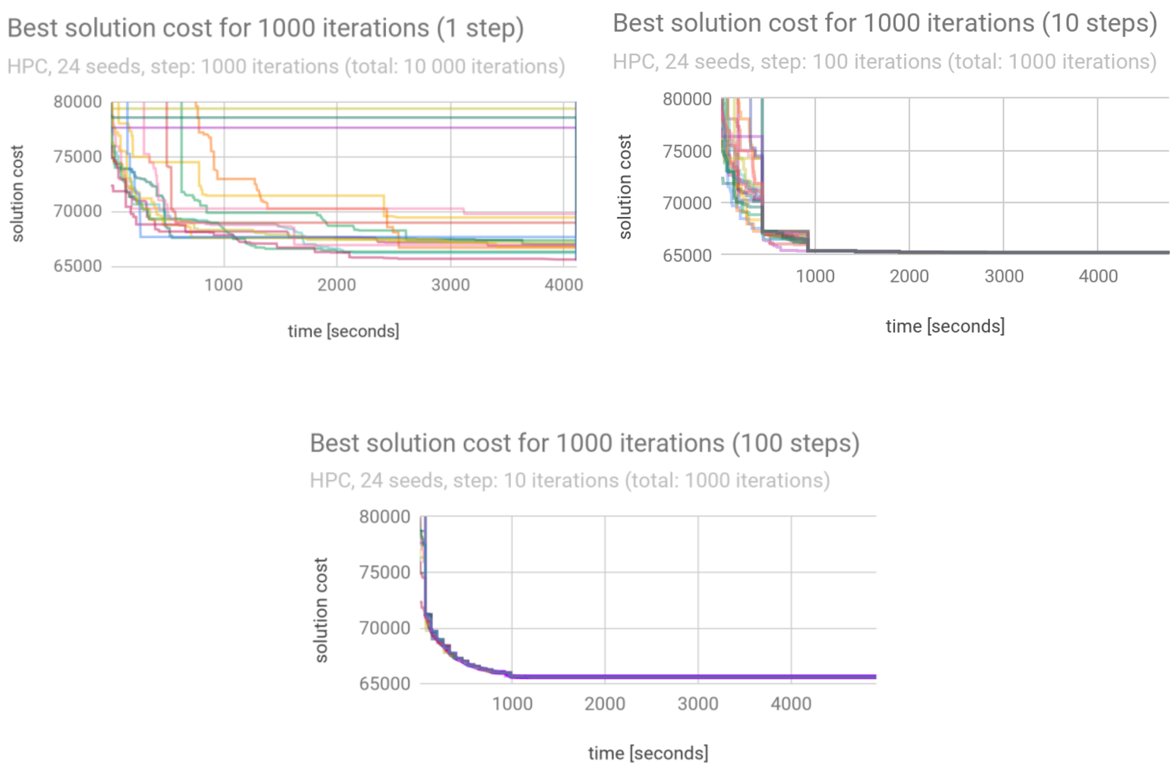

Figure 2: Best solution cost progressions for 1000 iterations where one step consisted of all 1000 iterations (upper left), 100 iterations (upper right) and 10 iterations (bottom).

Figure 2 shows the best solution cost progression through time, where each of the computations used step sizes of different length. We show only 1000 iterations for each of the computations. Results show that shorter steps significantly increase the convergence speed. The important issue is that we enable different threads to benefit from a better starting point, initial solution. It is clear that it is best to use as many threads and seeds) as possible, but an important open issue is to determine the best size (number of iterations) of the steps.

From Table 2 we can see that shorter steps are very effective in providing good results very fast, while longer steps may eventually bring us closer to the optimal solution. An idea for further work is to start with smaller steps, which are then increased, in order to enable finding better solutions.

5 CONCLUSION

We were interested in obtaining good solutions for VRP as fast as possible. We have tried some approaches, which produced good results.

Multi-seed method: We can conclude that with a bigger number of seeds (and corresponding threads) chances of finding better solutions are higher, since also the probability that one of the seeds will be good for a given problem is greater.

Table 2: Results for step method.

Total nr iterations	***Nr iterations per step***	***Nr seeds***	***Total computation time [s]***	***Best solution cost***	***Computation time for best solution [s]***	***Best solution after 1 min***	***Best solution after 5 mins***	***Best solution after 15 mins***	***Best solution after 30 mins***	***Time to get within 5% of best solution ever [s]***	***Time to get within 1% of best solution ever***
1000	100	6	3712	65401	2563	71570	67311	66031	65478	160	953
1000	100	24	4756	65220	4273	71844	67674	65379	65270	208	565
1000	10	24	4915	65630	1362	71285	67784	66027	65630	222	923
10 000	1000	24	41767	65268	20718	71844	67674	67600	66592	266	2108

Step method: We have developed this method to improve the performance, to enable finding good results faster. Each step resets the initial solution to the best solution found so far. The convergence becomes much faster, especially in the beginning.
Future work: We are interested in determining optimal step sizes, perhaps using smaller steps in the beginning and then increasing them. The next idea is to try with several different initial solutions, not just a single one, at each step. And the hardest problem, if solvable at all, would be to determine suitable seeds for specific problems.

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Special Session 3:

Data Science – Methodologies and Case Studies

OPEN GOVERNMENT DATA IMPACT AREAS IDENTIFICATION WITH DATA MINING TECHNIQUES

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Abstract: The availability of open government data (OGD) has increased in past years, so did various initiatives and research on OGD. Nevertheless, there is still very few research made on the impact of OGD and measuring the impact of OGD. We recognized an opportunity to identify impact areas of OGD with the help of individual open data use cases by employing text-mining techniques and then compare them with the ones from OECD surveys. Results indicate that the most prosperous technique used, beside keyword extraction and term frequency-inverse document frequency, was article classification based on creation of our own dictionaries. Further research will be focused on the field of upgrading newly defined dictionaries for impact areas classification.

Keywords: open data**,** public sector, impact of OGD, impact factors, data mining.

1 INTRODUCTION

Open Government Data (OGD) or Public Sector Information (PSI) is a government data, that is available to all with an idea to promote transparency, accountability and value creation along with the intention for the public to better understand government work and how well it performs [14, 21]. In the past couple of years, attention in OGD research has grown [1, 5, 24] and so is the availability of open data [11, 12]. While there are many benefits of OGD in various fields, such as political, social, economic, operational and technical [12], there is very few systematic and structured studies that have been conducted on the actual impact of OGD [18, 19, 24]. And since there is a research gap, measuring or identifying the impact of OGD can be quite challenging as benefits are often indirect [10]. Although the analysis of the economic benefits of open data is one way to describe the effect of government openness, the impact of open data is not connected to economic field only [13]. Since economic benefits may be easier to obtain, most research and assessment of the impact of OGD is based on surveys [4, 15]. Survey can and are providing important feedback, yet governments face constraints on staffing and funding of open data related activities as they meet other priorities in their work [24]. Nevertheless, there might be an opportunity in collecting valuable information from case studies of individual OGD initiatives, which already turned out to be helpful when it comes to understanding the impact of open data [22].

Since interest in OGD research has increased in the last few years, several indexes for evaluating open data impacts have emerged. Starting with Open Data Barometer (ODB), which was produced by the World Wide Web Foundation, it aims to detect prevalence and impact of open data initiatives by analysing global trends based on three kinds of data: A peer-reviewed expert survey, a government self-assessment simplified survey and secondary data selected to complement expert survey data [17]. Next, the Global Open Data Index (GODI), run by the Open Knowledge Network aims to show how to make data more useable, yet it does not focus on other common aspects of open data such as context, use or impact [7]. Finally, the report of OURdata (Open, Useful, Reusable Government Data) Index, introduced by the Organization for Economic Co-operation and Development (OECD) states, that it seems as if OECD countries are in a stage, where measuring the results of open data initiatives (previous and current) is needed to ensure continuity and long-term sustainability [16]. The report also states that the research on the social and economic benefits of open government data is still relatively limited, but a progress is being made in terms of the development of more advanced open data portals which are displaying more open data re-use examples to the public in a graphically friendly way [16].

As stated before, we recognized an opportunity to identify impact areas of OGD with the help of individual open data use cases [6]. By doing so and in an automated manner, we would shorten the time of data pre-processing phase and reduce the possibility of human error in business understanding phase of CRISP-DM methodology when developing a model to determine an objective assessment of OGD impact by automatic extraction of semantic structure and when validating impact areas defined by OECD. Motivation, mentioned in previous paragraph is a part of future research objectives and automatized recognition of impact areas is the main focus of this research paper. The main outcome of this research is an IT artefact, situated in a real-world scenario, which fits under the Design Science Research (DSR). The design cycle of the DSR followed the CRISP-DM methodology, which is commonly used in ML models building. Further we focused more on modelling and evaluation phase of CRISP-DM where we presented the results of this research and our findings.

2 METHODOLOGY

As already mentioned, methodological approach for this research is rooted in DSR, where the main objective is to create an IT artefact that is driven by business needs with a real-world problem [9]. As a part of DSR, which is the main methodology for automated recognition of impact areas, we also used CRISP-DM methodology, the purpose of which is to make data mining projects reliable, faster and cost efficient by following six phases: Business Understanding, Data Understanding, Data Preparation, Modelling, Evaluation and Deployment. By using CRISP-DM along with DSR, we addressed the objective of our research in an organized and documented way [2].

Following CRISP-DM, we first started to analyse OGD impact ecosystem, evaluation surveys and use cases from the European Data portal. We manually analysed first 50 use cases from the corpus (alphabetically ordered) in details and subjectively identified their impact areas, which served us as a validation group for our extraction algorithms. Once we have understood the data, we started pre-processing it. Since our group of 50 use cases did not exceed 1022 characters, we stored each use case as a list element in Python. Also using Python, we tried three different techniques for impact areas extraction, starting with keyword extraction, Term frequency–inverse document frequency (TF-IDF) and finally, using dictionaries. As the last step before deployment, we evaluated the results, which are presented in the next chapter.

3 RESULTS

Results of this research are further grouped in three areas, based on the data mining technique that was used.

3.1 Keyword extraction (Yake!)

First approach that we used was keyword extraction, since keyword extraction algorithms became the key components in many computer science applications. We used YAKE!

algorithm, which has five main steps: text pre-processing and candidate term identification, feature extraction, computing term score, n-gram generation and computing candidate keyword score and finally, data deduplication and ranking [3]. Further, we extracted top 5 keywords based on their weights (significance), which is the frequency of word occurrence in an article. We extracted relevant keywords for bigram, 3-gram and 4-gram. Comparison of the results is presented in Table 1, where metadata for the selected use case is first presented along with manually identified impact factors. Next, keywords for each n-gram are presented below for easier visual distinguishment.

Table 1: Selected use case meta data and manually identified impact factors along with keywords, extracted with all three n-grams.

Project name: 360waste		
Sector: Transportation	**Service type:** Mobile application	**Type of data:** Transport data
Impact area 1 (Manually identified)	more efficient waste collection	
Impact area 2 (Manually identified)	reducing logistics costs	
Impact area 3 (Manually identified)	improving route planning	
Impact area 4 (Manually identified)	decreasing pollution	
Yake! (bigram) keywords	volumetric, logistics, operating, decreases, collects	
Yake! (3-gram) keywords	collects, reduces, containers, efficient, waste	
Yake! (4-gram) keywords	Efficient, volumetric information, collection, costs, logistics costs	

As presented in Table 1, keywords that were extracted with Yake! algorithm were relatively close to manual extraction of impact factors but not enough for this method to be used for the entire corpus. Another issue with this method was, that there was a great variance between different articles, meaning that for some articles keyword extraction performed well, but for others not at all.

Since keyword extraction with Yake! was not successful, we continued with TF-IDF.

3.2 Term frequency-inverse document frequency (TF-IDF)

Term frequency-inverse document frequency is a numerical statistic method that shows, how important a word is to a document in a corpus and is often used as a weighting factor in information retrieval and text mining [20]. Before we processed our corpus with TF-IDF we loaded the necessary libraries for text pre-processing in Python. We used Natural Language Toolkit (NLTK) library for tokenization and lemmatization and Scikit-learn for TF-IDF vectorization.

Then we extracted five keywords with the highest TF-IDF score which are presented in Table 2, again along with metadata for the selected use case and it's manually identified impact factors.

Table 2: Selected use case meta data and manually identified impact factors along with keywords, extracted with TF-IDF.

Project name: 360waste		
Sector: Transportation	**Service type:** Mobile application	**Type of data:** Transport data
Impact area 1 (Manually identified)	more efficient waste collection	
Impact area 2 (Manually identified)	reducing logistics costs	
Impact area 3 (Manually identified)	improving route planning	
Impact area 4 (Manually identified)	decreasing pollution	
TF-IDF keywords and their score	Container (0.48), 360waste (0.24), which (0.22), contract (0.22), efficient (0.22)	

As displayed in Table 2, results of TF-IDF are even less informative as the ones from keyword extraction with Yake! and again, there was a great variance of keywords performance between different use cases. Finally, we tried the simplest approach which is building our own dictionaries.

3.3 Creating our own dictionaries for classification of documents

Finally, we tried with creating our own dictionaries that are, when they are perfected over time, achieving high performance [8]. We set out to create four different dictionaries that are representing impact factors that were identified by OECD: Political, social, environmental and economic impact. Dictionaries were created by combining related words for each impact factor from Thesaurus.com along with cross-validating them with keywords that were manually identified on 50 examined use cases. Dictionaries and their content are presented in Table 3.

Table 3: Manually created dictionaries with their values.

Political impact
'political impact', 'administrative', 'bureaucratic', 'legal', 'legislative', 'regulatory', 'supervisory', 'official', 'authority', 'law', 'ministry', 'politics', 'regime', 'state', 'regulation', 'civic', 'constitutional'
Social impact
'social impact', 'civil', 'community', 'societal', 'social', 'collective', 'inhabitant', 'inhabitants', 'resident', 'citizen', 'citizens', 'taxpayer', 'taxpayers', 'user', 'end user', 'history', 'historical', 'historic', 'education', 'educational', 'traffic', 'transport', 'parking'
Environmental impact
'environmental impact', 'natural', 'climate', 'habitat', 'surroundings', 'agriculture', 'environment', 'environmental', 'horticulture', 'agronomy', 'rural', 'landscape', 'countryside', 'forest', 'air quality', 'water quality', 'ecological', 'garbage', 'waste', 'farms', 'farmers'
Economic impact
'economic impact', 'economic', 'budgetary', 'fiscal', 'monetary', 'profitable', 'business', 'businesses', 'finance', 'employment', 'employments', 'career', 'costs', 'job', 'jobs'

Next, we compared every use case in the corpus with our dictionaries and we classified documents based on their belonging to each impact factor group.

Results of this classification were better in comparison with the before used methods but much more effort and research should be performed when creating dictionaries to offer more efficient classification and with less possible bias. Results of the classification for the first 10 use cases are presented in Table 4 along with the source article and its original classification.

Table 4: Results of the classification in comparison with the source article and its original classification.

Use case name	Sector (predefined)	Our classification (impact areas)
48er	Environment	Social, Environmental
360waste	Transportation	Environmental, Economic
1848	Government & Public sector	Political, Social
9292	Transportation	Social
AccessEd	Population & Society	Social
Adzuna	Population & Society	Economic
AflaMD	Education, Culture & Sport	Political, Social
Ager Technology	Agriculture, Fisheries, Forestry & Foods	Environmental
AgriOpenData	Agriculture, Fisheries, Forestry & Foods	Social, Environmental
Agroknow	Agriculture, Fisheries, Forestry & Foods	Social, Environmental

3 CONCLUSIONS

The purpose of this paper was to automatically identify impact areas of Open government data use cases. By doing so we would be able to compare and validate them with existing impact areas from the literature and OECD. Three different techniques were used: keyword extraction, term frequency-inverse document frequency and document classification with manually defined dictionaries. None of the above-mentioned techniques provided us with expected results, while document classification turned out to be the most prosperous with the presumption of building better and more extensive dictionaries. Since we used TF-IDF as one of the methods, Latent semantic indexing (LSI) could also be tested as proposed in the literature [23].

Since automatic extraction of impact areas didn’t show promising results, further research should focus on manual identification of impact areas and data mining should be used for automatic extraction of semantic structure instead, once the impact areas are defined and validated. Nevertheless, this research faced a limitation of relatively small corpus of use cases, which was 50, and has to be considered.

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SMEs READINESS IN UTILIZING DIGITAL TECHNOLOGIES AND DATA IN DIGITAL TRANSFORMATION

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Abstract: The rapid development of digital technologies allows enterprises to connect easier, collaborate and create new (digital) products and services. This has also increased the potential of data. In practice, however, value creation from data use is still low. We address digital maturity in the context of digital technologies and data utilization of micro, small and medium-sized enterprises (SMEs) in Slovenia. The results of a nationwide digital maturity assessment of 613 SMEs show that the majority of Slovenian SMEs lag in digital maturity or are at an early stage, while data usage is still very sparse.

Keywords: digital transformation, survey, analysis, digital technology, data

1 INTRODUCTION

Technological developments in recent decade (e.g. blockchain, Internet of Things, artificial intelligence, digital twins) have enabled enterprises to improve their business processes [4], supply chain management, better engage with customers [20], develop new products [3] and innovate their business models [5]. These changes are called digital transformation (DT) and refer to the changes in the way enterprises do business and how individuals and societies live their lives [10,13]. One of the barriers to successful DT is also the immaturity of data [15], which are key to successfully transform to a data-driven enterprise (data-driven DT) [17]. Despite the availability of data, data utilization is still very poor [12]. Sometimes enterprises do not even know what data they generate, collect and where the data is stored (i.e. dark data) [6]. This is particularly evident in the micro, small and medium enterprise (SME) sector, which struggle to keep up with the larger, usually more digitally mature enterprises [9]. Therefore, it is necessary for enterprises to understand the data they collect and analyze using digital technologies and tools. SMEs in Slovenia represent 99% of all enterprises [16], with a very dispersed structure. In 2019, there were a total of 204 771 (99.9%) registered SMEs, of which 194 425 (94.8%) were micro enterprises, 8 126 (4.0%) were small enterprises and 2 220 (1.1%) were medium-sized enterprises [19]. Most SMEs were engaged in other service activities (54.7%), followed by trade (17.5%), civil engineering (13.2%) and industry (14.6%). In the context of digital transformation driven by data (data-driven DT), previous literature has focused on the perspective of business model innovation and data analytics [11,14], how to become a data-driven organization [1], and various data maturity models [7,18,21]. Since none of the works provide a comprehensive overview of digital technologies and data usage, this paper addresses this issue, by providing a digital maturity assessment results of 613 Slovenian SMEs, with the aim to identify the current state of digital technologies and data utilization. We aim to answer the following research questions:

- RQ1: "What is the current state of digital technologies and data utilization in SMEs?"
- RQ2: "What are the main differences between the sizes of SMEs in digital technologies and data utilization?"

2 METHODOLOGY

The general approach in this study is design science research (DSR) (Figure 1), the strategy in which an IT artefact is developed to solve a real-world problem based on the existing body of knowledge [8]. To assess the SMEs digital maturity level, we developed a multiple-criteria decision model using the DEX method [2], which is described in detail in [10]. Each SME would have its digital maturity level assessed against 34 basic and 17 aggregate criteria. The detailed analysis of SMEs' digital maturity level served as feedback information for the SMEs and digital voucher award criteria in collaboration with Digital Innovation Hub Slovenia (DIHS). To collect the data from the SMEs, the assessment model was linked to an online questionnaire, which consisted of 34 questions corresponding to the 34 basic criteria of the model. The questions were measured on discrete descriptive scales, mapped to the model. An example of question and scale is shown in Table 1. SMEs applying for digitisation voucher funding were required to complete the assessment, which was made available from December 2020. A total of 613 SMEs completed the assessment until April 2021.

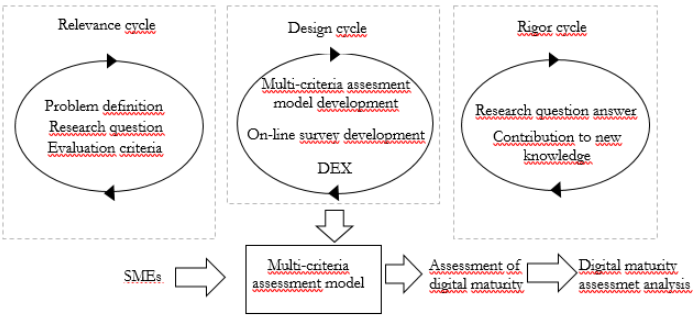

Figure 1: Research methodology

Table 1: Scales for the attribute "Data strategy"

Scale	***Question - Which of the statements best describes your data management strategy?***	
No.	***Value***	***Description***
1	Data not organized	Our data is not organized and is stored in various systems.
2	Support for daily operations	Our data is managed in a way to carry out companies' daily activities.
3	Integrated data management	We collect, store and manage our data for decision support purposes.
4	Data as strategic resource	Data is our strategic resource for increasing added value.

3 RESULTS

We present the results of the digital maturity level assessment of 613 SMEs, of which there were 253 micro, 274 small and 86 medium-sized enterprises. Figure 2 shows the final assessment of digital maturity measured on a four-point descriptive scale (lagging behind, initial stage of digitalization, advanced stage of digitalization, digital winner). The X-axis shows the digital maturity level broken down by enterprise size (Y-axis), expressed as a percentage (black coloured bar – micro; grey – small, dashed - medium-sized enterprises). The results show that most enterprises are digitally lagging behind; micro (68.8%), small (65.3%) and medium-sized (50%), but indicates differences in digital maturity level by the enterprise size (Figure 2). None of the enterprises achieved the "advanced level of digitalization". Three SMEs were assessed as "digital winners" (two micro and one small enterprise), all are active in other administrative and support services, one is from the East and the other two from the West region. To explore differences in digital maturity level by enterprise size, we performed Kruskal-Wallis test (using SPSS). There are significant differences in digital maturity level between the micro and medium-sized enterprise ($H(2) = 9.592$; $p = .002$) and the small and medium-sized enterprise ($H(2) = 9.592$; $p = .011$), but no differences in digital maturity level between the micro and small enterprises ($p = .433$).

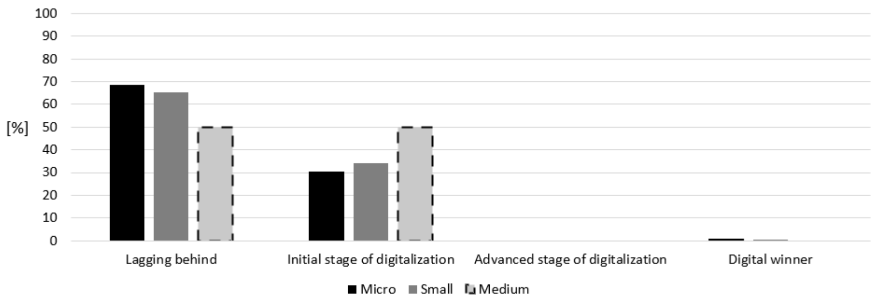

Figure 2: Digital maturity level assessment

3.1 Digital technologies utilization

Next, we analysed the elements related to digital technologies and data utilization. Digital technologies are divided to ***'Basic Business Technologies'*** (measured by "Business Support Solutions" and “Digital Workplace”), ***'SMACIT'*** (measured by “Social Media”, “Mobile” and “Cloud”) and ***'Advanced Technologies'*** (measured by “Blockchain”, “Industry 4.0” and “Data Analytics”). Figure 3 shows that SMEs use basic business technologies the most (micro (43.9%), small (48.5%), medium-sized (72.1%)), and advanced technologies the least (59.8% of SMEs are "low users", 37.2% are "medium users", 3.2% of SMEs were assessed as "high users" of advanced technologies). Among these, "Blockchain" is the least used (Figure 4). Only 2 micro enterprises use Blockchain and none of the small and medium-sized enterprises. The low usage is observed for "Industry 4.0" technologies (on average, only 4.9% of SMEs use Industry 4.0 technologies) and "Data Analytics". Most SMEs use partial data analytics solutions (micro (63.6%), small (71.2%), medium-sized (72.1%)). About 30% have not implemented any data analytics (28.5% of micro, 22.3% of small, 16.3% of medium-sized). A small proportion (micro (6.7%), small (6.2%) and medium-sized (11.6%)) use advanced data analytics systems in their business, while the use of artificial intelligence was reported by only three micro and one small enterprise. Of these, one micro enterprise works in the information and communication sector (West region), one in the professional scientific and technical activities sector (West region), and one in the finance and insurance sector (East region). The small enterprise operates in other administrative and support service activities sector (East region). All three micro-enterprises achieved the digital maturity rating "initial stage of digitalization", while the small enterprise achieved the rating "digital winner".

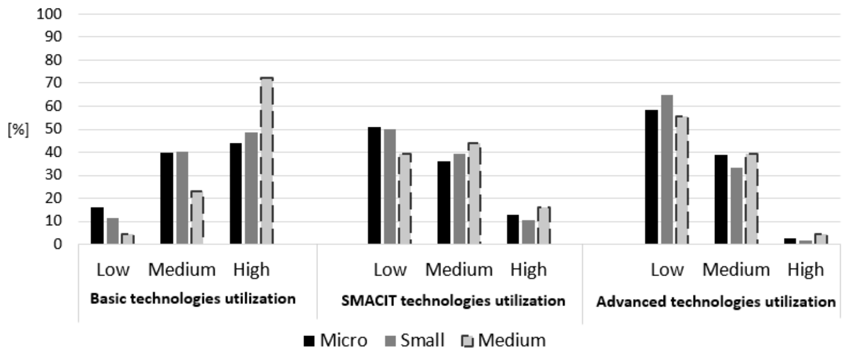

Figure 3: Digital technologies utilization by enterprise size

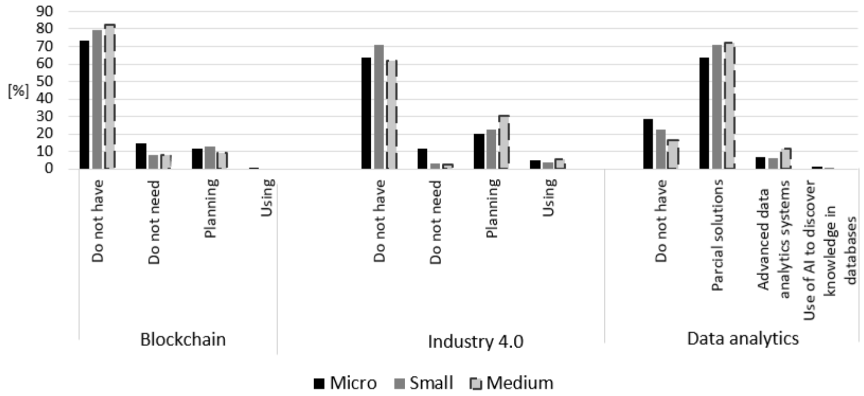

Figure 4: Advanced technology utilization by the enterprise size

3.2 Data utilization

Last, we present the purposes for which SMEs use data and how data-ready they are. Figure 5 shows the level of implemented data management by SME size, expressed as a percentage. Up to 31% of all sampled SMEs have no data organized (micro (31.6%), small (27.3%), medium (12.8%)). Most SMEs use data for day-to-day business operations (58.5% micro, 60.5% small, 68.6% medium-sized). Only 16% or less have integrated data management and only 5.4% (2% of micro, 1.1% of small and 2.3% of medium-sized) see data as the most important strategic source for adding value to products and services.

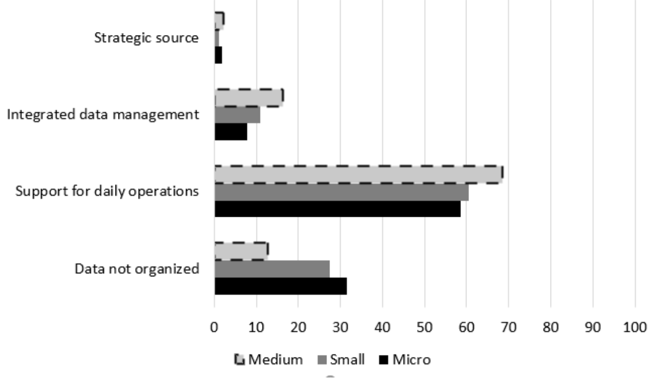

Figure 5: Data management strategy

In Table 2, we present the results of Kruskal-Wallis test for the variables “Blockchain”, “Industry 4.0”, “Data analytics” and “Data strategy”.

Table 2: Results of Kruskal-Wallis test

Variable(s)	***Kruskal-Wallis H***	***Differences between groups (size of enterprise)***	***df***	***Sig***
"Blockchain"	H(2) = 3.703	no statistically significant differences	2	.157
"Industry 4.0"	H(2) = 3.729	no statistically significant differences	2	.155
"Data analytics"	H(2) = 5.667	no statistically significant differences	2	.059
"Data strategy"	H(2) = 13.302	micro – medium * small - medium*	2	.000* .013*

*Statistically significant differences

There were no significant differences in using Blockhain, Industry 4.0 and Data analytics technologies by enterprise size. However, significant differences in data strategy are between the micro and medium-sized enterprise and small and medium-sized enterprise.

4 CONCLUSION

The analysis of 613 SMEs that had their digital maturity level assessed within the digital voucher program showed that most SMEs are lagging behind or are in the early stages of digital maturity. While they use basic technologies broadly, their use of SMACIT technologies is assessed at low to medium level and the advanced technologies to a low level. Furthermore, data-related criteria showed that SMEs are not ready to fully exploit the power of data. The assessed SMEs are those who had applied for a digitalization voucher and thus are already aware of the digital transformation and as such do not represent the general SMEs population. Further research will explore two directions. First, we need to address the general SMEs population, and second, investigate the results of the digital voucher program. This will help in better understanding the state of digitalization in SMEs and provide important insights for policy makers to implement proper measures for faster digital transformation.

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DESIGN OF A MODEL FOR IMPLEMENTATION OF BUSINESS INTELLIGENCE METHODS IN DECISION-MAKING PROCESSES

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Abstract: This paper aims to introduce a model composed of critical factors influencing the application of business intelligence (BI) in decision-making. The proposed model is based on the unified theory of acceptance and use of technology (UTAUT), specifically its second version, and specifics of BI projects obtained from the pilot research and literature review. The paper newly presents an adjusted structure of factors that influence the implementation of BI in decision making. Already defined moderate variables are supplemented by new factors: the business field, size of company and job level to find possible differences within types of companies, and determinants of price value and hedonic motivation were excluded.

Keywords: business intelligence, technologic innovation, UTAUT (2), decision-making.

1 INTROCUTION

Companies face technological innovations and quick development times, and management has to promptly react to this changing environment. Working well with information represents one of the most important competitive advantages on the market [1]. At the organisational level, there is often a gap between the successful implementation of a project and the positive acceptance of the technology itself. This difference occurs for two reasons. The first is the lack of experience of individuals with innovative technologies and their implementation, while the second is the lack of communication between users of technology, technology owners, developers and suppliers of new solutions [2]. Researches have also revealed what factors are essential for the proper use of the BI system: management support, training, organisational culture, well-defined vision and goals, alignment of BI strategies with business strategy, quality of data and systems and IT infrastructure [3], [4]. However, despite growing investment in BI systems, many organisations are still unable to achieve the required benefits from these systems due to insufficient and inefficient use [5].

For the research, the UTAUT 2 theory was chosen from the most frequently used models of the technology acceptance. The involvement of the model in its original version with the business intelligence implementation project has only been recorded in three studies [6]–[8] in the last 20 years [3]. There is therefore scope for verification of this model to the needs of the introduction of BI into business processes with a view to facilitating the decision-making process. The last nine turbulent years from the last UTAUT 2 update, ending with an unprecedented situation caused by covid-19, could change the defined links and add or remove some critical factors.

The aim of the research is to introduce an adjusted model of implementing business intelligence methods into decision-making processes within the corporate environment. The proposed scheme is based on the basic characteristics of the UTAUT 2 model and will be complemented by lessons learned from the pilot research conducted in February 2020.

Most models dealing with the implementation of business intelligence only define the factors influencing user behaviour [9], [10]. The proposed scheme in this paper is extended by the active use of BI in decision-making processes. The inclusion of all factors is briefly justified and other moderating variables are already added to the model, which have already been determined in the pilot research, or their determined degree of influence is one of the partial goals of long-term research.

In order to fulfil the objectives of this paper, its structure is as follows. After the short introduction, within a methodology a brief literature review concentrating on the introduction of the term business intelligence, the most used models of acceptation technological innovation with the emphasis on BI tools, and basic characteristics of the pilot research are presented, third section presents the results of the data analysis. A short conclusion with limitations and plans for future research is given at the end.

2 METHODOLOGY

Literary research focuses briefly on explaining the basic specifics of business intelligence and UTAUT 2 theory. Subsequently, characteristics of the conducted pilot research are presented.

2.1 LITERATURE REVIEW

Business intelligence represents a complete and effective approach to working with data and information in the business environment. Outputs influence strategic decision processes. The basis of BI is to transform source data into knowledge, with which the right decisions are made. It can therefore be included among technological innovations, which are defined as a process in which technology (change, improvement) has been identified as a critical success factor for increasing market competitiveness [11].

Regarding the connection of already generally valid models with the principles of business intelligence, authors most often rely on the DeLone and McLean Information Systems (IS) Success Model and Davis's technology acceptance model. The data is based on a systematic examination of the literature dealing with the adoption, utilisation and success of the business intelligence system. These theories listed in Table 1, which summarises the five most commonly used models, were predominant [3].

Table 1: The most frequently used models in BI research. Source: own processing according to [3]

Theoretical framework	Frequency
DeLone and McLean Information Systems (IS) Success Model	16
Technology acceptance model (TAM)	15
Diffusion of innovation	10
Resource-based view (RBV)	4
The unified theory of acceptance and use of technology (UTAUT)	3

The Unified Theory of Acceptance and Use of Technology (UTAUT) was designed as a combination of the previous eight theories dealing with acceptance and motivation to apply technology in order to create a unified theory [12]. Like the above-mentioned models, this theory has been commented on, refined and modified over time. The last major update was published in 2012 and design scheme is shown in Figure 1 [13].

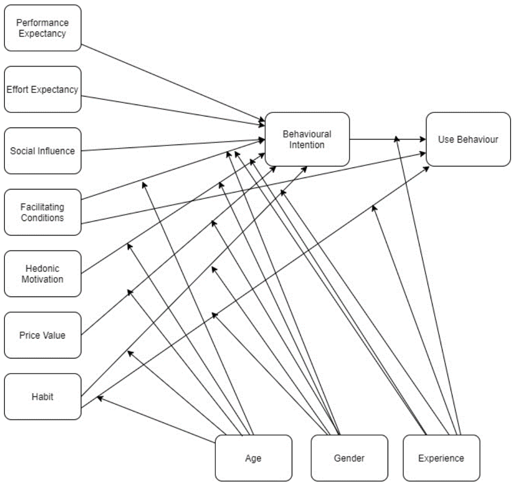

Figure 1: UTAUT 2. Source: Own processing according to [13]

2.2 PILOT RESEARCH

The pilot research was conducted in several phases. Obtained data from the questionnaires were further processed using mainly descriptive statistical methods, and the results are presented in section 3. The selection was made on a voluntary basis. This method is one of the least invasive techniques used when a relatively small sample is needed. The sample corresponds to the interest of the respondents. The risk is low representativeness and also the fact that similar personalities can report (Reichel, 2009). However, companies do not want to provide this type of data. Accordingly, for the presented research, this sample was found to be sufficient and the results serve for the first idea of the researched topic within the long-term research.

From a total amount of 90 distributed questionnaire, 75 filled forms could be included to be analysed. Based on the initial set of questions, the respondents were divided into groups according to the size of the organization and the level of their job position. Most respondents, a total of 53, performed their work in large companies (more than 250 employees), 15 of them worked in a medium-sized enterprise (50-249 employees) and finally 7 were part of micro and small companies (0-49 employees). Regarding the breakdown by job level, 40 respondents were specialists without direct subordinates, and 35 were members of management. Specifically, 8 managers were part of the company's top management, 21 worked in the middle management, and 6 belonged to the line management.

3 RESULTS

One of the sets of questions from the questionnaire survey was devoted to the use of selected decision-making methods in practice. Respondents could choose any number of tools between 5 different groups and it was also possible to add to the "other" free text. The list of submitted instruments with registered frequencies is shown in Table 2.

Table 2: Overview of exploited decision-making methods. Source: Own

Decision-making tools	Frequency (max 75)
Intuition and experience	61
Consultation with colleagues	50
Data analysis	47
Multicriteria decision-making methods (MCDM)	19
Consultations with experts outside the company	14
Other	2

Although the questions were aimed at the decision-making process and the methods used, the results still indicate the importance of the factors of experience and social influence not only in the UTAUT 2 model, but also in general. Intuition and **experience** were even the most frequently mentioned decision-making methods. This option has been selected by almost 80% of respondents (61 out of 75). Opinions attained through previous experience subsequently influence namely the gaining of confidence in the given technology and, at the same time, future behaviour. The feedback gained as a result of prior experience is reflected within the determinant of habit as well [14]. On the other hand, lack of experience is then a frequent factor in the failure to implement similar projects [2].

Many studies have also shown the importance of **social influence** in the adoption and implementation of a new technology [15]–[17]. Consultation with colleagues was chosen as the second most common support for the decision-making process (50 out of 75). Colleagues, as essential people from the closest working environment, can, according to the research, significantly influence the user behaviour connected with decision-making process.

The results also showed some differences of opinion between different groups of employees divided by job position. Therefore, the level of the **job position** within the organisational structure will also be included among the moderating variables [18].

The next part of the questionnaire tried to reveal the obstacles that employees have to face when introducing new tools into company processes. The histogram in Figure 2 shows the most commonly reported barriers. Respondents could mark any number of obstacles. On average, they chose 2 of them.

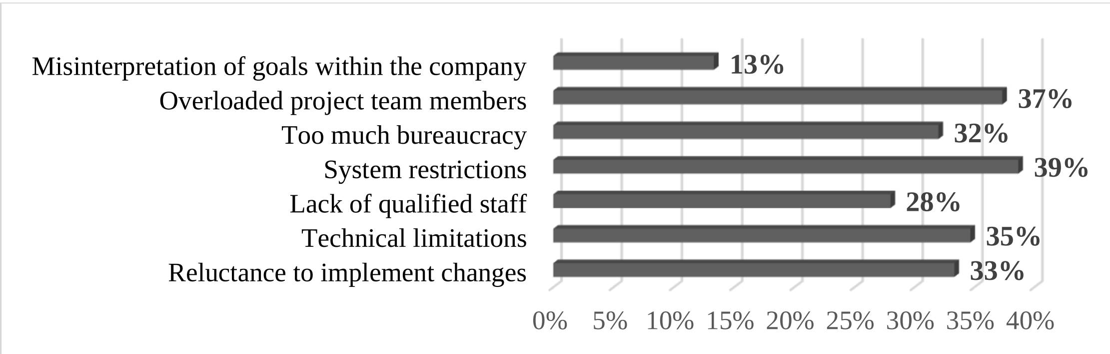

Figure 2: Most frequently indicated obstacles (relative frequency). Source: Own

System restrictions and overloading of the project team are seen by the majority of respondents as the main barriers to the success of the implementation of technological innovations. Indications of system constraints as the most common obstacles and technical constraints as the third in order can be included in the wording under the determinant of **facilitating conditions**.

The factors price value and hedonic motivation introduced for the possibility of using UTAUT 2 in the consumer context will not be used for further research.

Initial independent variables of **performance expectations**, indicating the degree to which individuals believe that technology will help them perform their tasks, and the **expected effort** associated with difficulties in using the system, are fundamental factors influencing the intention to leverage technological innovation [12], [19], [20].

Long-term research is devoted to the integration of business intelligence methods into decision-making processes. For this reason, the design of the model has been extended by one level, which will directly include **the use of BI in decision-making** in relation to behavioural intention and user behaviour. The original UTAUT 2 model already predicts the direct influence of facilitating conditions and habit on user behaviour in general [13]. And since the pilot research has also revealed a key element for gaining a **habit** - experience as the most commonly used decision-making method and as the most frequently mentioned barriers to the implementation of these projects were linked to (non) providing **facilitating conditions**, their crucial impact on the use of business intelligence in the decision-making process is likewise assumed.

For further research and possible use of the model across sectors and companies of different sizes, the moderating variables age, gender, experience will be supplemented by the **field of business and size of company** factors as well. The combination of the above literature search with a focus on the UTAUT 2 model and the conducted pilot research is represented by the own design of the model of introducing business intelligence into business processes presented in Figure 3.

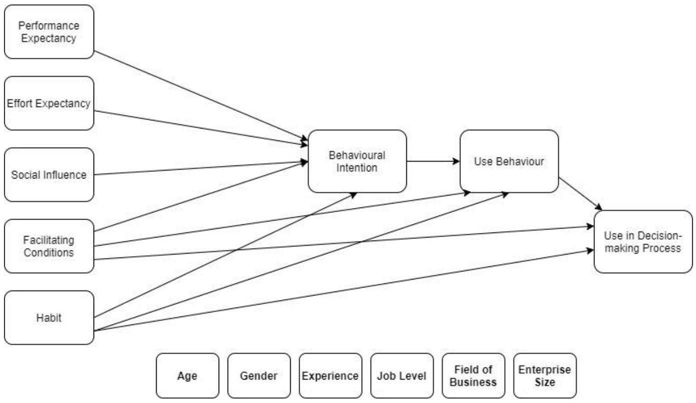

Figure 3: Design of a business intelligence integration model. Source: Own.

4 CONCLUSIONS

In these times affected by the consequences of the global covid-19 pandemic, the importance of correct data interpretation and their conversion into relevant information has increased. It is not only the social level, but also companies are being pushed into digitisation and optimisation of business processes, which is closely related to the subsequent use of obtained data. The UTAUT 2 scheme was most recently updated within the most used models defining the factors of successful implementation of technological innovations, and was therefore selected as a suitable basis for the presented research. The update of the UTAUT 2 model used for the purposes of this research was introduced in 2012. Presented theories are updated about once every ten years and after almost ten years there is an opportunity to check defined linkages and outputs.

Pressure on the speed of information processing thus ranks the principles of business intelligence among the fastest developing tools for decision support. For this reason, the presented model was extended by the active use of these tools in the decision-making process. The pilot research was conducted just before the outbreak of the pandemic (February 2020). This fact can represent one of the limits of the research. On the other hand, results can serve as an important comparison with the planned follow-up investigation.

The aim of further research is to confirm or supplement critical factors influencing the application of business intelligence in decision-making within the verification of the presented model. In most companies, these tools are at least partially implemented, but there is a lack of key factor mapping for including the obtained outputs in the decision-making process.

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PERFORMANCE TESTING OF FEATURE SELECTION ALGORITHMS FOR GENERALIZED ADDITIVE MODELS

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Abstract: In this paper, the performance of 10 feature selection algorithms for Generalized Additive Models (GAMs) are compared on two real-world datasets. Concept of concurvity is introduced as a redundancy in the initial feature set. Results show that most of the algorithms tend to prefer large models with concurvity. To tackle the concurvity phenomenon, recent algorithms incorporate some extra constraints and tackle concurvity as pairwise relationship between features. Our solution, a Hybrid Genetic - Harmony Search Algorithm (HA) introduces constrains on concurvity more generally. Results show that HA applies a few, not redundant features with predictive performance not significantly decreasing.

Keywords: generalized additive model, feature selection, regularization, boosting, genetic algorithm, harmony search algorithm

1 INTRODCTION

In supervised machine learning our aim is to predict a well-defined target variable as accurately as possible by utilizing the known values of several feature variables. Nowadays many complex algorithms are available to solve this task. On the other hand, more and more authors, like [7], [15] draw attention to the fact that those algorithms that provide the most accurate estimates of the target variable are poor at determining marginal effects of the feature variables to the target. However, in certain practical applications, the most important result of supervised learning is not necessarily the accurate estimation of the target, but the discovery of each feature's marginal effect. For example, a bank has to offer a clear reasoning when declining a credit application.

In our current bid data environment, when the number of possible features is large, determining marginal effects can be challenging even for a linear regression model. One tool that can be utilized to make supervised learning models more interpretable is feature selection as proposed by [9] and [15].

In this study, we examine the performance of several feature selection algorithms that can be utilized in the context of Generalized Additive Models (GAMs). We examine the case of GAMs as according to [9], GAMs represent a balance between model interpretability and prediction accuracy. In the case of GAMs, marginal effect of the features can be determined, and we are not bound by pre-defined linear, logarithmic, or any other closed functional forms when representing the non-linear effect of features. However, the model does assume an additive structure, so we should apply features that are uncorrelated in a non-linear sense.

Several feature selection algorithms can be applied in a GAM framework. These algorithms can be separated to four clusters. One, is the cluster of stepwise methods implemented with the help of [19] when the GAM applies thin plate splines. The second cluster is for regularization methods such as the COSSO [12] and the penalized thin plate splines [13]. The third cluster contains methods that are utilizing popular boosting techniques, like the GAMBoost algorithm [17] or the Modified Backfitting procedure [2]. In the fourth cluster, the algorithms are based on the Hilbert-Schmidt Independence Criterion (HSIC) [18] and aim to avoid selecting redundant features. The best examples are the mRMR [6] and the block HSIC Lasso [5]. However, these algorithms only examine pairwise independence of the features, so they cannot tackle a case where one feature can be accurately estimated by the combination of several other features. In our previous works, we proposed a hybrid genetic-improved harmony search algorithm (Hybrid Algorithm, HA) that applies thin plate splines to produce a best subset feature selector that is capable to find parsimonious models. The performance of this algorithm is also examined.

The performance of the algorithms examined in this study is tested on two real world datasets [20] and [21]. On the larger dataset [21], CART Decision Tree and Recursive Feature Elimination (RFE) combined with a Random Forest learner is also applied as a benchmark algorithm that is not based on GAM learners.

2 FEATURE SELECTION IN GAMS

Let $Y = [y_1, y_2, \dots, y_n]^T \in \mathbb{R}^n$ be a vector of observed values of a random variable with a distribution from the exponential family. In a GAM, the expected value of Y can be estimated by (1) by utilizing the observed values of $X_j = \left[x_{j1}, x_{j2}, \dots, x_{jn}\right]^T$ feature variables [8].

$$h\big(E(Y)\big) = \varepsilon + \sum_{j=1}^{p} f_j\big(X_j\big) \tag{1}$$

Where $h(\cdot)$ is a link function for the distribution of Y and $\varepsilon = [\varepsilon_1, \varepsilon_2, \dots, \varepsilon_n]^T$ is the vector of model errors and $f_j(\cdot)$ is a transformation function for the jth feature. The number of features is p. The most important task to tackle in (1) is the representations of the $f_j(\cdot)$ transformation functions.

In this paper f_js are represented by thin plate splines [19] and their parameters are estimated via penalized iteratively reweighted least squares (P-IRLS) [19]. The advantage of this representations is that it automatically selects the appropriate functional form for each f_j via a penalty on the second derivative of f_js. The only factor that needs to be determined is the maximum number of spline bases to use in each f_j. We denote these values as k_j for the jth feature. The optimal choice for each k_j should be the smallest integer that is large enough so the resulting thin plate spline function f_j can capture most of the variance in X_j. Fortunately, there is a statistical test proposed by [1] that test the null hypothesis that $Var\big(X_j\big)$ is not significantly different from $Var\left(f_j\big(X_j\big)\right)$.

Given a set of m possible features $X = \{X_1, X_2, \dots, X_m\}$, the task is to select a subset of $\tilde{X} = \left\{X_1, X_2, \dots, X_p\right\} \subseteq X$ features, such that the resulting GAM has the best out-of-sample performance. To achieve the best out-of-sample performance, we need to compromise in using in-sample information. If we use too few in-sample information, we will fail to gain a good enough understanding of the relationship between features and the target. However, if we use too much in-sample information, we will overfocus our model and it will have poor out-of-sample performance.

Out-of-sample performance for our model can be achieved in several ways. In our current study, we utilize the adjusted McFadden pseudo R-squared measure, $\bar{R}^2$ [14]. During feature selection, $\tilde{X}$ should be selected such that $\bar{R}^2$ is maximal. On the other hand, evaluating every possible subsets of X is a NP-hard problem [9].

To avoid redundancy of features in the final model, we should apply some extra constraints. So, we must measure the non-linear extension of multicollinearity, called concurvity [19]. [19] proposes an index of concurvity in GAMs that apply thin plate splines as f_j transformation functions. The index is bounded between 0 and 1, with 0 indicating no problem, and 1 indicating total lack of identifiability. The three indices are all based on the idea that a smooth term, f_j, in the model can be decomposed into a part, g_j, that lies entirely in the space of one or more other terms $f_{c \neq j}$ in the model, and a remainder part that is completely within the term's own space. If g_j makes up a large part of f_j then there is a concurvity problem. The index is the square of $\frac{\|g_j\|}{\|f_j\|}$, that is the ratio of the squared Euclidean norms of the vectors of f_j and g_j evaluated at the observed covariate values. In this paper, if the chosen concurvity measure is above 0.5 for a X_j feature, then we consider that feature redundant (has harmful concurvity). This is in line with the recommendations of [19].

Several algorithms are proposed to solve this feature selection problem in GAMs. In this paper, the performance of the algorithms listed in Table 1 are compared. The algorithms were selected based on the number of Google Scholar references for the scientific paper in which they were first published, and the availability of implementations in R or Python packages. Detailed description of each algorithm can be found in the references given in Table 1.

Several have warned that stepwise and regularization methods of feature selection can result in a non-consistent feature selection process if multicollinearity or concurvity is present in the set of possible features: [4], [10], [22].

It is important to note that both the mRMR and HSIC-Lasso algorithms attempt to penalize for concurvity in their aim functions. However, these algorithms can only penalize the relationship of feature pairs. The methods cannot account for concurvity that arises if a feature can be approximated by the non-linear combinations of several other features.

3 HYBRID GENETIC – HARMONY SEARCH ALGORITHM FOR GAMS (HA)

In our previous work [11], we proposed a hybrid genetic-improved harmony search algorithm (Hybrid Algorithm, HA) as a best subset feature selector that is capable to find multicollinearity-free models. In this paper, our HA solution is extended to address the multivariate case of concurvity which is not accounted for by the mRMR and HSIC-Lasso algorithms. The flow chart of the algorithm is given in Figure 1. The aim function in our current paper is the $\bar{R}^2$.

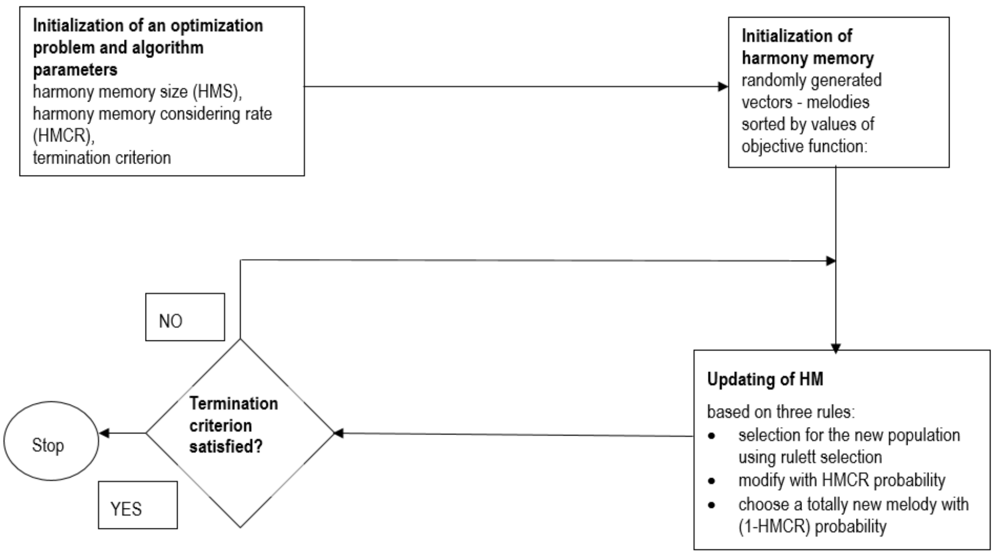

Figure 1: Flow chart for the Hybrid Genetical – Harmony Search Algorithm

The HA represents the possible solutions for $\tilde{X}$ as a binary vector of length m. The HA is only applicable in a GAM framework if this does not change. If we apply thin plate splines for representing the f_j smooth functions, we can keep the binary decision point of the HA.

In the algorithm, we apply the following procedure. If an X_j feature is selected in the current GAM, then by default $k_j = 10$ propsed by [19]. If the value set of X_j is smaller than 10, then k_j equals to the number of unique values in X_j. If the p-value for the test defined in [1] is below $\alpha = 0{,}01$, then k_j is increased by 5 until the null hypothesis can be accepted at $\alpha = 0{,}01$.

The most important advantage of the HA is that during feature selection it aims to eliminate concurvity directly. This means that during a memory update, we only transfer solutions where the concurvity measure introduced in Section 2 is below 0.5 for all features. If the ith solution in a memory satisfies this constraint, then a binary variable, C_i takes a value of 1, and 0 otherwise.

Furthermore, only those features should be preferred, where we can reject the null hypothesis that its f_j smooth function is identically 0. A test for this null is proposed by [13]. If at a user defined significance level, the null hypothesis can be rejected for all features in the ith solution in a memory, then a S_i binary variable takes a value of 1, and 0 otherwise.

Incorporating these two conditions is solved in the memory update step of the HA. During this phase, when selecting the better than average solutions from the memory, the average objective function of the current memory is defined by (2). We only accept the ith solution in the memory as a better than average solution if it satisfies the condition $C_i = S_i = 1$.

$$\bar{R}_M^2 = \frac{\sum_{i=1}^{N} \bar{R}_i^2 \cdot C_i \cdot S_i}{\sum_{i=1}^{N} C_i \cdot S_i} \tag{2}$$

Where N is the memory size, and $\bar{R}_i^2$ is the objective function of the ith solution in the memory. If $\sum_{i=1}^{N} C_i \cdot S_i = 0$, then $\bar{R}_M^2$ is simply the arithmetic mean of $\bar{R}_i^2$s, and every solution in the current memory can be accepted as a better than average solution in the memory.

It is important to notice that the C_i and S_i constraints in the algorithm can cause having no solutions in the initial random memory where $C_i = S_i = 1$. So, it can take several iterations to find solutions that satisfy every constraint. This implies that expected runtime of HA depends on the quality of the initial random memory. To address this, a smaller memory size is chosen, which ensures a shot expected runtime, and the algorithm is run several times with a small maximal generation number. This way several initial random memories can be tested, ensuring the desired variability.

4 NUMERICAL RESULTS

Performances of the 10 examined algorithms are compared on two real-world datasets. The first dataset contains 9 variables of 1030 concrete girders. The task is to estimate the comprehensive strength of concrete material as a non-linear function of age and ingredients. As $m = 8$, the feature selection task is small, which means all the possible subsets can be generated and the global optima is easily selected. This dataset is mainly used to finetune the parameters of the algorithms. In the second dataset, the task is to estimate for clients in a Taiwanese bank if they are to report default on their credit card loans in one month from now. This dataset consists of 30000 observations and 26 possible features. The feature selection task in this case is not solvable via examining all possible feature subsets and selecting the best one. More detailed descriptions of each dataset can be found in [20] and [21]. All the numerical experiments are implemented in R version 4.0.2. except for the HSIC-Lasso. For this algorithm, only Python implementation is available [5].

In the Concrete dataset the target is continuous and normally distributed [20], so the link function for the GAMs is the identity. Predictive performance of the final models from the algorithms is measured by the $R^2 = \mathrm{cor}(Y, \hat{Y})$ on a randomly selected 20% test set. In the Credit Card default dataset, the target variable has a Bernoulli distribution [21], so the link function for GAMs is the logit and to evaluate predictive performance, we examine the Area Under the ROC Curve (AUC) on a randomly selected 20% test set. All algorithms are run 30 times. Since these algorithms are heuristics, the best model out of 30 trials is shown.

Table 1: Numerical Results of the Examined Algorithms on the Concrete and Credit Card Default datasets.

Algorithm	**No. Selected Features (Concr., Cr. Card)**	**No. Features that Violate Concurvity Constraints (Concr., Cr. Card)**	**R^2 (Test Set, Concr.)**	**AUC (Test Set, Cr. Card)**	**Exp. Runtime on Cr. Card (min)**	**St. D. of Rtimes on Credit Card (min)**
Full model	(8, 26)	(7, 22)	0.881	0.769	0.305	0.041
Cosso [12]	(5, 7)	(4, 5)	0.851	0.701	64.272	20.979
Double Penalty TPS [13]	(8, 23)	(7, 19)	0.881	0.768	6.624	0.105
TPS with Shrinkage [13]	(8, 24)	(7, 20)	0.877	0.767	5.183	0.065
Nonnegative Garrote [3]	(8, 24)	(7, 20)	0.782	0.767	0.670	0.003
Stepwise [10]	(8, 26)	(7, 22)	0.881	0.769	0.309	0.045
GAMBoost [17]	(8, 13)	(7, 7)	0.892	0.761	692.237	9.497
Modified Backfitting [2]	(5, 16)	(2, 11)	0.879	0.765	0.443	0.214
mRMR [6]	(4, 6)	(0, 1)	0.816	0.744	1.629	0.035
HSIC-Lasso [5]	(5, 5)	(2, 3)	0.864	0.741	0.446	0.048
Hybrid Algorhitm, HA	**(4, 3)**	**(0, 0)**	**0.844**	**0.749**	**147.257**	**15.079**
Decision Tree	(-, 1)	(-, 0)	-	0.641	0.013	0.001
Random Forest with RFE	(-, 26)	(-, 22)	-	0.756	132.543	0.758

Table 2: Optimal parameters for the HA.

Parameter	**Optimal value**
initial $HMCR$ probability	5%
initial mutation (bw) probability	90%
maximal $HMCR$ probability	35%
minimal mutation (bw) probability	10%

The most important numerical results for the two datasets are summarised in Table 1. The optimal parameter set identified for the HA on the Concrete dataset is summarised in Table 2. HA finds it 19/30 times with these parameters, otherwise returns the mRMR model.

Results indicate that feature selection algorithms with no constraints on concurvity tend to prefer large models. Models proposed by the mRMR, and HSIC-Lasso algorithms had violated the concurvity constraints in some features. If our aim is to build a sparse model and we have no serious time constraints, HA is preferrable to the other examined algorithms. If our aim is simply to maximize predictive power GAMBoost, full GAM or other machine learning algorithms (like Random Forest) are preferred.

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EMPIRICAL ANALYSIS OF THE HUNGARIAN INSURANCE MARKET[1]

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Abstract: This paper focuses on the market structure of the Hungarian insurance market. After the change of regime, the monopoly situation of the Hungarian insurance market started to develop rapidly. The sector still has a strong oligopolistic character, so it worth examining how close the market is to a state of perfect competition. From the estimated elasticity of total revenues with respect to changes in input prices, we can deduce the market structure based on the methodology of Panzar and Rosse (1987). We estimate the input price elasticity with a static and a dynamic panel model. Our research shows that the structure of the Hungarian insurance market significantly differs from the perfect competition case between 2010 and 2019. The knowledge of the market structure is important for modelling phenomena and new regulations effectively in the sector, which is important for the supervision to be able to protect the costumers.

Keywords: Hungarian insurance market, market structure, Panzar—Rosse model, dynamic panel model.

1 INTRODUCTION

Modelling a sector plays a crucial role in the preparation of new regulations and supervisor decisions. Knowledge of the market structure has a critical role in the maintenance of modelling Systematically Important Financial Institutions. Insurance market is a large and risky sector with a lot of clients all over the world. When market competition rises, the situation of consumers improved as well. On the other end of the spectrum, in case of a monopoly, the costumers are completely vulnerable. Thus, it is an important factor that how strong the competition observed in the market can be.

This research addresses the question about the market structure of the Hungarian insurance sector. Studying the participants of the Hungarian insurance market, the answer is not clear, so it is worth examining the problem more thoroughly. The objective of the study is to determine whether the monopoly or the perfect competition case fits better for the balance sheet data between 2010 and 2019.

The history of Hungarian insurance dates back a long time. In the 1800s, many domestic and foreign insurance companies operated in the country. However, most of them were destroyed during the World War II. In socialism, like in several Eastern European countries [16], insurance has operated as a state monopoly in Hungary since 1952. In 1986, the only insurer company split into the new State Insurer and the Hungária Insurer, and it became allowed to establish new companies. The market started to develop rapidly, foreign companies

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appeared in the market, in parallel the supervisor authority has also evolved. Therefore, after the change of regime, the market has undergone significant transformation.

The structure of the current Hungarian insurance market cannot be clearly defined. According to the Association of Hungarian Insurers in 2019 not less than 31 insurance companies were in the market [10]. Breaking out of the monopoly position, the market has now undergone a major transformation towards perfect competition. On the other hand, in terms of premium income, the top 10 companies cover more than 80% of the market. The position of the market-leading insurers is stable, and their order has changed only slightly in recent years, which does not confirm the hypothesis of perfect competition.

Previous researchers have established several methods, which can be used at empirical analyses of the market structure, see Panzar and Rosse model [13] or Iwata model [7]. The Panzar and Rosse method uses the sum of the factor price elasticities of the reduced form revenue equation to create testable hypothesis about the market structure. Studies over the past decades have provided important information on market structures mainly in the bank industry based on this method in Canada [12], in Italy [5], or in a general way [3],[14]. The method can be used in other markets for instance in cigarette market [15], and the Panzar—Rosse model is often used in the insurance sector also, see [11], [1], [18], or the case study of the Turkish non-life insurance market [9], Italian car insurance [6], Chinese [8], Bulgarian [17] markets or the analyses of the insurance market of Ecuador [4].

The Hungarian insurance market structure is studied empirically indeed rarely, this article fills in this gap by using the Panzar—Rosse method in the case of Hungarian insurance market.

2 THEORETICAL BACKGROUND

The analysis of the insurance market is based on the Panzar—Rosse model [13], which gives testable implications of profit maximizing companies in different market structures. Its great advantage is that the amount of data required for the analysis is relatively small, only the revenues and factor prices of the companies. There is no need for explicit information about the structure of the market. The reduced form revenue equation is the following:

$$\pi = R(y,z) - C(y,w,t) \tag{1}$$

Where $R(y,z)$ is the reduced form revenue function, y is the decision variable and z are further exogenous variables, which influence the revenue function. $C(y,w,t)$ is the cost function, where w is the vector of exogenous factor prices and t is the vector of additional exogenous variables, that influence the costs.

This simple method assumes profit maximizing companies. The testable expression is the sum of the factor price elasticities of the reduced form revenue equation:

$$H = \sum_i \frac{\partial R^*}{\partial w_i}\frac{w_i}{R^*} \tag{2}$$

Where * means the profit maximizing values.

The paper of Pazar and Rosse [13] gives different theorems about the value of H for competitive and monopolistic markets to be able to distinguish these models. In the case of monopoly, the elasticity is nonpositive ($H \leq 0$). Here monopoly means that the revenue function does not depend on the decision of the rivals. A further assumption is that in the case of perfect competition and monopolistic competition the companies are observed in the long run equilibrium and entry and exit are free in the market. In monopolistic competition $H \leq 1$. In the long run competitive equilibrium the elasticity is unique ($H = 1$). To test the long run equilibrium the same equation is fitted but the dependent variable is the ROA, which is a proxy of the company's return.

3 METHODOLOGY

To test whether the market is competitive or monopolistic we built empirical models. From the Hungarian insurance market we chose the ten biggest companies and collected the required information about them between 2010 and 2019. In this way we had the opportunity to build a balanced panel dataset with 10 cross-section observations and 10 time periods.

The following equation is estimated with a panel dataset:

$$lnTR = \alpha + \beta_1 lnPL + \beta_2 lnPBS + \beta_3 lnPFK + \gamma LTA + \delta \mathrm{ROA} + \epsilon Life + \zeta \qquad (3)$$

where TR: total revenue, PL: unit price of labor, PBS: unit price of business services, PFK: unit price of financial capital, LTA: ratio of losses paid to total assets, ROA: Return on Assets, Life: ratio of life insurance in portfolio. ROA was omitted from the model as a selection step, because of serious collinearity issue.

These values can be calculated with the financial report of the companies. To see the market structure, we should test the hypothesis about the factor price elasticity (H), that can be calculated as the sum of the coefficients of the factor prices ($\beta_1 + \beta_2 + \beta_3$). Taking the logarithm of the dependent variable and the main three explanatory variables is feasible.[2]

We use two approach of panel modelling, static and dynamic. The static way means that we do not use any autoregressive, lagged variables. The easiest way to estimate a pooled OLS model. It is a simple OLS for panel data. There could be one serious problem, the unobserved effect which hurts the exogeneity assumption. In that case the goal of the estimation is to eliminate the unobserved effect. We can make a within or fixed effects transformation in that case. It means that we take the average of cross-section observations over time and then subtract it from the original equation. In this way all the time constant effects disappear (unobserved effect and all explanatory variables which are constant over time) [19].

The dynamic way uses autoregressive approach, the lag of the dependent variable as explanatory variable. In that case several problems occur during estimation. When the lagged value of dependent variable correlates with the error term, the fixed effect estimation could not solve the problem of endogeneity. Arellano and Bond [2] use Generalized Method of Moments (GMM) estimation, in which they use first differencing to eliminate individual effect. They solve the endogeneity problem by using all the lagged values of dependent variable as instruments. The method is also called one-step GMM in case of panel modelling. The hypothesis about the factor price elasticity (H) could be tested in this specification because the lag of dependent variable and the instruments belong to control variables.

4 RESULTS

We conclude the results of static and dynamic panel models below (see Tab. 1).

[2] To provide positiveness in case of taking logarithm we shifted the values of PBS and PFK with an epsylon above zero. The parameters did not show significant difference after this change-over. The result seems robust.

Table 1: Results of fixed effects and GMM model

	Fixed effect model			***GMM model***		
	Coefficient	*Standard error*	*P-value*	*Coefficient*	*Standard error*	*P-value*
Constant	25.597	0.425	0.000	0.059	0.009	0.000
lnPL	0.002	0.018	0.907	0.005	0.012	0.658
lnPBS	0.042	0.061	0.496	-0.036	0.074	0.622
lnPFK	0.037	0.043	0.390	0.025	0.018	0.162
LTA	-4.536	3.621	0.214	13.129	2.880	0.000
Life	-0.802	0.467	0.090	1.035	0.342	0.003
lnY(t-1)				0.698	0.198	0.000
n	100			80		
t	10			10		
Instruments	-			42		
Sargan test	-			χ^2=53.561 and p-value=0.023		
AR(2) test	-			z=0.211 and p-value=0.833		
$\boldsymbol{\beta_1+\beta_2+\beta_3=0}$	F=1.049 and p-value=0.308			F=0,006 and p-value=0.937		
$\boldsymbol{\beta_1+\beta_2+\beta_3=1}$	F=136.349 and p-value=0.000			F=177.729 and p-value=0.000		

The first model is the fixed effects panel model. The first thing what is obvious is that none of the variables is significant in the model (alfa=1%). It is not a strange phenomenon, multicollinearity could be the reason, which is common in panel models due to the data structure. Below the results of the model we report the two parameter tests. These are simple linear parameter restriction, so we could implement an F test for the sum of coefficients.
In the case of monopoly, the elasticity is nonpositive (H≤0). In this case that means that the revenue function does not depend on the decision of the rivals. The value of the appropriate test is 1.049 with 30.8% p-value. It means that, we cannot reject the null hypothesis, we accept monopoly market.

In monopolistic competition H≤1. In the long run competitive equilibrium, the elasticity is unique (H=1). The value of the second appropriate test is 136.349 and the p-value is near 0. It means that we reject the null hypothesis, so there is no perfect competition. The result of the two tests shows that the insurance market is a monopoly or a monopolistic competition.

It is rational and realistic to make the model dynamic. In the one-step GMM model we use the lag of dependent variable as an explanatory variable. It is significant, our choice seems appropriate. The model should meet some requirements. The first is the AR(2) test. It is testing the lags' number and model specification. The null hypothesis says that the first lag of Y is enough. The p-value of the test is 83%, so more lags are not needed in the model. The second requirement is the Sargan over-identification test. Due to instruments over-identification could occur in the model. In our model the p-value of the test is 2.3%. This is not unambiguous, it is on the edge of acceptance and rejection. Thus, it could be a limitation here.

The parameter tests (H≤1 and H≤0) provide the same result as in the fixed effects panel model. It seems a quite robust result in this way. In the static and dynamic panel estimation we got the same decisions in the hypothesis testing.

5 SUMMARY

We examined the market structure of the Hungarian insurance sector with the help of empirical analysis. Based on the Panzar and Rosse model, we tested input price elasticity. Using a static and dynamic panel model we got the same results. The Hungarian insurance sector is a monopoly or monopolistic competition market. We reject the following null hypothesis: sum of the parameters of unit price of labour, unit price of business services and unit price of financial capital is one, thus the market is not a perfect competition.

The scope of this study was limited in terms of the time period and the number of companies. Greater efforts are needed to work with a larger sample. Further interesting research question could be the examination of the insurance sector at regional or even European level. Understanding the market structure of Systematically Important Financial Institutions has importance, so a similar study is worthwhile for the banking sector, which would allow a comparison of the two sectors.

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FACTORS OF MOTOR POLICIES CASCO COVERAGE RISK EXPOSURES

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Abstract: Information discrepancy between insurance company and its clients is mostly in favor of the latter, therefore, as preventive measures, insurance companies inspect subjects and objects of insurance and perform risk assessments. Analysis of a five year portfolio of motor policies shows that group of policies from transition with unknown subjects and objects of insurance represent twice as high exposure to the realization of coverage risks compared to renewed policies. Distribution of exposures and realizations through the age of the vehicle is another factor with considerable impact, again with transition group twice as high.

Keywords: insurance, policy, risk, exposure, coverage, prevention

1 INTRODUCTION

The management of the realization of future insured risks ranges from assessments and advice to policyholders to reduce probable risks [3, 15] to entry inspections of the condition of insured objects upon entering into an insurance contractual relationship. Adjusting the offer to individual customers [3] requires in-depth analytical monitoring [7] and individual treatment [15], in which good policyholders are rewarded, and those with increased risk must bear an additional premium burden [2].

Customers strive for the best conditions for the lowest possible price, while insurance companies strive for optimal prices for the services they offer [1, 12]. It is a conflict of interests, so negotiations take place, with both sides having to make concessions in order for both to gain something [13]. Long cooperation under optimal conditions grows bond, but when the insurance company benefits, a negative attitude develops on the side of a client as the disadvantaged party, who tends to compensate through abuse of an insurance contract for the loss or damage to which is exposed [5, 10]. Individualization of customer treatment is gaining ground, through which the impact on portfolio sustainability and profitability is optimized and at the same time the offer is adjusted to individual customer's needs [2, 3, 12, 14].

For those clients who abuse the insurance system for their own unjustified benefits to the detriment of other honest policy holders, it makes sense to establish analyzes and control mechanisms that will exclude them from the portfolio, burden them financially accordingly [5, 6, 11, 14] or stop the abuse by obtaining information on the condition of the insured object. We can assume that the client has an advantage over the insurance company in cases when he does not want to disclose certain information or tries to conceal it [9, 11], so we can make an assessment of situations [6, 9] where such a discrepancy between the knowledge of relevant information is such that it poses a serious risk to the success of the business model of insurance companies.

In the present paper we assess predictive and preventive measures to recognize and act against such a bad actors in the Casco motor insurance [2, 8]. To achieve this goal, we performed an analysis and assessment of several years of historical data of Casco motor insurance contracts and realized risks, through which we came to the findings that enable a more optimal adjustment of the business model.

In following chapters, we first reviewed the relevant literature, defined the methodology, the data set and identify research questions. We analyzed and interpreted the obtained analysis results, and in the end we presented the findings with an impact on the business model.

2 LITERATURE REVIEW

The organization of the insurance business model requires sound and sustainable management of the collected contributions, so that they are sufficient to cover most claims, which requires appropriately high contributions [12] to cover the anticipated possible future claims events. Predicting appropriate contribution rates, reserves and future claims is in the domain of actuaries [1], who ensure that the business model bears the burden of probable future risks and brings a certain profit to the owners of insurance companies.

Insurance companies are regulated [7] and must operate with transparency and disclose all relevant facts about the products (conditions, coverage), while customers disclose only what is prescribed as mandatory by the legislator. Certain information could put customers in a negative light, so it is in their best interest that those are not known to the insurance company [10]. A special category are previous damages of the insured objects, which were not covered because the client did not have this type of insurance coverage, but would like to cover this damage from future insurance contract, which requires deception of the insurance company in the underwriting process or such underwriting procedure that does not require inspection of the insured object [11]. The discrepancy between the actual state of the insured objects and the information held by the insurance company poses a risk that any of the coverages will be unjustifiably realized.

3 METHODOLOGY

3.1 Baseline assumptions for building a multiparameter model to assess exposure to coverage risks

Insured objects entering the insurance company's portfolio for the first time are unknown and we only know about them, what the client is obliged and willing to disclose. For existing customers who add new coverages at policy renewals, the exposure assumption changes. Thus, we assume as the leading risk parameter the first entry of the insured object into the insurance company's portfolio with included observed coverages or the addition of coverages with greater claims exposure upon renewal of insurance.

We limited ourselves to car insurance, which represents the largest group of insurance in the portfolios of general insurance companies. Among them, Casco insurance has a higher claims exposure, so as the second risk parameter we chose those Casco coverages that have a poor result in themselves, as claims payments are greater than or close to the amount of collected premium. The set was limited to 5 representative covers with the largest negative effect on cash outflows: Full Casco and 4 Partial Casco coverages for glass, lights and mirrors, animals and parking lots.

In this research, we focus on the adjusted indicator, which shows whether the exposed coverage risks have been realized, regardless of how many claims were filed under each policy for each cover risk. The analysis will check the extent of the observed coverages (OC) and the extent of exposed coverage risks (ECR), share of the realized observed coverages (ROC) and realized exposed coverage risks (RECR) - we observe everything in the relationship to the entire portfolio and within the renewal and transition groups. We will check the distribution of these indicators also against the age of the vehicle, through which we will check the impact of this parameter in connection with ECR and RECR.

3.2 Data

Historical data for motor insurance and claims of one of the Slovenian insurance companies for a period of five years was used, which provided a sufficiently large representative sample with more than six hundred thousand policies and related claims. Data on all motor policies of the selected period, which were issued from January 1^{st} 2014 onwards and expired by December 31^{st} 2019, as well as data on claims related to them, was obtained.

Indicators with a value of 0 and 1, respectively, were assigned to the observed coverages, depending on whether the coverage was additionally included in the policy (renewal) or selected at the transition. Indicators with a value of 0 and 1, were also assigned for realized claims from exposed coverages on the policies, depending on whether the observed coverage risk was realized or not. The policies were assigned '**transition**' values for vehicles entering the insurance company's portfolio for the first time. The remaining policies were assigned to the '**renewal**' group.

As a risk parameter, the policies were assessed with values from 0 to 5, depending on whether the policy has no exposed coverage risks (for transitions) or when the policy is renewed and the same coverage remains as on the pre-policy - value 0 (no risk), values from 1 up to 5 define the number of exposed coverage risks on the policies (for transitions) or additional covers from the set of five observed exposed coverage risks in the renewal of the policies (risk exists).

3.3 Research questions

The research sought answers to how the observed indicators OC, REC, ROC and RECR are distributed:

1. How are policies with renewal and from transition distributed throughout the portfolio?
2. What proportions do policies with OC, REC, ROC and RECR represent in the total portfolio?
3. What is the share of policies with OC by groups renewal and transition in the total portfolio? What is this share within the renewal and transition groups?
4. What is the share of policies with REC by renewal and transition groups in the total portfolio? What is this share within the renewal and transition groups?
5. What is the share of policies with ROC within the renewal and transition groups in the total portfolio? What is this share within the renewal and transition groups?
6. What is the share of policies with RECR within the renewal and transition groups in the total portfolio? What is this share within the renewal and transition groups?
7. What is the distribution of ECR and RECR according to the age of the vehicles?

4 RESULTS

Renewal policies group: represents 77.09% of the portfolio, 47.17% of them include one or more observed coverages and 5.31% of them include exposed coverage risks. The realized observed coverages represent 7.72% and realized exposed coverage risks represent 1.04% of all policies.

Transition policies group: represents 22.91% of the portfolio, 11.33% of them include exposed coverage risks. The realized exposed coverage risks represent 2.07% of all policies.

The distribution of OC, ECR, ROC and RECR in relation to the total portfolio is shown in Figure 1 below. The narrower results for both subgroups show the following:

- within the renewal: the share of policies with OC is 61.19%, policies with ECR is 6.88%, ROC are 10.02% and RECR are 1.35%;
- within the transition: policies with ECR are 49.44%, ROC are 9.19% and RECR are 9.04%.

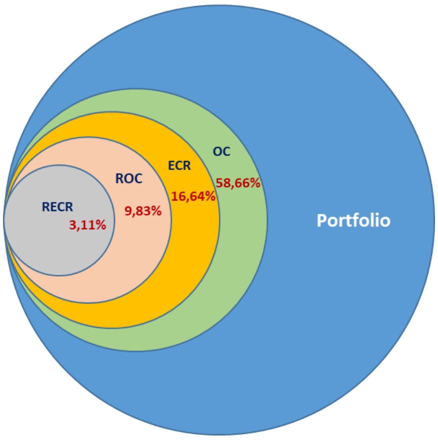

Figure 1: The share of OC, ECR, ROC and RECR in the portfolio of policies

The results of the ECR and RECR distribution analysis are shown in Figures 2 and 3.

A comparison of the obtained results shows that more than three quarters of the policies belong to the renewal group (77.09% vs. 22.91%) and that these policies also represent the majority of policies with OC (47.17% vs. 11.49%). However, the ECR shows that there are twice as many such policies in the portfolio of transition vs. renewals (11.33% vs. 5.31%).

The comparison of ROC again shows a higher realization of OC in the renewal group (7.72% vs. 2.10%), while in RECR the picture is reversed, as there are twice as many such policies in the portfolio of transition vs. renewal (2.07% vs. 1.04%).

A more detailed analysis within the renewal and transition groups shows that in the renewal group there is a larger share of policies with observed coverages (61.19% vs. 50.14%), while the ECR shows that there are significantly more such policies in transition than in renewal (49.44% vs. 6.88%). Realizations by all observed coverages are quite close (10.02% vs. 9.19%), while in RECR the picture is reversed, as the share of such policies in transition is significantly higher than the renewal (9.04% vs. 1.35%).

The analysis of the distribution of ECR and RECR by vehicle age shows a marked upward deviation for the transition group, according to both criteria, which confirms the assumption that unknown subject of insurance represent an increased level of exposure to the realization of coverage risks. The greatest damage exposure is in new vehicles, with a larger drop at the age of two years, after which it rises sharply and reaches a peak at the age of 4-6 years and then slowly falls towards the age of 20 years when it reaches the bottom.

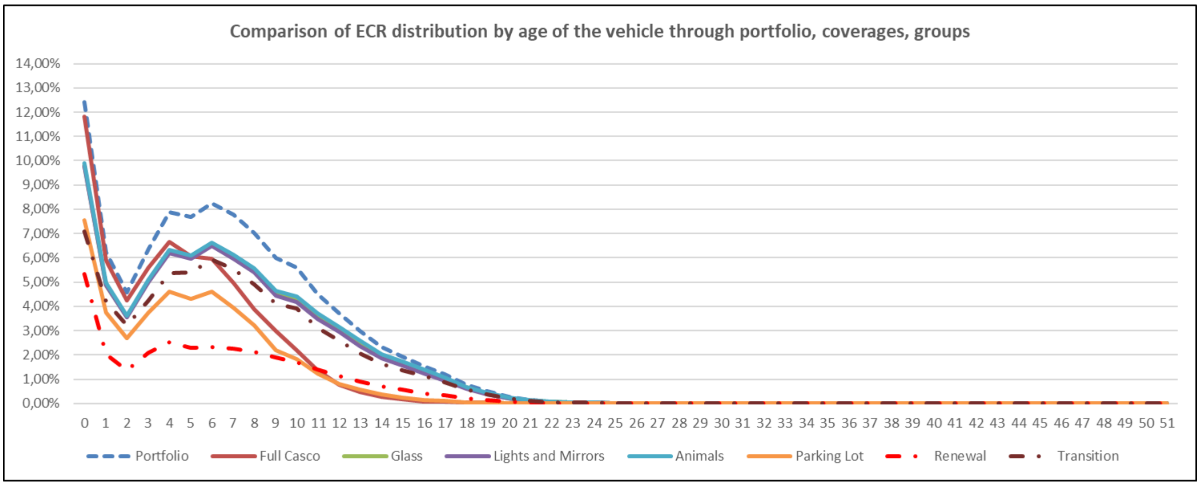

Figure 2: Comparison of ECR distribution by the age of the vehicle

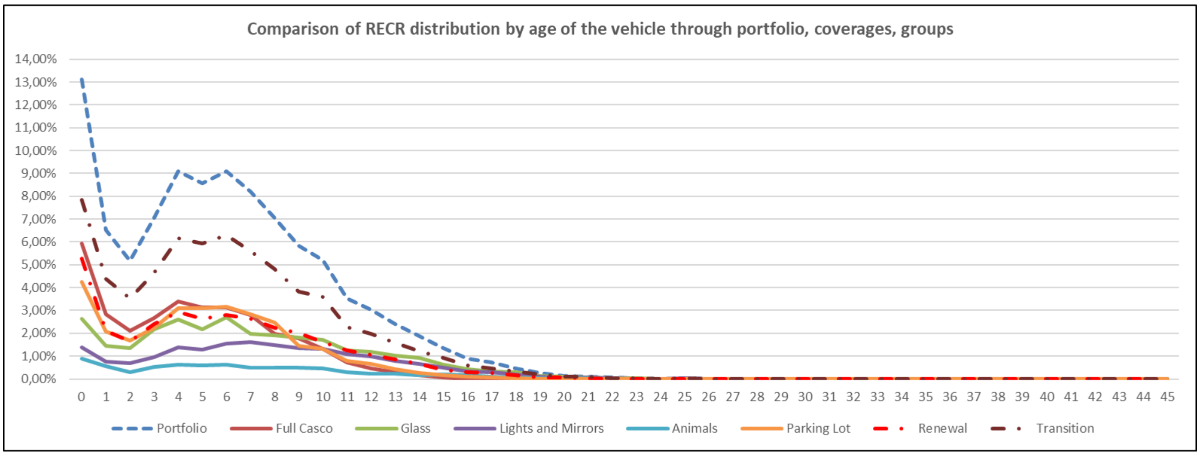

Figure 3: Comparison of RECR distribution by the age of the vehicle

5 CONCLUSIONS

In this paper, we compared exposure to coverage risks and the realization of those exposed coverage risks in two distinct groups of policies, e.g. renewed policies and group of policies from transition. We assumed that policies within the transition group and with renewal subgroup, where exposed coverage risks were added to the policies at the renewal, will have more exposed coverage risks and higher realization of those risks in comparison with the policies with observed risks and no changes at the renewal. Both assumptions proved true with twice as high realization of exposed coverage risks in the transition group compared to renewal group and twice as high realization of exposed coverage risks of renewed policies with added exposed coverage risks compared to non-changed renewed policies with observed coverages.

Previous researches were predominantly observing and analyzing past claims history and client behavior with a focus on generalized adaptation of insurance conditions to limit extensive realization of highly exposed coverage risks or with individual treatment of the clients through tracking use of the insured objects (e.g. telematics). Search in literature did not give any result, compared to approach in the present study.

Present research and analysis results would enable insurance companies to focus inspections on insurance objects with higher exposure to coverage risks to prevent unjustified claims and to improve business profit lines and to make business models sustainable.

An upgrade of this research would be a study of the multiplicative effects of multiple claims from observed coverages on an individual policy, with a study of the impact of the loss result, i.e. the financial evaluation of exposure factors. Additional useful insight would be provided by the study of the distribution of all observed indicators according to the age of policyholders, the comparison of regions and the comparison of policyholders as individuals vs. companies. A meaningful summary of further research should enable the comparison of different indicators of exposure to coverage risks and their realization, and the ultimate goal is to establish an analytical model for real-time identification of exposed motor policies and consequently apply the research model to other types of insurance.

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EVALUATION OF EFFICIENCY AND ITS DETERMINANTS IN CROATIAN HOTEL INDUSTRY

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Abstract: The main objective of this research was to evaluate the efficiency of Croatian hotels and provide insights into the sources of their efficiency. In order to obtain set goals, a two-stage analysis (DEA and truncated regression) was performed on a sample of 69 large and medium-size hotels that were operating in Croatia in 2019. Results of the research showed that the average value of overall technical efficiency amounted 51.32%. Additionally, it was found that ownership, location, size and star rating play significant and important role in determining the achieved level of efficiency.

Keywords: Croatia, efficiency and determinants of efficiency, hotel industry

1 INTRODUCTION

Tourism is becoming increasingly important in the world economy today. The last decade has been marked by the constant growth of tourist arrivals, which in 2019 reached a peak of 1.5 billion globally [23]. A turning point was in 2020 in which travel bans and restrictions were introduced to curb the spread of the Covid-19. The number of international tourist arrivals in the world in the first eight months of 2020 fell by 70 percent compared to the same period in 2019, resulting in the decrees of 700 million of foreign tourist arrivals. Losses of export revenues from international tourism amounted to 730 billion USD. The severity of the situation is reflected in the fact that this loss is eight times greater than the one in 2009, caused by the global economic and financial crisis [23].

Tourism in Croatia is following the world trends. The importance of tourism for the Croatian economy is reflected in the fact that foreign exchange income from tourism accounted for 19.4 percent of GDP and 37.3 percent of total Croatian exports in 2019. Like world tourism, Croatian tourism has suffered severe consequences of the Covid-19 pandemic. For example, in the first nine months of 2020, a 6.7 million tourist arrivals and 39.7 million overnight stays were recorded in Croatia. This presents only 37.6 percent of arrivals and 45.9 percent of the number of overnight stays during the same period in 2019 [4].

According to the type of accommodation, the largest decline in tourist arrivals and overnight stays was recorded in the hotel accommodation. Hence, hotels need to improve their efficiency and ensure smooth functionality. Having previously in mind, the aim of this research is to examine the level of efficiency of Croatian hotels in 2019 as well as to identify and analyse the influence of independent factors that determine hotels' efficiency. In order to create a homogeneous sample, only large and medium-sized hotels for which all necessary data were available have been included in the analysis, making in total 69 hotels that operated independently or as a part of a hotel group in 2019. Such sample selection is in line with previous research [14], [17] in which variable ownership (together with the other variables in the later stage of analysis) was used as a determinant of hotels' efficiency.

To the best of authors' knowledge, only one paper were dealing with the efficiency of Croatian hotels and in that paper a relation of efficiency and hotels' age and size were examined through two separate tests. However, given that the model which simultaneously (not individually and/or separately) encompasses and analyses potential influential factors can provide more accurate and comprehensive insight into the determinants of efficiency, this paper contributes to the existing literature by shading new lights on the sources of hotels' efficiency from the perspective of a country heavily relaying on seasonal seaside tourism. Moreover, this is the first time that the determinants of the efficiency of Croatian hotel industry were examined with the application of truncated regression analysis in which, aside from age and size, additional determinants i.e. ownership, location and star rating of the hotel were applied.

The study unfolds as follows. After the introductory section explaining the motives for conducting this research, the next section provides literature review related to the hotel efficiency. Third section gives insights into methodology as well as inputs and outputs used in DEA analysis and truncated regression. Fourth section provides efficiency scores and results of the truncated regression analysis, whereas the last section offers a conclusion.

2 LITERATURE REVIEW

Reference [14] conducted a first application of DEA methodology in hotel industry and since then, the literature of efficiency in the hospitality industry has developed rapidly. An overview of some of the research from Asia ([17], [18], [22]), Europe ([19], [15], [11]), South America [17] and Australia [1] is given below.

Using the DEA methodology, the authors [17] measured efficiency of 58 hotels in seven different regions in Oman and discovered that the average efficiency score obtained by input oriented CCR and BCC model was 0.70 and 0.83 respectively. The impact of contextual factors was also examined, showing that type of ownership (independent or chain dependent), nature and activities play no important role in hotels' efficiency, whereas hotel size, star rating and cultural attractions have the most significant effect on efficiency. On the other hand, in the research of [18], it was discovered that the hotel size has no significant impact on efficiency. The efficiency of 28 4-star and 5-star resort hotels in coastal Turkish regions in 2005 was examined by [22] who revealed that average value accomplished by output oriented CRS and VRS models were 0.71 and 0.79 respectively. Results also showed that 4-star hotels were quite efficient, while management style has no significant impact on efficiency.

Croatian authors [19] used output oriented CCR model to examine efficiency of 105 hotels in Croatia in 2013 and they suggested that a low average efficiency rate of 73 percent stems from a low average occupancy rate. Although differences in efficiency among hotels of a different quality and size were examined, the result showed only significant relationship between efficiency and hotel size. Efficiency scores of 13 companies with 20 5-star hotels and 15 companies with 36 4-star hotels were examined in the Algarve from 2005 to 2007 [15]. Values of input oriented CRS and VRS models amounted 0.519 and 0.729, whereas in the output oriented models were 1.923 and 1.534 respectively. By using the DEA methodology, [11] conducted a research on a sample of 50 luxury and A-class hotels operating either as independent or under a brand in Crete. The average efficiency values of the input oriented CCR and BCC models were 80.1 and 87.35 respectively. Results revealed that internationally branded hotels were the least efficient, whereas hotels operating under a national and local brand were relatively most efficient. It was also found that the main reason for hotels inefficiency was due to their input/output configuration and size of their operations.

Research in Ecuador [7] applied DEA methodology on a sample of 147 businesses during the period 2013-2017 and discovered that the average efficiency by province and years was 0.658 and that third category hotels were on average the most efficient in most provinces. In addition, it was found that hotels that operated in tourist areas used their inputs in a better way.

Reference [1] performed DEA to assess the technical efficiency of Australian hotels for the period 2004–2007. The results indicated that number of years in business, location, star rating and physical size were all positive and statistically significant in influencing the hotel efficiency.

3 METHODOLOGY AND VARIABLES

In this research, a two-stage analysis was applied. In order to obtain efficiency coefficient for each hotel included in the sample, in the first stage of investigation a Data envelopment analysis was performed, whereas in the second stage of analysis, achieved efficiency coefficients were used as dependent variable in a truncated regression model.

As a non-parametric technique that is based on liner programming, *Data envelopment analysis* is usually applied in research that aims to evaluate relative efficiency of business entities (i.e. firms or hotels, afterwards decision-making units - DMUs). After the seminal work of Farrel [6], the authors Charnes, Cooper and Rhodes [4] established CCR model based on the presumption of constant returns to scale (CRS), whereas later on Banker, Charnes and Cooper [3] developed BCC model, founded on the assumption of variable returns to scale (VRS). As CCR model assumes no significant association between efficiency and scales of operation, it estimates overall technical efficiency (OTE) of DMUs. On the other hand, BCC model calculates pure technical efficiency (PTE), which in combination with the scale efficiency (SE) enables decomposition of OTE. According to the model orientation, DEA models can be categorised as input and output oriented. In both of these models, DEA analysis separates efficient DMUs (whose efficiency scores amounted 100%) from those inefficient (with efficiency score lower than 100%). Based on the above presented, in this research an output oriented CCR model is applied. Model selection is in line with the study of [17], [10] and many others. In order to accomplish the analysis, a Performance Improvement Management Software (PIM-DEA) is applied.

According to microeconomic theory, in every production process a business entity (i.e. DMU) uses inputs such as capital, labour and/or land/materials in order to produce and sell goods or services. If DMU is successful, it will achieve the set goals, usually expressed in terms of profit maximization, revenue maximization or firm growth as stated in neo-classical and managerial theories of the firm. Therefore, in line with presented, four inputs (number of rooms, number of beds, costs of raw materials and supplies, and number of employees) and one output (operating revenue) were used in DEA analysis. The selection of inputs and output was guided by theoretical literature and empirical research, as well as by data availability.

As regards *truncated regression*, it is commonly applied in models in which sample has been truncated below or above specific thresholds of the regressand, meaning that some observations (based on a certain value of the regressand) are systematically removed from the sample. Although some researchers apply OLS regression to estimate regression coefficients, it must be noted that the application of OLS would produce biased parameter estimates as the efficiency scores of some hotels may achieve value of 100% (recall that boundaries of efficiency span between 0% and 100%). Therefore, a truncated regression, in which parameters are estimated via parametric maximum likelihood method, is preferable in this kind of research.

As a regressand or dependent variable, efficiency scores evaluated in the first stage of the analysis were applied, whereas as independent variables we used hotel's ownership, age, location, size and hotel's star rating. Each of the listed variable is calculated in the following manner: *hotel's ownership* is a dichotomous variable taking a value of 1 in case of independent hotel and zero otherwise; *hotel's age* denote a number of years that hotel operates in the hospitality industry; *hotel's location* is a dichotomous variable taking a value of 1 if hotel is located in the county by the sea, zero otherwise; *hotel's size* is measured as natural logarithm of hotel's total revenue; and *hotel's star rating* represents the number of stars associated to a particular hotel. Justification for the inclusion of the presented variables can be found in theoretical literature and in previously presented empirical research. All necessary data (except for the number of hotel's stars, for which information were collected from the web pages of Croatian Ministry of Tourism) were obtain from "info.BIZ 2.0"– database of Croatian Financial Agency [5]. This part of the empirical analysis was performed with STATA software.

4 RESULTS AND DISCUSSION

Before conducting DEA analysis, a correlation among selected inputs and outputs that on the most convenient way present functioning of hotels is performed and results revealed a strong positive and statistically significant relationship (with the range spanning from 0.92 to 0.99) among analysed four inputs and one output. Furthermore, as the coefficients of all variables were positive (meaning that an increase in inputs will cause increase in output), the data fulfiled isotonicity, hence the analysis could be performed with DEA methodology.

Results of the output oriented CCR model, which was applied on 69 hotels that were operating in Croatian hospitality industry in 2019, are presented in Table 1. For confidentiality reasons, a specific label (DMU number) is assigned to each hotel. In addition, due to space constraints some of the DMUs are not presented in the table. Still, complete table is available on request. According to the overall technical efficiency (OTE), out of 69 hotels, only three of them (DMU1, DMU4 and DMU39 i.e. 4.35% of total sample) were efficient as their efficiency score amounted to 100%. The efficient hotels form reference set for all inefficient hotels (66 hotels whose efficiency scores are less than 100%) and their operating practice can serve as a pattern that inefficient hotels should follow. Average value of OTE in hotel industry is 51.32% suggesting that on average a hotel can reduce its inputs (resources) or augment its outputs (services) by 48.68% in order to achieve frontier efficiency i.e. to become efficient. Less than half of analysed hotels (45%) perform at a level above the average.

Table 1: Overall technical efficiency (OTE) scores of Croatian hotels

	CCR	***DMU***	***CCR***	***DMU***	***CCR***	***DMU***	***CCR***	***DMU***	***CCR***
DMU1	100	**DMU6**	57.95	**DMU11**	77.47	**DMU16**	44.74	**…**	...
DMU2	54	**DMU7**	58.7	**DMU12**	66.39	**DMU17**	47.12	**…**	...
DMU3	59	**DMU8**	44.72	**DMU13**	39.77	**DMU18**	51.43	**DMU67**	46.23
DMU4	100	**DMU9**	67.2	**DMU14**	49.41	**DMU19**	35.26	**DMU68**	26.33
DMU5	99.48	**DMU10**	32	**DMU15**	34.6	**DMU20**	30.09	**DMU69**	40.38
Average	**51.32**								
No. of eff.	**3 hotels (4.35%)**								

Source: Authors' calculation

When comparing obtained results with those of [19] for Croatia and those of other studies performed at the European level (e.g., [15], [11]), our results show lower level of efficiency than previous research. Possible explanation for such a finding can be due to different sample selection e.g. the analysis of [19] encompassed 105 hotels of all size, whereas we focused our attention only on large and medium-size hotels as we wanted to create as much as possible homogeneous sample for DEA analysis. Likewise, some authors examined efficiency of hotel companies with 4-star and 5-star hotels [15], while the others were focused only on 50 luxury and A-class hotels [11]. Aside from some differences in sample and variable selection, possible reason for relatively low level of achieved efficiency may lie in high cost of raw materials/supplies and high labour costs as well as low occupancy rate and consequently low operating revenue realised by hotels from our sample.

Nevertheless, as efficiency (in general sense) represents the ratio of outputs and inputs, every hotel can improve its efficiency either by reducing used inputs whereas keeping output constant or by augmenting outputs whereas holding inputs unchanged or by simultaneously reducing inputs and augmenting outputs. Analysis of inputs and outputs used in this research showed that most hotels from our sample provide a relative oversupply of rooms/beds and are relatively overstaffed, and hence are not able to achieve high levels of efficiency. Therefore, it is of vital importance to those hotels (and Croatian hospitality industry in general) to attract new consumers and to expand the season by offering and promoting an attractive, differentiate and innovative range of higher value-added products and experiences.

After the efficiency scores for all analysed hotels were estimated in the first stage of the analysis, obtained scores were used as regressand variable in the second stage of the research in which hotel's ownership, age, location, size and star rating were applied as independent variables. Table 2 brings descriptive statics and results of the correlation analysis among regressors used in truncated regression. Correlation coefficients of all analysed independent variables are far below 0.6, suggesting no presence of multicollinearity, therefore we could proceed with the truncated regression for which the results are present in Table 3. Although the *truncreg* output retrieved from Stata does not include neither an R^2 nor a pseudo-R^2, it is possible to compute its rough estimation, which in this research amounted 0.35 or 35%.

Table 2: Descriptive statistics and correlation analysis

Descriptive statistics					***Correlation analysis***					
Variable	***Mean***	***Std. Dev.***	***Min***	***Max***	***Variable***	***O***	***A***	***L***	***S***	***Q***
Ownership (O)	0.377	0.488	0	1	***O***	1.000				
Age (A)	24.058	7.646	7	48	***A***	-0.132	1.000			
Location (L)	0.797	0.405	0	1	***L***	-0.277	-0.115	1.000		
Size (S)	18.279	1.051	16.57	21.45	***S***	-0.523	0.288	0.266	1.000	
No. of stars (Q)	3.855	0.601	2	5	***Q***	0.239	0.015	-0.002	0.192	1.000

Source: Authors' calculation

Table 3: Results of truncated regression (dependent variable OTE)

Variable	***Coef***	**P>|z|**
Ownership (O)	8.780378	0.024
Age (A)	0.157459	0.437
Location (L)	11.18316	0.005
Size (S)	3.738276	0.047
Star rating (Q)	7.689629	0.005
Cons	-64.44512	0.040
/sigma	11.83238	0.000

Source: Authors' calculation

Of all analysed variables only age of the hotel did not prove to be statistically significant. *Ownership* variable shows statistically significant difference between efficiency of independent hotels and those belonging to a chain of hotels, in favour of the former. In other words, independent hotels seem to be more efficient than chain hotels. A possible explanation for that can be found in the fact that independent hotels are more flexible in adjustments of their standards and practices/policies in order to meet changing market needs. They are also more flexible in adoption to local condition. Indeed, similar results were recorded by [11] which found that international hotels exhibit low efficiency due to their low ability to adjust to local market condition. Empirical results also partially coincide to those of [12] and [20] which found (in)significant difference between chain hotels and independent ones, depending on the measure of performance used in the research. Hence, hotels must weigh all benefits of belonging to a chain (e.g. obtained better distribution network; reduced cost of advertising, reservation system and management teams through economies of scale that are obtained by sharing these costs with other chain members, etc.) against all costs (e.g. lower level of flexibility; payment of different types of fees; going through expensive and stringent qualification evaluation, etc.) and pursue a policy of its best interest [21].

Location of the hotel also plays significant role in achieving higher level of efficiency. Hotels that are located in the county by the sea perform better than those located away from the coast. This is not surprising knowing that Croatian tourism is highly seasonable as it is based on "sea and sun“ tourism concept in which majority of tourism arrivals are realised during the summer months and are concentrated in coastal areas. As 20% of Croatian GDP is realised through tourists' expenditure (it is worth noting that this represents the largest share realised in the European Union), it is important that Croatia supply new tourism services that will alleviate risk of stagnation and help in maximization of tourism impact on other sectors of the economy [16]. This is in accordance with the Croatian tourism development strategy that emphasizes the prominence of diversified product development in order to cut down seasonality. Precisely, aside from “sun and sea” concept, additional tourism product development should be made in health tourism, cultural tourism, nautical tourism, golf tourism, wine and gastro tourism, adventure and sport tourism, as well as in rural and mountain tourism. These products developments will not only expand the season, but also contribute to the improvement of the efficiency of hotels that are not necessary located on the coast. The importance of hotel’s location on its performance is also confirmed in papers of [9] and [8].

Size of the hotel has positive and statistically significant impact on its efficiency. The larger is the hotel, the higher level of efficiency is achieved. It is well known that due to their size, the larger hotels are able to obtain economies of scale and supply their services at lower costs. These findings are in line with the results of [13] and [2] which confirmed positive influence of hotel’s size on its performance, where former stated that larger hotels achieve higher gross operating profit and occupancy rate than smaller ones primarily due to economies of scale in transactions and operational advantages. Large hotels may also enjoy high occupancy and sales revenue as they can provide a range of leisure and services activities (i.e. food and beverages, accommodation, animation and entertainment for guests’ children, spa, gym, laundry, swimming pool, conference facilities, etc.) which in turn enables them to achieve higher efficiency. These arguments correspond to [24] which found not only the evidence that product-specific scale economies exists in food and beverage, accommodation, and in other services in hotels, but also discovered the presence of economies of scope in providing accommodation and food and beverage services jointly.

Finally, *star rating* significantly and positively influence hotel’s efficiency. According to the obtained results, the more stars a hotel has the more efficient it is. As the quality of hotel is strongly associated with the number of its stars, it is clear that (given the results) the higher quality/luxury hotels are more efficient. A deeper insight into the results shows that the efficiency achieved by 2-star, 3-star, 4-star and 5-star hotels amounted 24%, 42.7%, 50.9% and 75.8% respectively, thus strongly indicating the importance of high-star hotels and their predominance in terms of efficiency. This finding stress the importance and necessity of upgrading the quality of existing hotels and, if needed, concentrating on building mainly high-star hotels. Moreover, as most hotels from our sample provide a relative oversupply of rooms/beds, a part of a hotels’ accommodation capacity can be renovated/rearranged in sections offering leisure, entertainment, health service, etc. Influence of hotels star rating on its efficiency and occupancy is confirmed by [18], whereas [19] demonstrated no statistically significant association between efficiency and hotel quality.

5 CONCLUSION

The aim of this paper was twofold. First, to examine relative efficiency score for 69 large and medium-size hotels that were operating in the Croatia in 2019, and second, to identify relevant sources of hotels (in)efficiency. Using the DEA methodology in the first step of the analysis, in which four inputs (number of rooms, number of beds, costs of raw materials and supplies, and number of employees) and one output (operating revenue) were chosen as variables that on the most convenient way describe functioning of hotel industry, it was possible to evaluate efficiency of each hotel in term of a single efficiency score. As efficient hotels form efficiency frontier and represent reference set for all inefficient hotels, their operating practice can serve as a pattern that inefficient hotels should follow. In other words, while using efficient hotels as benchmarks, inefficient hotels may directly improve their business performance by readjusting their input/output combination and by finding and implementing adequate strategies that will help them to create and if possible sustain competitive advantages. There is no universal formula for success. As each hotel has its own specific characteristics, each hotel should implement its own particular mix of different strategy in order to enhance its performance. Still, some general recommendation can be pointed out. Since profitability and efficiency are closely related, they could be raised either through revenue/output maximization (increasing the price of goods/services or increasing the occupancy) and/or through cost/input minimization (decreasing the costs of each particular goods/services). Decision to implement price increase policy is directly related to the price elasticity of demand. Only in case when the demand for product/service is inelastic (below 1), an increase in price will lead to increase in hotel's revenue. Otherwise, if the demand for product/service is elastic (above 1), increase in price will further decrease hotel's revenue. Likewise, by offering and promoting an attractive, differentiate and innovative range of higher value-added products and experiences, it would be possible to attract new consumers, increase the occupancy, penetrate new markets as well as to expand the season. On the other hand, in order to perform successful cost reduction, it is important to decrease only unnecessary expenses, since reduction in costs related to service quality and customer satisfaction can produce negative effects.

The results of the truncated regression in which efficiency scores were used as dependent variable, show that of all analysed independent variables (hotel's ownership, age, location, size and hotel's star rating), only age of the hotel has no significant influence on achieved level of efficiency. Precisely, empirical results reveal that: (1) independent hotels are more efficient than chain hotels; (2) hotels located in the county by the sea perform better than those located away from the coast; (3) larger hotels achieve a higher level of efficiency than their smaller counterparts; (4) hotels that have a higher star rating are more efficient than those with lower star rating. In line with stated, when deciding whether to be independent hotel or a part of chain, top managers must weigh all benefits of belonging to a chain against all costs, and pursue a policy of hotel's best interest. Likewise, aside from "sun and sea" concept, additional tourism product development should be made in health tourism, nautical tourism, adventure and sport tourism, etc. Furthermore, as large hotels are characterised by the presence of economies of scale and scope, some incentives for M&A activities among small and medium sized hotels may arise. Finally, due to the importance of high-star hotels and their predominance in terms of efficiency, it is important to upgrade the quality of existing hotels.

The suggestion for future research might be to evaluate overall, pure and scale efficiency of hotels operating in other European hospitality industry. Moreover, a cross-country analysis of factors that determine efficiency can be performed as well as further extend by introducing new variables. In addition, future research may focus on conducting a longitudinal study and carrying out trend analysis of efficiency.

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DETERMINANTS OF TOURISM DEMAND IN CROATIA

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Abstract: As the contribution of Croatian travel and tourism industry to GDP and total economy employment amounts 25% and 25.1% respectively, the importance that tourism has on Croatian prosperity is unquestionable. Hence, the main objective of this research is to examine the influence of different factors on tourism demand for Croatia. The analysis is conducted on the sample of 16 countries of origin and 9 competitor countries during the period 2012-2019 with the application of dynamic panel data model. All variables encompassed in the model i.e., price, income, corruption, terrorism and investments, show statistically significant influence on tourist arrivals in Croatia.

Keywords: Croatia, tourism demand, panel analysis

1 INTRODUCTION

According to the data of Croatian Bureau of Statistics, over the last two decades, Croatia has recorded a steady increase in the number of tourist arrivals and overnight stays. Since 2000, the number of tourist arrivals has almost tripled – from 7.1 million in 2000 to 19.6 million in 2019. Foreign tourists prevail with a share of 89% in total number of tourist arrivals in 2019. The majority of tourists visit Croatia during the summer season and stay in private accommodations, hotels and camping sites. World Travel & Tourism Council's data show that, in 2019, the contribution of travel and tourism industry to Croatian GDP amounted 25%, with a share of 25.1% in total economy employment. From these numbers it is obvious that Croatian economy is highly dependent on tourism.

As tourism demand modelling and forecasting is one of the most significant topics in tourism research, it has allured researchers from both academic and practice backgrounds [23]. In line with stated, the main aim of this paper is to investigate the factors that influence foreign demand for Croatian tourist product. The formulated model, besides traditional tourism demand determinants such as price and income, considers also Croatian hospitality investments as well as corruption perception and terrorism index of competitor destinations. Moreover, as the latter two determinants have been rarely investigated in general, and to the best of authors' knowledge have never been examined for Croatia in particular, by their inclusion into the proposed model, we directly contribute to the existing body of knowledge by shading new lights on their influence on tourism demand. Aside from being the first study in the domestic literature that observe terrorism index and corruption perception variables as determinants of tourism demand, this study also adds to the research on the demand for tourist product in less developed market.

The rest of the paper is structured in the following way. The section 2 provides overview of the literature related to tourism demand, while the section 3 give insights into the methodology and variables used in the empirical part of the analysis. Section 4 brings the results of the conducted analysis while the last section concludes.

2 LITERATURE REVIEW

There were numerous tourism demand modelling and forecasting studies in recent decades and all of these models differ mainly in terms of regressand and regressor variables, observed periods and data levels, empirical methodologies and emitting/receptive country pairs [5]. Generally, international tourism demand is usually measured in terms of the number of tourist visits, tourist expenditure by visitors and the number of overnight stays by tourists from the origin country in the destination. On the other hand, commonly used explanatory variables are the origin country population, the origin country earnings, price, consumer preferences, etc. [24]. The majority of studies were focused on modelling and forecasting inbound tourism in traditionally receptive countries.

Many authors were lately using dynamic panel data models for modelling tourist demand in their studies, e.g. [8], [9], and they confirmed that tourism demand in the past period has a notable effect on current tourism demand. As well, many authors also introduced some specific variables as determinants of tourism demand depending on their research objectives. Precisely, some studies were focused on special forms of tourism e.g. academic tourism [18], [6], while the others were interested in some very specific questions, e.g. how climatic variations between origin country and destination affect tourism demand [13]. Certain number of researchers were also addressing relations between tourism demand and social issues like corruption (e.g. [14], [17], [20]) and terrorism (e.g. [25], [19], [7]).

Some authors also conducted empirical analysis on tourism demand modelling and forecasting in *Croatia*. These authors used various methodologies such as autoregressive distributed lag (ARDL) approach [15], the Box-Jenkins approach [3], [12] and panel data approach [21], [22]. While [3] were focused on finding the most appropriate SARIMA model in describing German tourists' arrivals to Croatia, [12] tried to determine how much physical tourist traffic can be presumed in Croatia over the next five years based on tourism demand, accommodation capacities and seasonality of tourism. On the other hand, [15] showed that tourism demand is characterised by the positive and high-income elasticity, but not influenced by exchange rate and transportation costs. Still, based on methodological approach (which was similar to the one applied in this research), the variables and conclusions for the following two Croatian research were presented in more details. Using pooled annual data from 1998 to 2008 for four Croatian tourist regions (Dalmatia, Kvarner, Istra and Continental region) and applying the GLS regression method, [22] designed the model of demand for Croatian tourist product. As explanatory variables the authors used an average price, number of hotel's stars, GDP per capita of the origin country which generates the most tourists in region, the share of reservations and booking made online and the average age of the hotels. As a dependent variable, the number of overnight stays spent in hotels was employed. The main conclusions referred to the facts that income in Croatian key partnership countries is positively related to the tourism demand; that a rise in prices has negative impact on demand for tourism product, and that tourist businesses must take care of the usability of their own websites and have to ensure that customers can book services online. On the other hand, using panel data analysis, [21] evaluated dynamic model with GMM estimator on a dataset of 19 origin countries of tourists for the period from 1994 to 2009. The author found that income elasticity ranged from 0.2% to 0.5% depending on the applied model, while the price elasticity of substitute destinations ranged from 0.8% to 1.2%. In addition, results show that demand responds intensely to changes in relative prices and that capital investment has positive impact on the tourism demand in Croatia.

3 METHODOLOGY AND VARIABLES DESCRIPTION

Many of economic relations can be described as dynamic ones. Since previous consumption may affect the future one, when modelling tourism demand researchers usually incorporate dynamism by introducing a lagged dependent variable among explanatory factors. Garín-Muñoz [8], [9] explains the reasons that justify this inclusion. First, if the visitors are already familiar with the certain destination, their level of uncertainty is lower compared to the situation in which they visit a destination for the first time. Second, knowledge and information about the different tourist places spreads as people post their travel blogs on social media and/or talk about their holiday. In this way, an additional contribution to the reduction of the uncertainty for potential visitors is achieved. Finally, by neglecting the influence of past tourism, variables included in the model will be overestimated.

In line with stated, a lagged dependent variable ($Q_{i,t-1}$) is incorporated among the independent variables in the model which general form can be presented as:

$$\boldsymbol{Q_{it}} = \alpha + \delta \boldsymbol{Q_{i,t-1}} + \sum_{n=1}^{N} \boldsymbol{\beta_n X_{it}^n} + \boldsymbol{\varepsilon_{it}} \qquad \boldsymbol{\varepsilon_{it}} = \boldsymbol{v_i} + \boldsymbol{u_{it}} \tag{1}$$

where Q_{it} is the number of tourist nights from observed country i in period t, with i=1, . . .,M, t=1, . . ., T; δ is the speed of adjustment to equilibrium, $Q_{i,t-1}$ is the previous-year value of tourism demand i.e. tourist nights, α is a constant term, β's are the estimated coefficients, X_{it}'s are the predictors (i.e. income, price, corruption, terrorism, investments), ε_{it} stands for the disturbance, in which ν_i represents the unobserved country-specific effect while u_{it} denotes idiosyncratic error.

An obtained value of δ close to zero, would imply a high speed of adjustment toward its "optimal" level, while the value of δ close to one would indicate a very slow adjustment process. In the first case, the industry is fairly competitive, while in the second one, the industry is less competitive [2].

In models that incorporate dynamic specification, estimators such as OLS and GLS would produce biased and inconsistent estimates, hence, to overcome this problem, a Generalized Method of Moment procedure proposed by Arellano and Bond [1] is applied in this research. Still, to obtain a consistent and unbiased estimation, a GMM estimator require error to be serially uncorrelated. The examination of the first-order and second-order serial correlation is commonly done with Arellano and Bond test statistics (m1 and m2). GMM system estimator will be consistent only in case when there is no second-order serial correlation in residuals. A second specification test conventionally used in this sort of analysis is a Sargan test, which checks for validity of instruments. A dynamic panel model will be adequately specified only if a null hypothesis cannot be rejected. This would suggest that all chosen instruments, i.e. overidentifying restrictions, are valid.

All variables used in (1) were chosen based on relevant literature and previous research, as well as due to data availability. Concise description of all variables, together with their expected influence on tourist demand i.e. number of tourist nights, is provided in the following sections. The dataset refers to the period from 2012 to 2019 and it includes data on 16 countries of origin and 9 competitor countries.

Dependent variable (Q_{it}) is presented by the number of tourist nights from observed country *i* in year *t*. Only those countries of origin (United Kingdom and United States, Sweden, Slovakia, Slovenia, Poland, Netherlands, Norway, Italy, Hungary, Germany, Finland, France, Czech Republic, Denmark and Austria) from which Croatia realised the most tourist nights in given period are included in the sample. The data were collected from Croatian Bureau of Statistics, which defines tourist nights as every overnight stay of a person registered in an accommodation establishment.

Income (I). According to microeconomic theory, an increase in income for most of goods would increase demand for them. These types of goods are called normal. On the other hand, demand for inferior goods will decreases if income increases. In order to capture the impact of income on tourist arrivals, the majority of previous studies (e.g., [21], [22]) used GDP per capita in the origin country as a measure for tourist's income. The same variable is applied in this research and the data for it were collected from The World Bank official website. Since tourist travelling are mainly observed as normal or luxury good, the positive sign of this variable is expected.

Price (P). For the relative price variable, we followed the approach of [18], [4] and [10]. The variable representing the price of living in Croatia relative to the price of living in countries of origin is calculated as ratio of CPI_{CROt} and CPI_{it}. The data on CPIs (consumer price index) were obtained from The World Bank official website. As price and demand are inversely related, meaning that a decrease in price leads to an increase in demand, the negative sign of this variable is anticipated.

Corruption (Corr). As a measure of corruption, we applied the Corruption Perception Index provided by the Transparency International. This index ranks and scores territories/countries based on experts' and business executives' perception of how much a country's public sector is corrupted. Hence, this index is included in the model in order to examine how corruption perception in competitor countries affects tourism demand in Croatia. It is assumed that in the case of higher corruption perception in competitor destinations, tourists will prefer Croatia as their destination, ceteris paribus. For the calculation of this variable, average corruption perception indices of nine main competitor countries were taken into account. The competitors were selected following Croatian Institute for tourism [11] who finds Spain, Italy, Greece, Turkey, Malta, Bulgaria, Cyprus, France and Portugal as "Croatian wide competitive circle". Since the higher index indicates lower corruption perception, anticipated sign for this variable is negative.

Terrorism (Terr) influence is also included in the model by following the same approach as with corruption – how does terrorism in competitor destinations affect tourism demand in Croatia. As a measure of terrorism in competitor countries, their average rankings in the Global Terrorism Index (GTI) provided by Vision of Humanity were applied. All of nine competitors from Croatian wide competitive circle were taken into account, except of Bulgaria, Malta and Portugal for which the data were incomplete. It is assumed that visitors will prefer safer countries, so in case of terrorism in competitor destinations, they will spend their holidays in Croatia. Vision of Humanity ranks countries with highest indices (high level of terrorism) on the top and countries with lowest indices (absence of terrorism) on the bottom of the list. Given that the GTI rank is used in this model, a negative sign of terrorism variable is expected.

Investment (Inv). The last variable included in the model refers to gross investment made by stakeholders involved in providing accommodation, food, catering, and other hospitality services in Croatia. Data were collected from Croatian Bureau of Statistics. Following [16] who suggest positive effect of public and private investments on tourism growth, and [21] whose model showed positive and significant effect of capital investments on tourism demand, a positive sign of this variable is expected.

4 EMPIRICAL RESULTS AND DISCUSSION

Descriptive statistics of variables used in modelling foreign demand for Croatian tourist product is presented in the left part of the table 1. As all variables are presented in a form of natural logarithm, it is not surprising to observe a negative value for those variables whose original values were lower than 1, as it was for the variable price. The total number of tourist nights during the analysed period recorded significant increase, from 62.7 million in 2012, to

91.2 million in 2019. In a given sample, Germans (27.9%), Slovenes (11.2%) and Austrians (10.1%) prevail in the structure of total arrivals, while Danes (1.2%) and Finns (0.6%) are the least represented (2012-2019). According to the results of the correlation analysis (right part of the table 1), there is no presence of multicollinearity among analysed variables as none of the correlation coefficient is larger than 0.7 (or according to a stricter rule, larger than 0.6). The strongest correlation is recorded between price and investments and it amounted -0.56.

Table 1: Descriptive statistics and correlation analysis

Descriptive statistics					***Correlation analysis***					
Variable	***Mean***	***Std. Dev.***	***Min***	***Max***	***Q***	***I***	***P***	***Corr***	***Terr***	***Inv***
Q	14.691	1.002	12.055	16.810	1.000					
I	10.522	0.516	9.501	11.436	-0.405	1.000				
P	-0.016	0.029	-0.102	0.041	-0.120	0.102	1.000			
Corr	3.986	0.011	3.959	3.997	-0.028	0.001	0.066	1.000		
Terr	3.946	0.061	3.832	4.049	0.112	0.063	-0.479	0.072	1.000	
Inv	15.0123	0.3479	14.5147	15.4629	0.172	0.077	-0.560	-0.085	0.616	1.000

Source: Authors' calculation

The results of the estimated model for tourism demand (1) are presented in table 2. From this table it is clear that Sargan test indicates no presence of over-identifying restrictions. In addition, due to the insignificant p-value of m1 and m2 test, the null hypothesis (of no serial correlation) is accepted. As the model passed both of the presented (and earlier explained) tests, we can continue with the interpretation of the obtained results.

Table 2: Results of the dynamic panel model

	Q	
Variables	***Coef.***	***P***
Q_{t-1}	0.446671	0.000
I	0.895632	0.000
P	-1.396608	0.001
Corr.	-1.449419	0.000
Ter.	-0.478213	0.000
Inv.	0.118504	0.000
Cons	4.622719	0.013
No. of obs.	96	
Arellano-Bond (m1) (p-value)	0.2725	
Arellano-Bond (m2) (p-value)	0.4194	
Sargan test (p-value)	0.1960	

Source: Authors' calculation

The value of the lagged variable (Q_{t-1}), which represents tourism demand in previous year, is statistically significant and thus confirms the importance of incorporating the dynamism in the model specification. In line with the study [9], a lagged dependent variable can be explained as high loyalty of tourists to the selected destination as well as a crucial word-of-mouth effect on tourists' decision. Moderate value of δ coefficient (0.45) denotes that Croatian tourism industry is relatively competitive as demand for Croatian tourist product seem to have relatively moderate speed of adjustment. The signs of all coefficients are in line with our expectation and theoretical literature. In addition, all variables used in the proposed dynamic model are statistically significant at the level of 1%. Positive sign of *income* implies that the higher level of tourist income will increase tourist arrivals in Croatia. Since the value of the income coefficient, i.e., elasticity is 0.9%, a tourism product from Croatia can be consider as a normal good. Still, as this value is close to unity, it is on the edge of becoming luxury good. Similar results were recorded by [21] and [10]. In accordance with microeconomic theory, *price* has negative influence on tourist arrivals. The higher is the price, the lower is tourism demand (vice versa). The value of this coefficient (-1.4%) indicate that tourism demand is elastic, meaning that there is a substantial change in quantity demanded when the price of the tourism product changes. Due to the elastic demand, the best pricing strategy for hotels, apartments and other accommodations in Croatia would be to decrease a price (ceteris paribus), as on this way a higher level of revenues can be obtained. Presented results are in line with those of [9], [21], and [10]. When explaining the *index of corruption*, one must have in mind that higher value of this index indicates lower corruption perception. Therefore, the negative coefficient of corruption points toward proportional relationship between abroad corruption and tourist arrivals in Croatia, meaning that in the case of higher corruption perception in competitor destinations, tourists will prefer Croatia as their destination. This finding is in accordance with [17] and [20]. The same analogy can be applied for the variable *terrorism.* The obtained negative sign suggests that tourist arrivals in Croatia will increase in the case of higher terrorism activity in competitors' destinations. Researches of [25] and [7] also confirmed a significant impact of this variable on tourism demand. Finally, the influence of variable *investments* on tourism demand is positive, suggesting that any investment in accommodation, food, catering, and other hospitality services in Croatia will increase tourist arrivals. This result is in accordance with the one of [21] and [16] who were stressing the importance of taking care of tourists' well-being and the significance of the high-quality investments, as they may influence tourists' decision to visit a particular country.

5 CONCLUSIONS

Aiming to investigate the influence of different factors on tourism demand, this research used a panel dataset on 16 countries of origin and 9 competitor countries during the period from 2012 to 2019. As dynamic component is included in the formulated model, a GMM estimator was applied in the research. The results of the performed empirical analysis showed a statistically significant value of the lagged tourism demand variable with δ coefficient of 0.45 suggesting that Croatian tourism industry is relatively competitive as speed of adjustment toward its optimal level is not so fast. The results also indicate that all variables encompassed by the model have statistically significant influence on tourist arrivals in Croatia, while the sign of all coefficients are in line with the relevant literature. According to the obtained value of income elasticity (0.9%), a tourism product from Croatia can be seen as a normal good, for which the demand will grow parallel with the increase in tourists' income. On the other hand, price elasticity of -1.4% pointed toward an elastic demand for tourist arrivals. As microeconomic theory stress that (for elastic demand) higher levels of achieved revenue for hotels, apartments and other accommodation can be obtained only with a price reduction (ceteris paribus), managers should carefully plan and implement adequate pricing strategies. Achieved values for variables terrorism and corruption suggested that in the case of higher terrorism activity or corruptions in competitors' destinations, tourist will choose Croatia as a safer and more desirable country. In that sense, an adequate marketing mix and promotion of Croatia as a safe country by the Croatian National Tourist Board and other merit institutions are of vital importance. The results also revealed the importance of the investments in hospitality as they can produce beneficial effect on tourist arrivals.

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USE OF EMOTION IN DESIGNING BI DASHBOARDS

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Abstract: Due to increased focus on user experience and user interface optimization for users and customers, this trend leads to new methods for UX improvements. One of the methods is the use of emotion for getting additional feedback for UX designers. In this paper, we focused on finding relations among emotions, appearance, clarity, time, and a number of elements to improve Business Intelligence dashboards.

Keywords: UX – User Experience, UI – User Interface, BI – Business Intelligence, Designing BI dashboards, BI dashboards

1 INTRODUCTION

Using emotion in improving UX (user-experience) and adding value to development has been proven [3] [14] [15]. By nature, emotion drives human actions and decisions [16]. Using emotion in UX also contributes to the trend of using emotion in marketing [13]. UX is also considered as part of the marketing discipline. Improving the UX of any product has been proven to increase customer satisfaction and user satisfaction, leading to increased revenue, lower marketing costs, and justifying the return of the investments into better UX [10]. Also, better UX can increase the efficiency of employees [7].

Trends such as data analysis are booming not just in Business Intelligence (BI) but also in process mining, AI data automation, and others. This trend is booming due to the exponential growth of data, which can be related to Moore's law.[1]

Emotions are complex phenomena and are characterized by their high sensitivity and variability. The sensitivity of emotions to changes in personal, situational circumstances is reflected in the fact that emotions themselves can change without apparent changes in objective circumstances (based on a subjective assessment of the situation). In one situation, the emotions may be aroused, but not in another. [9]

Research supposes companies want to improve the UX of their BI dashboards to increase the efficiency of their employees or customers. Companies can use general UX designing methods for improving the UX, which has already been demonstrated in previous research [5]. Nevertheless, the traditional methods of measuring UX, such as eye-tracking, focus on measuring the manifestative effects of UX rather than the actual sentiment the system triggers. Therefore, in this paper, we focus on the sentimental analysis of UX. We believe that using emotion recognition software may help to speed up the process of software interface testing and, moreover, bring more precise results than other UX methods.

Most scientific articles focus on using emotions to express whether the user liked the product or not and whether the user is keen to use it further. [11] However, these studies do not mention how these emotions change in relation to the interface features such as the number of components, the use of white space or layout. In this paper, using FaceReader, the software for emotion recognition, we analyse how emotions can be used to formulate general design rules for Business Intelligence software. FaceReader is the most cited software worldwide for emotion recognition [4]. FaceReader recognizes Ekman's basic emotions, which include happiness, sadness, anger, surprise, fear, disgust and contempt [6]. FaceReader recognizes just the first six emotions from Ekman's seven basic emotions.

This paper aims to explore the possibility of using emotion recognition software to test user-friendliness during software development. To verify our hypotheses, we analyze the relationships between the User Experience and User Interface heuristics such as the number of elements, appearance, clarity, emotions and time necessary to complete defined tasks when testing various designs of the business intelligence dashboard. This study assumes that better UX & UI design is related to positive emotions such as happiness. Also, we suppose that confusing and ugly UX & UI designs can trigger negative emotions like sadness, anger, fear and disgust.

2 METHODOLOGY

This research is focused on revealing the dependencies among the number of elements, appearance, clarity, emotions, time, and various designs of business intelligence dashboards. Six different drafts (business intelligence dashboards) were selected with different designs, number of elements, colours, and indicators in the draft. It was most often a combination of tables, graphs, and numerical indicators. Two of the six images were specific in that they were drafts designed in spreadsheet software. The drafts are different in design; (draft 2) was a cleaned spreadsheet without colours, bold text, italics, or other graphic elements. The second table (draft 3) had precisely the same data, but graphic elements were used, such as bold text for headings and colours to separate the size of values. The number of elements in the draft was calculated for each draft. Numerical, graphic, and textual elements from the design were included in the elements.

The participants' tasks were to find two numerical values in all six drafts and say them aloud after finding them. The participants had never seen the drafts before, so the experiment results are coherent. Also, due to the coherence of the data, each participant had a randomly generated sequence of drafts and with the increasing number of repetitions, due to the "Law of Exercise"[1], participants could improve their ability to find values in the draft [8].

All research was conducted remotely due to the covid-19 pandemic. The whole experiment took place via the ZOOM platform. The experiment was recorded using an OBS studio for recorded computer areas and a webcam shot of each participant. Each participant's face was recorded for emotion analysis. The FaceReader software analysed manifestations of the participants' emotions from the recording. For the experiment, 20 participants from the field of management informatics across the bachelor's and master's degree programs were randomly selected. The population of all possible participants was 92 students. The age range of students was from 19 to 26 years.

For the experiment process, a date for the experiment interview was agreed on with every participant. The interviews were conducted online on the ZOOM platform. At the beginning of the interview, each participant was asked their age, gender, and questions that were not related to the experiment to put them at ease, so that each participant's emotions were as coherent as possible. It was also checked whether the participant had an adequately set up webcam that captured the entire face. Subsequently, a link to dashboard drafts was sent to the participant. Then the participant started sharing his screen and was instructed to open the first draft. Then the first question was read. After answering the first question, a second question was asked. This process was repeated for all drafts. The participant was timed for each draft,

[1] Law of Exercise – people get better with every repetition of some activity.

and time started after reading the first question and turned off after the second answer was heard. All six proposals were examined in this way. The last part of the interview was to score the appearance and clarity of the drafts. Every participant in the last part was asked to rate the appearance and clarity of each draft. Participants rated the drafts on a scale from 1-10, where 10 was the best score.

Subsequently, recorded images of participants' faces were analysed by FaceReader software. The data analysis was performed in JupyterLab. The correlation function in the Jupyter environment was used for the analysis of dependencies.

3 RESULTS

Table 1 shows the measured data for each BI dashboard draft from the experiment. The metrics of appearance, time, and clarity are the average of all values from all participants. The values of emotions are the average of all values measured by FaceReader software from all participants. Finally, the number of elements represents how many elements are in the design.

Table 1: Collected data from participants

Draft	*Number of elements*	*Time ⌀*	*Appearance ⌀*	*Clarity ⌀*		*Happy ⌀*	*Sad ⌀*	*Angry ⌀*	*Surprised ⌀*	*Scared ⌀*	*Disgusted ⌀*
Draft 1	223	33.25	4.9	4.35		0.104	0.049	0.100	0.028	0.011	0.039
Draft 2	215	22.55	3.45	5.75		0.094	0.059	0.080	0.021	0.024	0.043
Draft 3	215	17.4	5.1	6.7		0.079	0.054	0.116	0.020	0.025	0.024
Draft 4	159	18	7.2	7.3		0.074	0.049	0.055	0.028	0.014	0.027
Draft 5	42	14	8.925	8.85		0.152	0.038	0.067	0.019	0.016	0.037
Draft 6	173	22	7.1	6.7		0.060	0.058	0.074	0.029	0.020	0.026

A correlation matrix was created from the data in Table 1. Pearson correlation was used for the calculation. The results of the experiment are presented in Figure 1, where the individual dependencies of the metrics between each other can be seen. It can be seen from Figure 1 that the dependence between appearance and clarity is a high dependence with a correlation coefficient of 0.81. Furthermore, a very strong negative dependence between clarity and time was measured with a correlation coefficient of -0.93.

This means that poorer clarity correlates with a longer time to find the indicator in the proposal. A strong negative dependence was measured between clarity and the number of elements with a correlation coefficient of -0.87. Also, the number of elements negatively correlates with the appearance. The correlation coefficient is -0.88, where a higher number of elements negatively affects the appearance and also the clarity.

Dependencies between emotions and other metrics:

Happiness is negatively correlated with the number of elements and the coefficient -0.67; higher number of elements reduces user happiness. The dependence between happiness and appearance is weak, with a coefficient of 0.35. Between happiness and clarity, there is also a weak dependence with a value of 0.37. The relationship between time and happiness has not been measured.

Sadness is strongly correlated with the number of elements with a coefficient value of 0.78. The dependence between sadness and appearance is high and negative with a coefficient of -0.7. Between sadness and clarity, the dependence is negative and is moderately strong with a coefficient of -0.53. The relationship between sadness and time has not been measured.

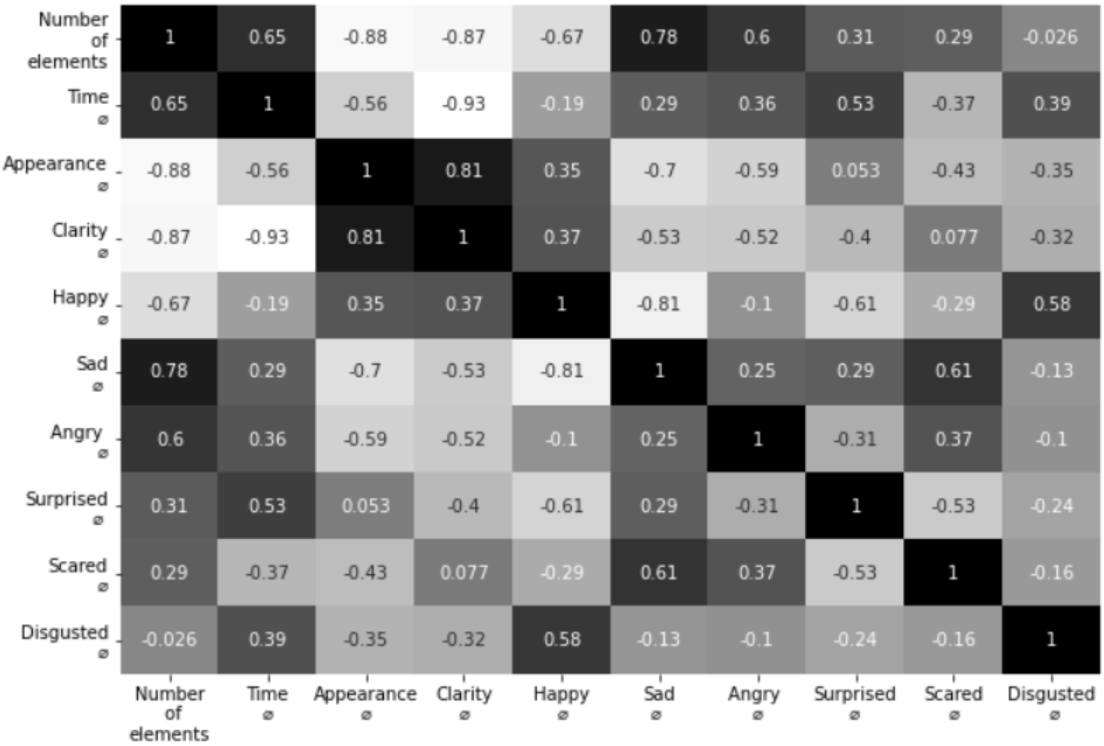

Figure 1: Results of experiment in the correlation matrix

Anger correlates with the number of elements, and the dependence is moderate with a value of 0.6. The angry emotion is negatively correlated with appearance and clarity. The strength of the dependence is medium, and the values are -0.59 and -0.52. A weak relationship between anger and time was measured with a value of 0.36.

Surprise correlates with time, and the value of correlation is 0.53. Surprise correlates with the number of elements with a value of 0.31. Furthermore, a negative dependence between surprise and clarity was found. The strength of the dependence is weak, with a value of -0.4. The relationship between surprise and appearance has not been measured.

The emotion scared negatively correlates with time, and the strength of dependence is weak with a value of -0.37. Scared negatively correlates with appearance. The value is -0.43. The relationships between scared, number of elements, and clarity were not measured.

Disgust correlates with time, and the dependence is weak with a value of 0.39. Disgust negatively correlates with appearance, and the size of the dependency is weak with a value of -0.35. Disgust further negatively correlates with clarity. The strength of the dependence is weak, with a value of -0.32. The relationship between disgust and the number of elements has not been measured.

4 DISCUSSION

In the research, we analyzed the relationships between the User Experience and User Interface heuristics such as the number of elements, appearance, clarity, emotions and time necessary to complete defined tasks when testing various designs of business intelligence dashboards. The experiment confirmed the assumption that good UX & UI design correlates with positive emotions and confusing and ugly UX & UI designs correlate with negative emotions. A similar hypothesis was tested in **[17]**, where they analyzed if completing complex tasks on websites could trigger anger via FaceReader. The results of their research were similar; complicated websites trigger the anger of users. Other research results [3] show that difficult and complex UI is hard to use and negatively influences the users' emotions. This provides further evidence to prove the results of this paper in that a higher number of elements and lower clarity trigger users' negative emotions like anger, sadness, disgust or fear.

Face recognition of emotion was reviewed and studies were conducted to validate if the results of face recognition software are reliable. Research papers focused on FaceReader indicate some limitations on the side of FaceReader and on the side of the environment's set-up, which can influence the results. The results in [12] point out the importance of the priming participants because priming influences measurement by FaceReader. Nevertheless, results from FaceReader in most cases match with participants' feeling during self-assessment. Similar conclusions are reported in [2]. The research in [18] shows that FaceReader has a statistically significant deviation compared to other methods of tracking emotion like EMC, but in self-assessment comparison there were no statistically significant differences in results compared to FaceReader. These papers show there can be inaccuracies in measuring emotions. However, none of the research proves high inaccuracy and, in most cases, FaceReader provides reliable results. Minor inaccuracies are also eliminated by a higher number of participants. In the research conducted here, 20 participants were involved, which we consider as reputable to mitigate inaccuracies caused by priming of participants or FaceReader.

5 CONCLUSION

The results confirmed that metrics connected with good UX & UI positively influence the emotion of the user. On the other hand, metrics connected with confusing and ugly UX & UI negatively influence the users. There is the correlation among metrics such as number of elements, appearance, clarity, and time to complete certain tasks and emotions.

Research conducted on a similar topic confirmed analogous results to this research.

Thanks to these findings, it is possible to make a few recommendations for designing and optimizing BI dashboards. If people say that a proposal is nice, then it is very likely that it is also clear. This logic also holds true the other way around – if the design is not nice, then it is most likely not clear. Another recommendation is to eliminate unnecessary indicators because a higher number of elements increases the time and reduces the clarity of the BI dashboard. Reduced clarity leads to lower appearance. A higher number of elements reduces user happiness. Also, if the designs are nice and clear, the user will be happier. The opposite is also true – if the designs are ugly and confusing, it makes the user unhappy. Ugly and confusing designs make users angry. Also, nicer designs and clearer designs make users less disgusted.

The research of the experiment was conducted during the covid-19 pandemic, and all data gathering was done through online interviews. This may lead to minor distortion between participants' results. However, despite the effort to ensure that all participants have the most similar conditions possible, it has not been possible to ensure that all participants have a high-speed internet connection and a quality webcam for the best possible emotion analysis record. Also, the environment in which the participants were located could affect the results of individual participants. Drafts of individual BI dashboards are sorted according to Table 1 and can be seen here[2].

Further challenges will be to replicate these results on other applications like websites, software applications or mobile apps and provide general recommendations for designing UX & UI. Further research can also lead to finding more indicators that can influence user's emotions.

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[2] https://github.com/Scherifow/USE-OF-EMOTION-IN-DESIGNING-BI-DASHBOARDS

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SEEKING HEALTH INFORMATION OVER THE INTERNET: CLUSTER ANALYSIS APPROACH TO ANALYZING DIFFERENCES AMONG EUROPEAN COUNTRIES

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Abstract: Health care has been recently under the strong impact of information and communication technologies, especially the internet. eHealth has become one of the most often mentioned concepts that raise hope for the increasing effectiveness of health care. Patients increasingly seek health information over the internet, thus increasing their access to knowledge and expertise available online. The paper aims to investigate the differences among individuals living in households with different levels of income and different levels of education in European countries according to their habits of seeking health information over the internet. For that purpose, K-means cluster analysis was used. We use the elbow method to determine the optimal number of clusters, which considers the percentage of variance explained as a function of the number of clusters. Data about the habits of seeking health information over the internet from the Eurostat database is used. Results indicate that education and income have a substantial impact on seeking health information on the internet. However, the differences among countries are the largest for the households with the income in the fourth quartile and the smallest for the households with the income in the first quartile.

Keywords: health care, e-health, information seeking, Internet, Europe, Eurostat, cluster analysis

1 INTRODUCTION

The usage of the internet increases every day, while it presents the medium and a platform for information exchange. However, due to unequal digital and economic development, countries have a persistent digital divide, especially in Internet access and usage [6]. One of the critical areas of internet usage is informing individuals about their health. Health information online presents a valuable resource for understanding individuals' health situations and engaging in self-management [1]. By using the internet as the relevant source of health information, individuals have grown more self-reliant in making decisions and controlling their health [2]. Usage of the Internet in the health field improved interactions among individuals and medical systems and enables getting additional information about health, diseases, medical treatment. However, caution is essential due to many fake and misinterpreted information [3]. On the other hand, demographic characteristics of individuals, such as age, education, income, ethnicity, impact their habits in finding health information via the internet [7]. Research shows that online health seekers are mostly highly educated young individuals with higher income levels [8].

The paper's primary goal is to investigate to what extent individuals living in households with different levels of income and different levels of education in European countries seek health information over the internet. Furthermore, we aim to determine the relationship between health information usage and the economic development measured by the Global Competitiveness Index (GCI) and information society development measured by the Digital Economic and Society Index (DESI) in European countries. For that purpose, we use the data collected from Eurostat and World Economic Forum and invetisgate it using k-means cluster analyses and Kruskal-Wallis teste. Findings show that the most developed European countries are also leaders in seeking health information over the internet.

The paper consists of five sections. After the introduction, the second section presents the methodology, data and statistical analysis. The third section provides research results of descriptive and cluster analysis, as well as Kruskal-Wallis test results. The last section concludes the paper with the limitations of the study and future implications.

2 METHODOLOGY

2.1 Data

Data about behaviour related to seeking health information over the internet are collected from Eurostat for the year 2018 and 26 European countries (Table 1). There are nine collected variables which are divided into four groups: (i) % of individuals seeking health information via the internet, living in households with income in 1st quartile (Q1), 2nd quartile (Q2), 3rd quartile (Q3), 4th quartile (Q4); (ii) % of individuals seeking health information over the internet, individuals with low, medium and high education; (iii) GCI and (iv) DESI.

Table 1: Variable used in the analysis, % of individuals, in 2018

Behaviour related to seeking health information over the internet	***Name of the variable***
Percentage of individuals seeking health information over the internet, living in households with income in the first quartile (Q1), second quartile (Q2), third quartile (Q3), and fourth quartile (Q4)	HEALTH_Q1_2018 HEALTH_Q2_2018 HEALTH_Q3_2018 HEALTH_Q4_2018
Percentage of individuals seeking health information over the internet, individuals with low, medium, and high formal education	HEALTH_LOW_2018 HEALTH_MEDIUM_2018 HEALTH_HIGH_2018
GCI	GCI_2018
DESI	DESI_2018

Source: Authors' work based on Eurostat data (2018), GCI data (2018), and DESI index data (2018)

2.2 Statistical Analysis

Statistical analysis is conducted in three main steps: (i) descriptive statistics; (ii) k-means cluster analysis; and (iii) Kruskal-Wallis test. First, the observed variables are analyzed using the measures of central tendencies and dispersion. Second, cluster analysis has been used for determining the level of digital divide among European countries regarding health-seeking behaviour. In this research, we use k-means, which is the partitioning cluster analysis. The machine learning approach, using V-fold methodology, is used for determining the optimal number of clusters. Third, the Kruskal-Wallis test compares the level of GCI and DESI across the clusters, which provides the basis for measuring the relationship of economic development and the development of information society with health information-seeking behaviour.

3 RESULTS

3.1 Descriptive analysis

Table 2 presents descriptive statistics for variables regarding health information seeking over the internet among individuals with different income and education levels (2018). The highest mean value has the variable "HEALTH_Q4_2018", measuring the percentage of people seeking health information over the internet in the fourth income quartile. Regarding education level, the highest mean value has the variable "HEALTH_HIGH_2018", measuring the percentage of people seeking health information over the internet with the high education.

Table 2: Descriptive statistics of health information seeking over the internet, in 2018, % of individuals

2018	*Valid N*	*Mean*	*Minimum*	*Maximum*	*Std. Dev.*
HEALTH_Q1_2018	26	40.038	8	68	15.565
HEALTH_Q2_2018	26	48.077	21	70	13.014
HEALTH_Q3_2018	26	56.038	26	74	12.045
HEALTH_Q4_2018	26	62.808	36	80	11.161
HEALTH_LOW_2018	26	44.462	12	73	17.075
HEALTH_MEDIUM_2018	26	57.654	24	81	13.115
HEALTH_HIGH_2018	26	70.731	44	90	11.918
GCI	26	72.027	60.1	82.8	6.952

Source: Authors' work based on Eurostat data (2018)

Figure 1 presents the percentage of individuals seeking health information via the internet, living in households with income in the 1st quartile (Q1), in the 2nd quartile (Q2), in the 3rd quartile (Q3), and the 4th quartile (Q4), in 2018. In all selected countries, individuals living in households with income in the 4th quartile seek health information via the internet the most. The leaders are Netherlands and Finland. The lowest percentage of individuals living in households with income in the 1st quartile seek health information via the internet. Countries that are lagging behind the most are Bulgaria and Romania.

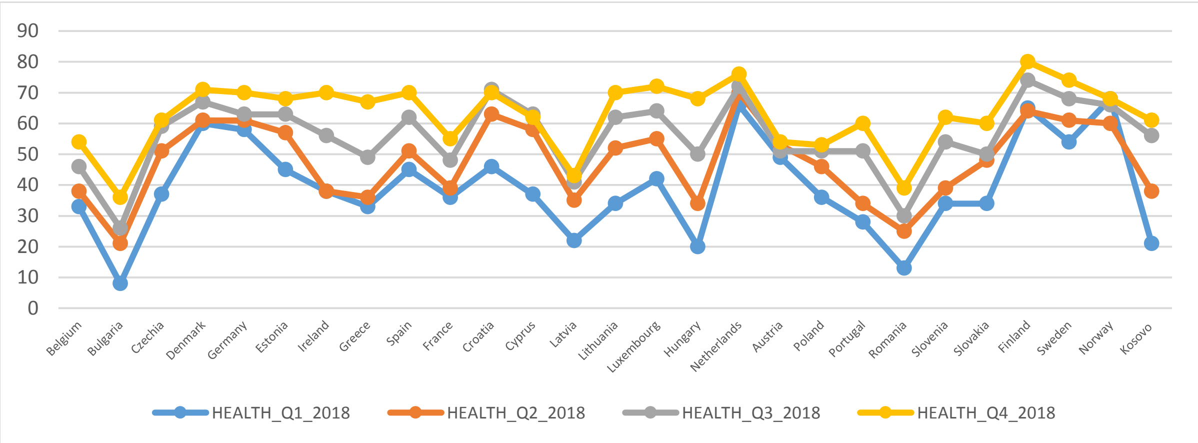

Figure 1: Percentage of individuals seeking health information over the internet, living in households with income in 1st quartile (Q1), 2nd quartile (Q2), 3rd quartile (Q3), and 4th quartile (Q4), in 2018, % of individuals
Source: Authors' work based on Eurostat data (2018)

Figure 2 presents the percentage of individuals seeking health information via the internet with low, medium, and high formal education, in 2018. The situation is quite similar to income level. In all selected countries, individuals with high formal education seek health information via the internet the most. The leaders are Netherlands and Finland. At the same time, those individuals with a low level of information seek health information via the internet the less like individuals from Bulgaria and Romania.

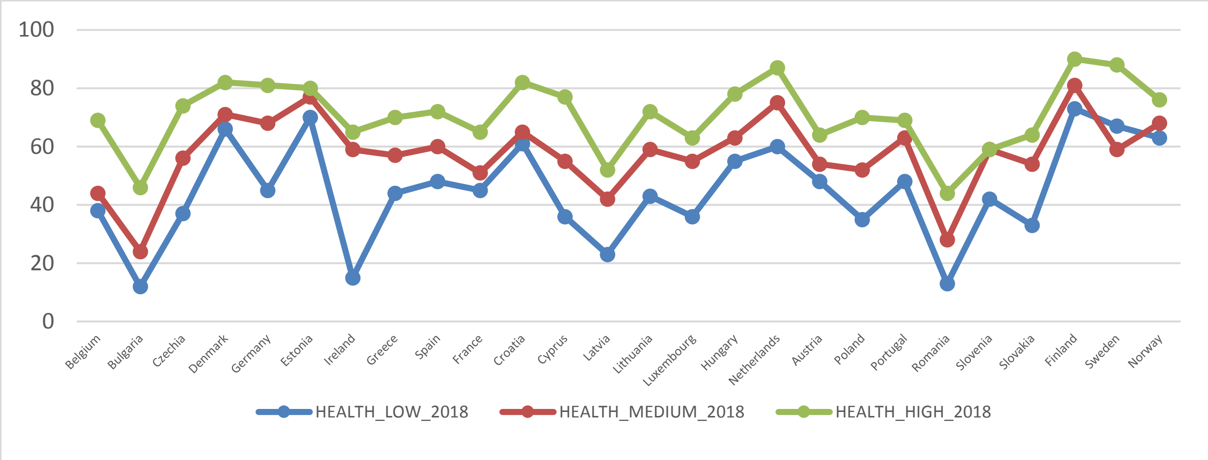

Figure 2: Percentage of individuals seeking health information over the internet, low, medium, and high formal education, in 2018, % of individuals
Source: Authors' work based on Eurostat data (2018)

Figure 3 presents the level of GCI and DESI index in 2018. There is a higher level of GCI index for all selected European countries than the DESI index in 2018. GCI index refers to macro and micro-economic aspects of competitiveness, while DESI index presents digital competitiveness. Therefore, all selected countries have a higher level of economic development than digital development.

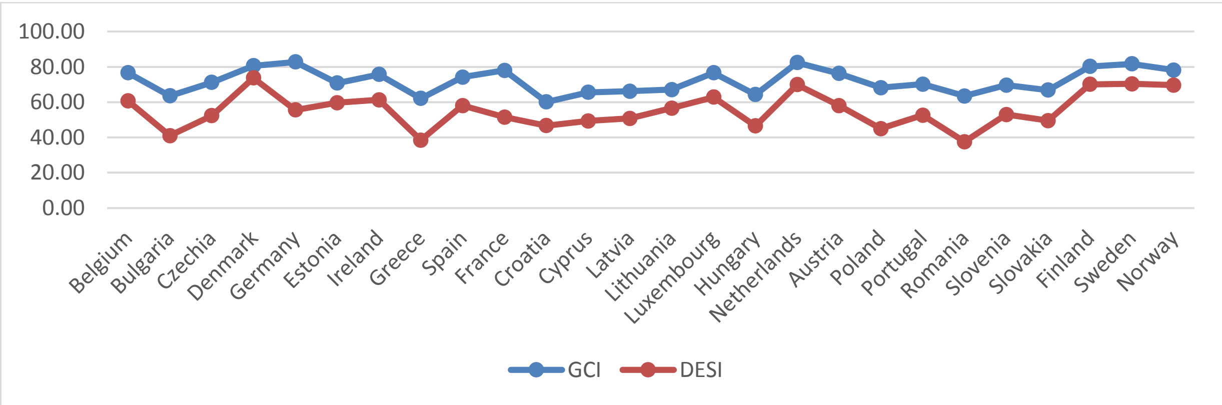

Figure 3: GCI and DESI index in 2018
Source: Authors' work based on DESI index (2018) and World Economics Report (2018)

3.2 K-means clustering

Validity of cluster analysis

The V-fold approach was used for determining the number of clusters in combination with the elbow rule. Figure 4 presents the graph of the cost sequence, which suggests that the solution with the three clusters is optimal. Table 3 presents results of Anova analysis and k-means clustering for seven variables (percentage of individuals seeking health information via the internet, living in households with income in the 1st, 2nd, 3rd, 4th quartile and percentage of individuals seeking health information via the internet with low, medium and high formal education in 2018) which are grouped into 3 clusters and for 26 selected European countries. All seven variables are statistically significant at 1%, which suggests that the given result of using three clusters is justified.

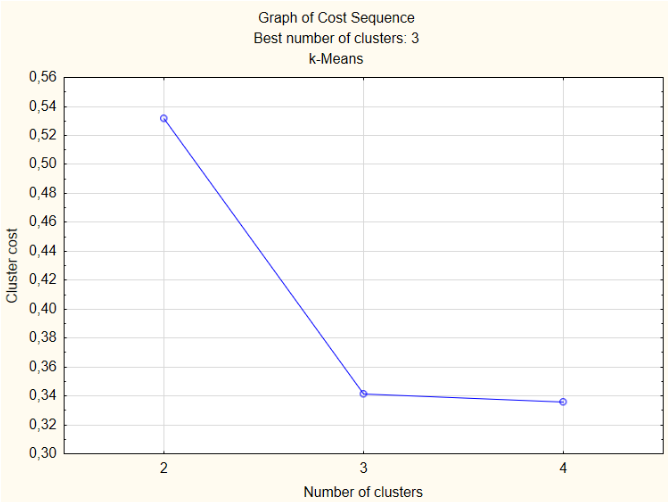

Figure 4: Graph of the cost sequence
Source: Authors' work based on Eurostat data (2018)

Table 3: Anova analysis, k-means clustering; 7 variables, 3 clusters, n=26 countries

	ANOVA for continuous variables; Number of clusters: 3					
2018	***Between SS***	***df***	***Within SS***	***df***	***F***	***p-value***
HEALTH_Q1	4769.862	2	1287.100	23	42.618	0.000***
HEALTH_Q2	3072.571	2	1161.275	23	30.427	0.000***
HEALTH_Q3	2870.695	2	756.267	23	43.653	0.000***
HEALTH_Q4	2348.763	2	765.275	23	35.296	0.000***
HEALTH_LOW	5489.187	2	1799.275	23	35.084	0.000***
HEALTH_MEDIUM	3436.285	2	863.600	23	45.759	0.000***
HEALTH_HIGH	2956.015	2	595.100	23	57.123	0.000***

Source: Authors' work based on Eurostat data (2018); *Note*: *** statistically significant at 1%

Cluster analysis

Table 4 presents cluster means for seven selected variables. The highest mean value has Cluster 3, which is followed by Cluster 1, and the lowest mean value has Cluster 2. It could be concluded that Cluster 3 are countries whose individuals with income in the 1^{st}, 2^{nd}, 3^{rd}, 4^{th} quartile and with low, medium, and high educational levels use the internet the most to seek health information. Furthermore, countries grouped into Cluster 2 use the internet the least to seek health information regardless of income and educational level.

Table 4: Cluster means, k-means clustering; 7 variables, 3 clusters, n=26 countries

2018	***Cluster 1***	***Cluster 2***	***Cluster 3***
HEALTH_Q1	35,7	14,3	57,8
HEALTH_Q2	44,8	27,0	62,1
HEALTH_Q3	54,4	32,3	68,0
HEALTH_Q4	62,5	39,3	72,1
HEALTH_LOW	40,2	16,0	63,1
HEALTH_MEDIUM	56,1	31,3	70,5
HEALTH_HIGH	68,7	47,3	83,3
Number of cases	15	3	8
Percentage (%)	57,7	11,5	30,8

Source: Authors' work based on Eurostat data (2018)

Table 5 presents countries across clusters. In Cluster 1, there are the following countries: Belgium, Czechia, Ireland, Greece, Spain, France, Cyprus, Lithuania, Luxembourg, Hungary, Austria, Poland, Portugal, Slovenia, Slovakia. Individuals from mentioned countries, including developing and developed countries, are in the middle regarding using the internet to seek health information regardless of income or education level. In Cluster 2, there are only three countries: Bulgaria, Latvia, Romania. These countries are primarily at the end of scale regarding economic or technology development. Individuals from countries grouped into Cluster 2 use the internet the less for seeking health information via the internet. The reason is that they are lagging from developed countries and cannot provide their citizens' knowledge nor infrastructure for using the internet. The most developed European countries are grouped into Cluster 3: Denmark, Germany, Estonia, Croatia, Netherlands, Finland, Sweden, Norway. The exception is Croatia regarding the GCI and Desi index level, while other countries are leaders regarding economic or technological development. However, the results of the descriptive analysis showed that for mentioned developed countries and also for Croatia, there is a high percentage of individuals seeking health information over the internet no matter on income or education in 2018. Individuals are more eager to seek information via the internet and to find more information about health issues.

Table 5: Countries across clusters

Cluster	***Countries***
Cluster 1	Belgium, Czechia, Ireland, Greece, Spain, France, Cyprus, Lithuania Luxembourg, Hungary, Austria, Poland, Portugal, Slovenia, Slovakia
Cluster 2	Bulgaria, Latvia, Romania
Cluster 3	Denmark, Germany, Estonia, Croatia, Netherlands, Finland, Sweden, Norway

Source: Authors' work based on Eurostat data (2018)

We evaluated the GCI and DESI mean values across clusters to determine if there is a positive relationship between economic development and using the internet for seeking health information (Table 6 and Table 7). Cluster 3 has the highest internet usage for finding health information, and countries grouped into Cluster 3 have the highest values of the GCI and the highest values of the DESI. Other clusters lagging regarding Internet usage for finding health information also lagged according to the values of the GCI index and DESI. The Kruskal-Wallis test (H=9.204, p-value=0.006) confirmed that the found differences are statistically significant at 1% for CGI across clusters. Besides, the Kruskal-Wallis test (H=10.231, p-value=0.010) confirmed that the found differences are statistically significant at 5% for DESI across clusters. Therefore, the hypothesis that there is a positive relationship between economic development, information society development and the internet to seek health information is confirmed.

Table 6: Descriptive statistics of GCI and DESI index according to clusters; Kruskal-Wallis of GCI and DESI index differences according to clusters

	GCI			***DESI***		
Clusters	***Means***	***N***	***Std. Dev.***	***Means***	***N***	***Std. Dev.***
Cluster 1	70,833	15	5,129	53,033	15	6,737
Cluster 2	64,433	3	1,531	43,100	3	6,894
Cluster 3	77,113	8	7,875	64,463	8	9,450
Total	72,027	26	6,952	55,404	26	10,100
H (2, N= 26)	9,204			10,231		
P-value	0,010**			0,006***		

Source: Authors' work based on GCI and DESI index (2018)
Note: *** statistically significant at 1%: ** statistically significant at 5%

4 CONCLUSIONS

The internet has become a vital source of information about health, diseases, and medical treatment for the general public, patients, and healthcare professionals. Although there could be fake information, misinformation, and potential difficulties with the confidentiality of information gathered, distributing the health information via the internet may make people better informed. In turn, this could lead to better health outcomes and more appropriate use of health service resources. However, ICTs infrastructure, income, information literacy, and educational level of the individuals are the source of significant differences among countries regarding seeking health information via the internet.

The paper aimed to investigate differences among individuals in European countries, focusing on their habits related to internet usage seeking health information. Our research applied cluster analysis and identified three clusters with distinctive differences according to analyzed variables on using the internet to seek health information. Research results showed that education and income are essential to enhancing Internet usage for finding health information among European countries. Furthermore, economic and IT development also influence individuals and their interest in health information via the internet.

Future research should determine how to foster information literacy and provide adequate IT infrastructure for individuals to gain health information via the internet, such as big data [4] and knowledge management [5]. There are also few limitations of our paper. The data should include more variables regarding seeking health information over the internet and investigate its relationship with different demographic characteristics like age, work experiences, places of living. In addition, different statistical methods should be conducted over a more extended period. Furthermore, comparing countries worldwide regarding seeking health information via the internet should give more a global overview, taking into account the position of developing countries.

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CRITICAL EDGES IN WEIGHTED CENTER PROBLEMS

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Abstract: A large number of location problems that are solved in transportation and logistics can be represented by a weighted p-center problem. In our paper, we suggest a method for the detection of critical edges according to the weighted p-center. Detection of such edges allow us to study the robustness of public service systems that are represented by a weighted p-center.

Keywords: weighted p-center, transportation network, critical edge, transportation performance.

1 INTRODUCTION

Location of emergency stations, firehouses, and depots belongs to the class of location problems that are usually represented by weighted p-median or p-center problems. Solutions of these problems are often suggested for ideal conditions and many authors do not consider various random events that can elongate the traverse time through the edge. The effect of such elongation of driving time through the single edge on properties of transportation networks was studied in [3], [6] and [7]. The impact of the elongation on the solution of the weighted p-median problem was studied in [2] and [5], where the transportation performance was defined. In [1], the changes of transportation performance were studied, when more than one edge is affected. Since the previous papers did not deal with the robustness of weighted p-centers, we decided to introduce the study of this concept. In our paper, we define the maximum transportation performance. We use it for the detection of the most critical edges for the given solution of a weighted p-center problem.

2 DEFINITIONS

Let a network $G = (V, E, w, t)$ be given, where V is the set of vertices, E is the set of edges, the function $w: V \to R_0^+$ represents the weights of vertices, and the function $t: E \to R_0^+$ represents the driving times through the edges. We will suppose in our paper that the driving times are natural numbers. The set of centers is denoted by S. The set of customers is denoted by U (where $S \subset V$ and $U \subset V$). We say that vertex $u \in U$ is affected by edge $e \in E$, if this edge belongs to the shortest path from u to S. Graph (network) G with deleted edge e is denoted by $G - e$. A bridge is an edge whose deletion increases the number of connected components of G. A significant bridge is an edge e whose deletion creates in $G - e$ a connected component that contains some customers (vertices from U) but no service center (vertex from S). The driving time from the closest center to the customer $u \in U$ is denoted by $t(u, S)$, where

$$t(u, S) = \min\{t(u, v): v \in S\}.$$

If we need to recognise the network in which we measure the driving time (say network G), then the driving time is denoted by $t_G(u,S)$.

The transportation performance that is carried out for customer u ∈ U is denoted by

$$W(u) = w(u) \cdot t(u,S).$$

In [2], a concept similar to the weighted p-median was used to define the total transportation performance

$$W_T = \sum_{u\in U} w(u) \cdot t(u,S) = \sum_{u\in U} W(u).$$

Similarly, we can define the maximum transportation performance

$$W_M = \max_{u\in U}\{w(u) \cdot t(u,S)\} = \max_{u\in U}\{W(u)\}.$$

Let $Y = \{e_1, e_2, \cdots, e_k\} \subset E$ be the set of edges and $x_1, x_2, \cdots, x_k$ be the extensions of driving times on these edges. We denote the total transportation performance with these extensions by

$$W_T(x_1, \cdots, x_k|Y)$$

and the maximum transportation performance by

$$W_M(x_1, \cdots, x_k|Y).$$

The changes of total and maximum transportation performance can be defined in the following way:

$$V_T(x_1, \cdots, x_k|Y) = W_T(x_1, \cdots, x_k|Y) - W_T,$$
$$V_M(x_1, \cdots, x_k|Y) = W_M(x_1, \cdots, x_k|Y) - W_M.$$

Both V_T and V_M are functions of k variables with domains $\langle 0, \infty)^k$.
The behaviour of V_T was studied in [2] and [5] for $k = 1$, and in [1] for $k = 2$. In these papers, it was shown that V_T is continuous, concave and piecewise linear in its domain. In the above-mentioned works, it was also shown how to compute the formula for V_T. In this paper, we do the same for V_M.

3 CHANGES OF MAXIMUM TRANSPORTATION PERFORMANCE

Text We consider the case $k = 1$. We suppose that there is an extension of driving time x on the edge e. For the function $V_M(x|\{e\})$, we will use the shorter notation $V_M(x|e)$. For each $u \in U$, we define a special function

$$V_M(x|e;u) = w(u) \cdot \left[\alpha(x|e;u) \cdot (t_G(u,S) + x) + \left(1 - \alpha(x|e;u)\right) \cdot t_{G-e}(u,S)\right] - w(u) \cdot t_G(u,S),$$

where $G - e$ is network G without edge e, $\alpha(x|e;u) = 1$ when the edge e belongs to the shortest path from u to S, even when there is an extension of driving time x on the edge e, and $\alpha(x|e;u) = 0$ otherwise. It means that the value of $\alpha(x|e;u)$ changes from 1 to 0, if it is profitable to avoid the edge e for value x. It is easy to consider that this situation happens when $x = t_{G-e}(u,S) - t_G(u,S)$.

Hence, we can write

$$\alpha(x|e;u) = \begin{cases} 1; \ if \ x \in \langle 0, t_{G-e}(u,S) - t_G(u,S)), \\ 0; \ if \ x \in \langle t_{G-e}(u,S) - t_G(u,S), \infty). \end{cases}$$

From this, we obtain

$$V_M(x|e;u) = \begin{cases} w(u) \cdot x; \ if \ \alpha(x|e;u) = 1, \\ w(u) \cdot \left(t_{G-e}(u,S) - t_G(u,S)\right); \ if \ \alpha(x|e;u) = 0. \end{cases}$$

There are two special cases:

i. $\forall x \in \langle 0, \infty) \ \ V_M(x|e;u) = w(u) \cdot x,$
ii. $\forall x \in \langle 0, \infty) \ \ V_M(x|e;u) = w(u) \cdot \left(t_{G-e}(u,S) - t_G(u,S)\right) = 0.$

Case ii. means that the edge e does not belong to the shortest path from u to S and we can omit such vertex u from our computations.
Moreover, for every $x \in \langle 0, \infty)$, it holds

$$V_M(x|e) = \max_{u \in U}\{V_M(x|e;u)\}.$$

It was mentioned above that the function V_T is continuous, concave and piecewise linear. Moreover, for $k = 1$ (and $t(e)$ from natural numbers), the formulas of V_T change only in non-negative integers. The following example shows that V_M is not concave and its formulas can change also in points that are not integers.

Example. Network G is in Figure 1. Customers are in vertices u_1 and u_2. Their weights are $w(u_1) = 3$ and $w(u_2) = 2$. The unique center is located at vertex s. The studied edge e is between vertices v_2 and s.

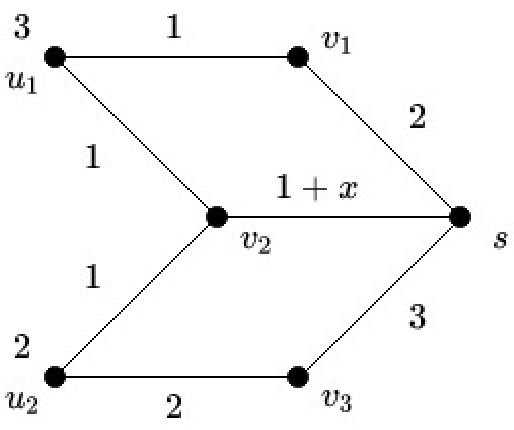

Figure 1: The network G from example.

For functions $V_M(x|e;u_1)$ and $V_M(x|e;u_2)$, we have

$$V_M(x|e;u_1) = 3 \cdot [\alpha(x|e;u_1) \cdot (2 + x) + (1 - \alpha(x|e;u_1) \cdot 3)] - 3 \cdot 2,$$

$$V_M(x|e;u_2) = 2 \cdot [\alpha(x|e;u_2) \cdot (2+x) + (1 - \alpha(x|e;u_2) \cdot 5)] - 2 \cdot 2,$$

where

$$\alpha(x|e;u_1) = \begin{cases} 1;\ if\ x \in \langle 0,1) \\ 0;\ if\ x \in \langle 1,\infty) \end{cases} \text{ and } \alpha(x|e;u_2) = \begin{cases} 1;\ if\ x \in \langle 0,3) \\ 0;\ if\ x \in \langle 3,\infty). \end{cases}$$

Hence, we have

$$V_M(x|e;u_1) = \begin{cases} 3x;\ if\ x \in \langle 0,1) \\ 3;\ if\ x \in \langle 1,\infty) \end{cases} \text{ and } V_M(x|e;u_2) = \begin{cases} 2x;\ if\ x \in \langle 0,3) \\ 6;\ if\ x \in \langle 3,\infty). \end{cases}$$

If we use the rule

$$V_M(x|e) = \max_{u \in U}\{V_M(x|e;u)\},$$

then we obtain the following formulas

$$V_M(x|e) = \begin{cases} 3x;\ if\ x \in \langle 0,1) \\ 3;\ if\ x \in \langle 1,3/2) \\ 2x;\ if\ x \in \langle 3/2,3) \\ 6;\ if\ x \in \langle 3,\infty). \end{cases}$$

The graph of the function $V_M(x|e)$ can be seen in Figure 2. Since each of the functions $V_M(x|e,u)$ is non-decreasing, $V_M(x|e)$ is also non-decreasing. Functions $V_M(x|e,u)$ are continuous and, together with properties of $max\{\cdots\}$, we obtain the result that $V_M(x|e)$ is also continuous on $\langle 0,\infty)$. Hence, this function is continuous and non-decreasing; it is easy to show that it is also piecewise linear.

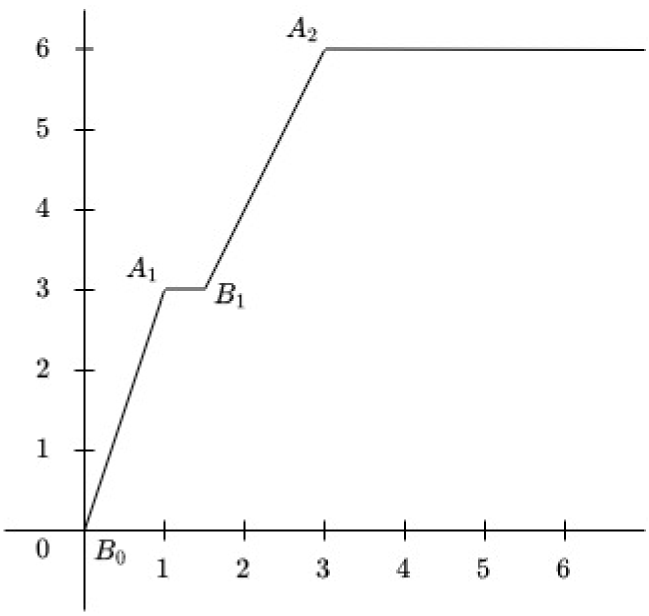

Figure 2: Graph of the function $V_M(x|e)$.

4 ALGORITHM FOR COMPUTATION OF MAXIMUM TRANSPORTATION PERFORMANCE

In this section, we introduce an algorithm for the computation of function $V_M(x|e)$. We distinguish between two cases: i) e is not a significant bridge, and ii) e is a significant bridge.
i) Edge e is not a significant bridge.
The algorithm for the computation of $V_M(x|e)$ is

1. Find set U_e of the vertices affected by edge e.
2. For each $u \in U_e$ compute $d(u) = d_{G-e}(u,S) - d_G(u,S)$.
3. Omit each vertex $u' \in U_e$ such, that there is vertex $u \in U_e$, for which $w(u) = w(u')$ and $d(u) > d(u')$.
4. Omit each vertex $u' \in U_e$ such, that there is vertex $u \in U_e$, for which $w(u) > w(u')$ and $w(u) \cdot d(u) \geq w(u') \cdot d(u')$.
5. From the remaining vertices create sequence $\langle u_1, u_2, \cdots, u_k \rangle$,

   where $i < j \Leftrightarrow w(u_i) > w(u_j)$.
6. Let $B_0 = [0,0]$.
7. For $i = 1, \cdots, k \quad A_i = [d(u_i), w(u_i) \cdot d(u_i)]$.
8. For $i = 1, \cdots, k-1 \quad B_i = [d(u_i) \cdot w(u_i)/w(u_{i+1}), d(u_i) \cdot w(u_i)]$.
9. Function $V_M(x|e)$ has for $i = 1, \cdots, k-1$ formula

$$V_M(x|e) = \begin{cases} w(u_i) \cdot d(u_i), for\ x \in \langle d(u_i), d(u_i) \cdot w(u_i)/w(u_{i+1}) \rangle \\ w(u_i) \cdot x, for\ x \in \langle d(u_i) \cdot w(u_i)/w(u_{i+1}), d(u_{i+1}) \rangle \end{cases},$$

$V_M(x|e) = w(u_1) \cdot x$ for $x \in \langle 0, d(u_1) \rangle$ and $V_M(x|e) = w(u_k) \cdot d(u_k)$ for $x \in \langle d(u_k), \infty \rangle$.

ii) Edge e is a significant bridge.
In this case we must change the following steps of the previous algorithm:

8. For $i = 1, \cdots, k \quad B_i = [d(u_i) \cdot w(u_i)/w(u_{i+1}), d(u_i) \cdot w(u_i)]$.
9. Function $V_M(x|e)$ has for $i = 1, \cdots, k-1$ formula

$$V_M(x|e) = \begin{cases} w(u_i) \cdot d(u_i), for\ x \in \langle d(u_i), d(u_i) \cdot w(u_i)/w(u_{i+1}) \rangle \\ w(u_i) \cdot x, for\ x \in \langle d(u_i) \cdot w(u_i)/w(u_{i+1}), d(u_{i+1}) \rangle \end{cases},$$

$V_M(x|e) = w(u_1) \cdot x$ for $x \in \langle 0, d(u_1) \rangle$ and $V_M(x|e) = w(u_k) \cdot x$ for $x \in \langle d(u_k), \infty \rangle$.

The final value that can be assigned to the edge e is

$$\int_0^\infty V_M(x|e) \cdot f(x) dx,$$

where $f(x)$ is an appropriate probabilistic density function. In our tests with total transportation performance, we use Erlang distribution because it represents the time of delay in Poisson processes [4]. Determination of the convenient statistical distribution for the random variable x will be the goal for our future research.

5 CONLUSIONS AND FUTURE RESEARCH

In this paper, we defined the function V_M, which represents the changes of maximum transportation performance. We suggested the algorithm that can compute the formula of V_M for every edge. Thanks to this algorithm, we are able to assign a non-negative number to each edge of the network. This number evaluates an impact of the extension of driving time to the ability of located centers to provide service to the customers. In the future, we plan to test this approach on real data from Slovakia and to determine the most critical edges (road segments) for located emergency stations in regions of this country.

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2-rainbow independent domination numbers of some graphs

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Abstract: By suitably adjusting a known tropical (path) algebra technique we compute the rainbow independent domination numbers of Cartesian products $C_n \Box P_m$ and $C_n \Box C_m$ for all n and $m \leq 5$, and also of generalized Petersen graphs $P(n, 2)$.

Keywords: rainbow independent domination, rainbow independent domination number, product graphs, generalized Petersen graphs, path algebra

1 Introduction

Ordinary domination is a problem that arises in combinatorial optimization. In this task one is keen to determine the minimum number of places in which to keep a resource such that every place either has a resource or is adjacent to the place in which the resource exists. It is quite common that in practical applications some additional constraints or desires are taken into account. Relatively recently, different kind of domination problems have been studied in the literature ([1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 15, 16, 17, 18, 19]). In particular, two similar but different types of rainbow domination numbers with suitably encoded independency, have been studied: namely the independent rainbow domination numbers of graphs ([17], [5]) and the rainbow independent domination numbers of graphs ([12]).

In [5], independent rainbow domination numbers of generalized Petersen graphs of $P(n, 2)$ and $P(n, 3)$ were established. To do this a known tropical (path) algebra technique for polygraphs was suitably adopted. In the current article we suitably adjust this technique in order that it works also in the case of rainbow independent domination case.

This is a preliminary paper where we report on some ideas and results, the details of these proofs will appear in a full paper to be submitted elsewhere.

2 Preliminaries

2.1 Rainbow independent domination of graphs

Let F be a graph, $S \subseteq V(F)$ and let $w \in V(F)$. The open neighborhood of w in S is denoted by $N_S(w)$, i.e., $\{u \mid uw \in E(F), u \in S\}$. Similarly, the closed neighborhood of w in S is denoted by $N_S[w]$, i.e., $N_S[w] = \{w\} \cup N_S(w)$. If $S = V(F)$ and no confusion can arise, we will write $N(w)$ and $N[w]$ instead of $N_S(w)$ and $N_S[w]$, respectively. If $T \subseteq V(F)$, then we define $N(T) = \cup_{x \in T} N(x)$. A subset S of $V(F)$ for which the vertices are pairwise non-adjacent is called an independent set S of a graph F. The degree of a vertex w is the total number of edges incident to w. The interval $[i, j]$ of integers $i \leq j$ is defined by $[i, j] = \{k \in \mathbb{N} \mid i \leq k \leq j\}$.

In [12] the notion of t-rainbow independent domination was introduced. For a function $f : V(F) \to \{0,1,2,\ldots,t\}$ we denote by V_i the set of vertices to which the value i is assigned by F, i.e., $V_i = \{v \in V(F) : f(v) = i\}$. A function $f : V(F) \to \{0,1,\ldots,t\}$ is called an t-rainbow independent dominating function (tRiDF for short) of F if the following two conditions hold:

(1) the set V_i is independent for $i = 1,\ldots,t$, and

(2) for every $v \in V_0$ it holds that $N(v) \cap V_i \neq \emptyset$ for every $i = 1,\ldots,t$.

The weight of $tRiDF$ f of a graph F is the value $w(f) = \sum_{i=1}^{t} |V_i|$. The *t-rainbow independent domination number* $i_{rit}(F)$ is the minimum weight over all $tRiDF$s of F.

Let H be a subgraph of F and $f : V(F) \to \{0,1,2,\ldots,t\}$. We say that f is a *partial tRiDF* for H if it satisfies the following two conditions:

(1) the set V_i is independent for every $i = 1,\ldots,t$, and

(2) for any vertex v of H with $f(v) = 0$ it holds that $\cup_{u \in N(v)} f(u) = \{1,\ldots,t\}$, i.e., all colors appear in the neighborhood of v.

Note that a $tRiDF$ f can alternatively be given by an ordered partition $(V_0, V_1, \ldots, V_t)$, where $(v \in V_i \iff f(v) = i$ for $i = 0,1,2,\ldots,t)$. We sometimes simply write $f = (V_0, V_1, \ldots, V_t)$.

In [17] and [5] a closely related notion of t-independent rainbow domination was studied. However, as explicitly pointed out and illustrated in [12] these two notions are different.

2.2 Polygraphs

Let $G_1,\ldots,G_n$ be arbitrary mutually disjoint graphs and denote by $Y_1,\ldots,Y_n$ a sequence of sets of edges such that an edge of Y_i joins a vertex of $V(G_i)$ with a vertex of $V(G_{i+1})$ ($Y_i \subseteq V(G_i) \times V(G_{i+1})$ for $i \in [1,n]$). A *polygraph* $\Omega_n = \Omega_n(G_1,\ldots G_n; Y_1,\ldots Y_n)$ over monographs $G_1,\ldots,G_n$ has the vertex set $V(\Omega_n) = V(G_1) \cup \ldots \cup V(G_n)$, and the edge set $E(\Omega_n) = E(G_1) \cup Y_1 \cup \ldots \cup E(G_n) \cup Y_n$. For convenience, we set $G_0 = G_n$ and $G_{n+1} = G_1$. Thus, $Y_0 = Y_n$, so we may write, for instance, $Y_0 \subseteq V(G_0) \times V(G_1) = V(G_n) \times V(G_1)$, or $Y_n \subseteq V(G_n) \times V(G_{n+1}) = V(G_n) \times V(G_1)$.

If all graphs G_i are isomorphic to a fixed graph G (i.e., there exists an isomorphism $\psi_i : V(G_i) \longrightarrow V(G)$ for $i = 0,1,\ldots,n+1$, and $\psi_0 = \psi_n$ and $\psi_{n+1} = \psi_1$) and all sets Y_i are equal to a fixed set $Y \subseteq V(G) \times V(G)$ (i.e., $(u,v) \in Y \iff \big(\psi_i^{-1}(u), \psi_{i+1}^{-1}(v)\big) \in Y_i$ for all i), we call such a graph *rotagraph*, $\omega_n(G;Y)$. A polygraph is called *nearly rotagraph*, if $n-1$ of its monographs are isomorphic to a fixed graph G and consequently at most two consecutive sets Y_i are not equal to the fixed set of edges Y.

Typical examples of polygraphs are Cartesian products of graphs and generalized Petersen graphs. The Cartesian product $G \Box H$ of graphs G and H is the graph with a vertex set $V(G) \times V(H)$, where two vertices are adjacent if and only if they are equal in one coordinate and adjacent in the other. For example $G = C_n \Box C_m$ is a graph with $V(G) = \{v_{i,j} : i \in [0,n-1], j \in [0,m-1]\}$ and $E(G) = \{e_{i,j} : e_{i,j} = (v_{i,j}, v_{i+1,j}), i \in [0,n-1], j \in [0,m-1]\} \cup \{e'_{i,j} : e'_{i,j} = (v_{i,j}, v_{i,j+1}), i \in [0,n-1], j \in [0,m-1]\}$, where indices i and j are read modulo n and m, respectively (see e.g. [8]).

For positive integers $n \geq 3$ and k, $1 \leq k < \frac{n}{2}$, the generalized Petersen graph $P(n,k)$ is defined to be the graph with the vertex set $\{u_i^1, u_i^2 : i \in [0,n-1]\}$ and the edge set $\{u_i^1 u_i^2, u_i^1 u_{i+k}^1, u_i^2 u_{i+1}^2 : i \in [0,n-1]\}$, in which the subscripts are computed modulo n (see e.g. [5, 17, 4]).

3 Theoretical Framework

Applying path algebra techniques to compute domination numbers of rotagraphs and fascigraph is not new [10].

We proceed by providing a formal definition of the weighted digraph which can be associated with a given polygraph that allows application of the algebraic approach. Intuitively, we are going to construct a directed graph in which vertices correspond to restrictions of $tRiDF$ functions to pairs of consecutive monographs and arcs correspond to pairs of vertices which both are a restriction of the same $tRiDF$ on one monograph.

Given a polygraph G, we define an auxiliary associated digraph $\mathcal{G}$ as follows. The vertices of $\mathcal{G}$ are ordered tuples of subsets of vertices $(D_0, D_1, D_2, \cdots, D_t)$ such that $D_0 \cup D_1 \cup D_2 \cup \cdots \cup D_t = V(G_i) \cup V(G_{i+1})$ for some $i \in [1, n]$ and there is a partial $tRiDF$ $f = (V_0, V_1, V_2, \cdots, V_t)$, for the subgraph induced on $V(G_i) \cup V(G_{i+1})$, defined (at least) on $V(G_{i-1}) \cup V(G_i) \cup V(G_{i+1}) \cup V(G_{i+2})$, such that $D_0 = V_0 \cap (V(G_i) \cup V(G_{i+1}))$, $D_1 = V_1 \cap (V(G_i) \cup V(G_{i+1}))$, ... , $D_t = V_t \cap (V(G_i) \cup V(G_{i+1}))$. We denote by $\mathcal{V}(\mathcal{G})_{i,i+1}$ the set of vertices that are partial $tRiDF$ for $V(G_i) \cup V(G_{i+1})$. Obviously, $\mathcal{V}(\mathcal{G}) = \cup_{i=1}^{n} \mathcal{V}(\mathcal{G})_{i,i+1}$.

The weight of vertex $D = (D_0, D_1, D_2, \ldots, D_t)$ is, by definition,

$$w(D) = \frac{1}{2}(|D_1| + |D_2| + \cdots + |D_t|).$$

For a later reference we introduce some more convenient notations. A vertex of $\mathcal{G}$ is an ordered tuple of sets that meet some monographs, so the restriction of D to monograph G_i is denoted by

$$D^i = D \cap G_i.$$

More precisely, this means $D^i = (D_0^i, D_1^i, D_2^i, \ldots, D_t^i)$, where $D_0^i = D_0 \cap V(G_i)$, $D_1^i = D_1 \cap V(G_i)$, ... , $D_t^i = D_t \cap V(G_i)$.

In words, vertices of $\mathcal{G}$ are partial $tRiDF$ of two consecutive monographs. Two vertices of $\mathcal{G}$ are connected when they exactly match on the common monograph. As the edge sets X_i and X_{i+1} meet on the monograph G_{i+1}, the two partial $tRiDF$ are both defined on vertices of G_{i+1}, and they can either match or differ on these vertices.

More formally, two vertices u, v of $\mathcal{G}$ are connected by an arc (u, v) if, (1) for some i, $u \in \mathcal{V}(\mathcal{G})_{i-1,i}$, $v \in \mathcal{V}(\mathcal{G})_{i,i+1}$, and (2) u and v match on $V(G_i)$. More precisely, $u_0^i = v_0^i$, $u_1^i = v_1^i$, ... , $u_t^i = v_t^i$. Clearly, $u \cap v$ is a partial $tRiDF$ for G_i. Clearly, $u \cup v$ is a partial $tRiDF$ for $G_{i-1} \cup G_i \cup G_{i+1}$.

(We use a brief notation for the intersection of $(t+1)$tuples, i.e., $u \cap v = (u_0, u_1, u_2, \ldots, u_t) \cap (v_0, v_1, v_2, \ldots, v_t) = (u_0 \cap v_0, u_1 \cap v_1, u_2 \cap v_2, \ldots, u_t \cap v_t)$. The weight of the arc (u, v) is, naturally, defined as the sum of weights of u and v, hence

$$w(u, v) = w(u) + w(v).$$

Note that $w(u, v) = w(u) + w(v) = w(u^{i-1}) + w(u^i) + w(v^i) + w(v^{i+1}) = w(u^{i-1}) + 2w(u^i) + w(v^{i+1}) = \frac{1}{2}(|u_1^{i-1}| + |u_2^{i-1}| + \cdots + |u_t^{i-1}|) + |u_1^i| + |u_2^i| + \cdots + |u_t^i| + \frac{1}{2}(|v_1^{i+1}| + |v_2^{i+1}| + \cdots + |v_t^{i+1}|) = w(u_{i-1}) + 2w(u_i) + w(u_{i+1})$. By induction, a walk given by consecutive arcs $(u_1, u_2), (u_2, u_3) \ldots (u_{\ell-1}, u_\ell)$, has weight $w(u_1) + 2w(u_2) + \cdots + 2w(u_{\ell-1}) + w(u_\ell)$. In words, a walk meets some consecutive monographs. By definition, it gives rise to a partial $tRiDF$ on the union of monographs that the walk crosses, i.e., are related to the inner vertices of the walk. The weight of the walk is the sum of cardinalities over all inner monographs, plus half of the cardinalities of the first and last vertex on the walk.

The following theorem states that the t-rainbow independent domination number is closely related to certain walks in the associated graph $\mathcal{G}$. It is proved in a very similar manner as [5, Theorem 3.1]. To avoid too much repetition of ideas we omit the details of the proof.

Theorem 3.1 *The t-rainbow independent domination number $i_{rit}(\Omega_n(G_1, G_2, \ldots, G_n;\ X_1, X_2, \ldots, X_n))$ of the polygraph $\Omega_n(G_1, G_2, \ldots, G_n; X_1, X_2, \ldots, X_n)$ equals the minimum weight of a closed walk of length n in $\mathcal{G}$.*

Consider two consecutive monographs G_k and G_{k+1} and the corresponding vertices in $\mathcal{V}(\mathcal{G})_{k,k+1}$. Let $L = \{u^k \mid u \in \mathcal{V}(\mathcal{G})_{k,k+1}\}$ and $R = \{u^{k+1} \mid u \in \mathcal{V}(\mathcal{G})_{k,k+1}\}$ be the sets of all restrictions of arcs to the two monographs. Let $A(k, k+1)$ be the matrix with elements a_{ij}, for $i \in L$ and $j \in R$, where the value of a_{ij} is

$$a_{ij} = \begin{cases} w(u) & \text{if } (i,j) = u \in \mathcal{V}(\mathcal{G})_{k,k+1} \\ \infty & \text{otherwise} \end{cases} \tag{1}$$

Let us compute the product $P = A(k-1, k)A(k, k+1)$,

$$P_{ij} = \min\{w(i,x) + w(x,j)\},$$

where x runs over all ordered tuples of subsets of $V(G_k)$ such that both $(i,x) \in \mathcal{V}(\mathcal{G})_{k-1,k}$ and $(x,j) \in \mathcal{V}(\mathcal{G})_{k,k+1}$. In words, the product is the weight of a path that starts at $V(G_{k-1})$ and ends at $V(G_{k+1})$, such that the two intersections are, respectively, the ordered tuples i and j, and has minimum weight. Therefore, by induction, the mimimum weight of a closed walk of length n on polygraph with n monographs will appear as a diagonal element of the corresponding product of matrices. The conclusion can be stated formally as

Theorem 3.2 *For $k = 1, 2, \ldots, n$, let $A(k, k+1)$ be the matrices defined by (1). Then the t-rainbow independent domination number of polygraph $\Omega_n(G_1, G_2, \ldots, G_n; X_1, X_2, \ldots, X_n)$ equals*

$$i_{rit}\left(\Omega_n(G_1, G_2, \ldots, G_n; X_1, X_2, \ldots, X_n)\right) = \operatorname{tr}(A(1,2)A(2,3)\ldots A(n, n+1))$$

Now consider the special case when the polygraph is a rotagraph. Observe that in this case the matrices $A(k, k+1)$ are independent of k. Thus we can define a matrix $A = A(1,2)$ with elements $a_{ij} = w(i,j)$, $(i,j) \in \mathcal{V}(\mathcal{G})_{1,2}$ and write

Corollary 3.3 *The t-rainbow independent domination number of rotagraph $\omega_n(G; X)$ is*

$$i_{rit}\left(\omega_n(G; X)\right) = \operatorname{tr}(A^n).$$

Finally, we will need a version of this result for the case when the polygraph is an *almost rotagraph*. Recall that a polygraph is an almost rotagraph, if all monographs but one are isomorphic: $G_2 \simeq G_3 \simeq \cdots \simeq G_n$. Consequently, also X_1 and X_n may differ from other $X_i = X$.

Corollary 3.4 *Let polygraph $\Omega_n(G_1, G_2, \ldots, G_n; X_1, X_2, \ldots, X_n)$ be an almost rotagraph, that is $G_2 = G_3 = \cdots = G_n = G$ and $X_2 = X_3 = \cdots = X_{n-1} = X$. Then $i_{rit}(\Omega_n(G_1, G, \ldots, G;$ $X_1, X,\ \ldots, X,\ X_n))$ equals*

$$\operatorname{tr}(A(1,2)A^{n-2}A(n,1)) = \operatorname{tr}(A(n,1)A(1,2)A^{n-2}) = \operatorname{tr}(A^k A(n,1)A(1,2)A^{n-2-k})$$

for any $k \in [1, n-2]$, where $A = A(2,3)$.

Proof. Clearly, using Theorem 3.3 we have $i_{rit}(\Omega_n(G_1, G, \ldots, G;\ X_1, X,\ \ldots, \mathrm{X},\ X_n)) = \operatorname{tr}(A(1,2)\ A^{n-2}A(n,1))$. The other statements can be easily seen by shifting the indices of the monographs.

4 Results

As graphs $C_n \square P_m$, $C_n \square C_m$, and $P(n, 2)$ are clearly rotagraphs or almost rotagraphs (see [5] and [15]), we can use the above techniques to obtain the rainbow independent domination numbers of these graphs. The results are summarized below.

For $n \geq 3$ it holds
$$\gamma_{r2}(C_n \square P_1) = \begin{cases} \left\lceil \frac{n}{2} \right\rceil, & n \equiv 0, 3 \bmod 4, \\ \left\lceil \frac{n}{2} \right\rceil + 1, & n \equiv 1, 2 \bmod 4. \end{cases}$$
For $n \geq 4$ it holds
$$\gamma_{r2}(C_n \square P_2) = n.$$
For $n \geq 3$ it holds
$$\gamma_{r2}(C_n \square P_3) = \begin{cases} \left\lceil \frac{4n}{3} \right\rceil, & n \equiv 0, 1, 2, 4, 5 \bmod 6, \\ \left\lceil \frac{4n}{3} \right\rceil + 1, & n \equiv 3 \bmod 6. \end{cases}$$
For $n \geq 3$ it holds
$$\gamma_{r2}(C_n \square P_4) = \begin{cases} \left\lceil \frac{7n}{4} \right\rceil, & n \equiv 0, 2, 3, 6 \bmod 8, \\ \left\lceil \frac{7n}{4} \right\rceil + 1, & n \equiv 1, 4, 5, 7 \bmod 8. \end{cases}$$
For $n \geq 20$ it holds
$$\gamma_{r2}(C_n \square P_5) = \begin{cases} \left\lceil \frac{13n}{6} \right\rceil, & n \equiv 0, 1, 2, 6, 8 \bmod 12, \\ \left\lceil \frac{13n}{6} \right\rceil + 1, & n \equiv 3, 4, 5, 7, 9, 10, 11 \bmod 12. \end{cases}$$
For $n \geq 3$ it holds
$$\gamma_{r2}(C_n \square C_3) = \begin{cases} n, & n \equiv 0 \bmod 6, \\ n + 1, & n \equiv 5 \bmod 6, \\ n + 2, & n \equiv 2, 3, 4 \bmod 6, \\ n + 3, & n \equiv 1 \bmod 6. \end{cases}$$
For $n \geq 4$ it holds
$$\gamma_{r2}(C_n \square C_4) = \begin{cases} \left\lceil \frac{5n}{3} \right\rceil, & n \equiv 0 \bmod 12, \\ \left\lceil \frac{5n}{3} \right\rceil + 1, & n \equiv 2, 4, 5 \bmod 12, \\ \left\lceil \frac{5n}{3} \right\rceil + 2, & n \equiv 1, 3 \bmod 12. \end{cases}$$
For $n \geq 8$ it holds
$$\gamma_{r2}(C_n \square C_5) = 2n.$$
For $n \geq 3$ it holds
$$\gamma_{r2}(P(n, 2)) = \begin{cases} \left\lceil \frac{4n}{5} \right\rceil, & n \equiv 0, 9 \bmod 10, \\ \left\lceil \frac{4n}{5} \right\rceil + 1, & n \equiv 7, 8 \bmod 10, \\ \left\lceil \frac{4n}{5} \right\rceil + 2, & n \equiv 3, 4, 5, 6 \bmod 10, \\ \left\lceil \frac{4n}{5} \right\rceil + 3, & n \equiv 1, 2 \bmod 10. \end{cases}$$

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Abstract: The measurement of electricity consumption at 15-minute granularity is increasingly mandated in the EU, including for households, and this also allows, once sufficient data have been collected, the prediction of future consumption at the same time intervals.
In this paper, we present preliminary results of the industry project that aimed to build AI models for next day electricity consumption at 15-minute granularity. We identified the main influencing factors, developed scripts and databases to collect data about these features and the electricity consumption data for each 15-minute interval, and finally developed AI models to predict the future electricity consumption for each 15-minute interval and for each measurement point.
Finally, we provide time complexity analysis for computing the modes and the predictions. Additionally, we also evaluated possible ways parallelization within R and provide results of a computational study using R libraries parallel and doParallel.

Keywords: AI models, influencing factor, electricity consumption prediction, neural network, random forest, parallelization

1 INTRODUCTION

In this paper we present the results of developing and testing new algorithms for predicting the future electricity consumption of individual end-users at a granularity of 15 minutes. The work was part of an applied research project where we first identified and analyzed several factors that have a significant impact on electricity consumption. For these factors, we identified suitable and stable data sources and developed scripts to automatically retrieve and store this data in the MongoDB database. The entire system was developed using the Python and R programming languages and the Mongo database DB [2, 8, 11].
Here we report only the results of the new algorithms based on the similar days method and generalized linear models. The algorithms were comprehensively evaluated by splitting the historical data into a learning set and a test set. By calculating the MAPE (mean absolute percentage error), the quality of the predictions was determined. The results obtained show that both algorithms developed are very good, with the model based on generalized linear models behaving better on average.

2 PROBLEM DESCRIPTION

Due to climate change, many research and development efforts are focused on developing technologies to reduce greenhouse gas emissions. Our contribution is mainly in the area of efficient operation of grids. Due to the increasing number of small and dispersed power generators, the use of power grid has changed drastically. It is completely different from the type of usage for which the grid was built decades ago. On the other hand, the dispersed small resources move the power generation closer to the end of the power supply chain, which in turn changes the whole concept of operation. Therefore, with the increase of small resources, it is necessary to control the operations at the lowest level of the grid. The solution to these new challenges is complete digitization and the use of advanced algorithms to maintain the stability of the grid.

Electricity is an inflexible resource. We are still unable to store large amounts of produced electricity for later use. Therefore, careful production planning is required, which must be precisely matched to current consumption. Large power plants are very inflexible in adjusting output power. Any changes and quick adjustments are inefficient and financially very expensive. For these reasons, it is extremely important to accurately plan the generation of electricity according to the expected consumption over time. From January 2021, this must be done with 15-minute accuracy in the European synchronous power grid. However, it is also necessary to consider the generation of small, distributed sources of electricity that are highly dependent on the weather - solar energy and wind. This is why smart forecasting models that facilitate and significantly reduce the cost of power generation and distribution are so important. Several studies on this topic can be found in the literature [5, 6, 7, 10].

In Slovenia, for several years, consumption metering points have been equipped with smart meters that measure electricity consumption at 15-minute intervals. This data is extremely valuable as it provides deep insight into electricity consumption and enables the development of software solutions based on artificial intelligence. In this paper, we describe some ways to intelligently predict future electricity consumption based on this data.

3 INFLUENCING FACTORS AND DATA

The analysis of the influencing factors showed us these results:

1. **Time factors**: time of day, day of week, day of month, month, season, and day factors (working day, weekend, holiday, long weekend) are very important for understanding and predicting future electricity consumption for small households and also for larger industrial consumers.
2. **Weather factors** (air pressure, temperature, humidity, precipitation, wind speed, power or solar radiation) are less important. We concluded that weather data is important for predicting electricity consumption for small consumers (households), and less important for larger (industrial) consumers.
3. **Past consumption**: our research showed that past consumption is an important factor for predicting future consumption. The most important past consumption is that of the last 7 days.
4. For large consumers, **business activity** is also important. Consumers from the same industry tend to have similar consumption curves (e.g., automotive or heavy industry), but we only had this data for 10 large consumers, so we could not consider this factor in building forecasting models.

The fluctuations on certain days are still very high, so we conclude that there are other important characteristics that we have not considered before because they were not available to us (e.g. exceptional events in production, work schedules, etc.).

The study used the following consumption data and data about selected influencing factors: (i) 15-minute measurements of electricity consumption for 2722 metering points as of 3/1/2020, including medium and large metering points (connection power over 40kW); (ii) half-hourly weather data for all weather stations in Slovenia for the period from 1 January 2020.

4 TWO ALGORITHMS

4.1 Similar Days Method

Based on the influencing factors included, we clustered each consumer's daily consumption (small, large), with the number of clusters ranging from 3 to 20. The first step of the cluster analysis is to choose the similarity measure between the two data units. We chose three measures:

1. **Euclidean distance** between the points - a natural distance from a real environment, which is easy to interpret: if x and y are the vectors of daily consumption for a measurement point for two different days, then the Euclidean distance between them is

$$d_E(x,y) = \sqrt{\sum_i (x_i - y_i)^2} \tag{1}$$

2. **The relative L1 distance** comparing the differences between two consumptions belonging to **the** same time interval with the center point between these two values:

$$d_{L_1}(x,y) = \frac{\sum_i |x_i - y_i|}{\sum_i |x_i + y_i|} \tag{2}$$

3. **Adaptive dissimilarity**, that combines dissimilarity on raw values and dissimilarity on temporal correlation behaviors as follows:

$$d_{CORT}(x,y) = \Phi\big(CORT(x,y)\big) \cdot d_E(x,y) \tag{3}$$

where CORT is the measure for the proximity between the dynamic behaviors of x and y, d_E is the Euclidean distance and Φ is the adaptive tuning function that modulates the relative importance of CORT:

$$CORT(x,y) = \frac{\sum_t (x_{t+1} - x_t)(y_{t+1} - y_t)}{\sqrt{\sum_t (x_{t+1} - x_t)^2 \sum_t (y_{t+1} - y_t)^2}}, \Phi(u) = \frac{1}{1 + e^{ku}} \tag{4}$$

The third distance was often giving best results. We used library TSdist (https://cran.r-project.org/web/packages/TSdist/TSdist.pdf) to compute this distance.

Based on the silhouette criterion and the dispersion analysis within clusters, we decided on 15 groups. Based on these findings, we developed the first solution to predict future consumption based on clustering. That is, we created 15 profiles of typical daily expenditure for each consumer using hierarchical and non-hierarchical classification. We then created a forecast by predicting which cluster the selected day's consumption would fall into based on the weather, calendar, and historical influencing factors. These predictions were made using random forests and neural networks [1, 4, 9].

4.2 Generalized linear models

In parallel, we developed an algorithm to predict future consumption based on generalized linear models. On the training dataset, we created 96 such models for each consumer, one for each 15-minute interval. We used all the influencing factors that we had identified in previous studies (see Section 3).

4.3 Evaluation of results

If x is the sequence of actual consumptions and y is the sequence of our predictions, then the quality of the prediction is measured by the Mean Absolute Percentage Error (MAPE):

$$\boldsymbol{MAPE(x,y) = \frac{1}{N}\sum_{i=1}^{N}\frac{|x_i - y_i|}{|x_i|}} \tag{5}$$

5 RESULTS

5.1 Analysis of 2722 measuring points

Both algorithms were tested on 2722 measurement points for which we have data as of March 1, 2020. For first three weeks in September 2020, we calculated the model for each metering point based on data up to the end of the Thursday of the previous week, and then forecast consumption for each metering point for all days from the Saturday following that Thursday until the next Friday. All forecasts were summed and compared to the total consumption of those measuring points and MAPEs were calculated. Table 1 shows the MAPE values for all algorithms used. The following list shows that the calculated MAPEs are good, especially those obtained with generalized linear models (last column), since the MAPE values are often below 5% and almost always (for 24 out of 26 days) below 10%.

Table 1: MAPE for all measuring points for the first three weeks of September 2020.

DATE	Similar Days Method + random forest	Similar Days Method + neural networks	Generalized Linear Models
5.09.2020	0,05	0,11	0,03
6.09.2020	0,09	0,05	0,07
7.09.2020	0,06	0,17	0,05
8.09.2020	0,19	0,12	0,09
9.09.2020	0,08	0,14	0,07
10.09.2020	0,03	0,03	0,09
11.09.2020	0,05	0,05	0,02
12.09.2020	0,06	0,03	0,03
13.09.2020	0,12	0,16	0,10
14.09.2020	0,13	0,09	0,04
15.09.2020	0,37	0,27	0,09
16.09.2020	0,06	0,06	0,04
17.09.2020	0,03	0,06	0,07

18.09.2020	0,03	0,03	0,02
19.09.2020	0,05	0,05	0,03
20.09.2020	0,04	0,04	0,06
21.09.2020	0,12	0,08	0,06
22.09.2020	0,22	0,10	0,13
23.09.2020	0,05	0,07	0,05
24.09.2020	0,05	0,20	0,09
25.09.2020	0,03	0,07	0,03

5.2 Time complexity of model construction

Building models for each consumer is the most time consuming. Table 2 shows (1) the average times and standard deviations of these times for constructing generalized linear models and models based on the Similar Days Method using random forests or neural networks, and (2) the average times and standard deviations of these times for computing the predictions based on previously computed models. The computations were performed on a virtual machine with Ubuntu operating system and 8 virtual cores on a physical server with two Intel (R) Xeon (R) Silver 4208 CPU @ 2.10GHz processors and 16 GB RAM allocated. For the computations we used RStudio Server and the program R version 4.0.4 on the platform x86_64-pc-linux-gnu.

Table 2: comparison of computing times to build models and predictions

	Similar Days Method + random forest (sec.)	Similar Days Method + neural networks (sec.)	Generalized Linear Models(sec.)
Time to build a model (average)	2.27	50.18	12.56
Time to build a model (standard deviation)	0.43	6.09	1.28
Time to compute prediction (average)	0.09	0.08	0.75
Time to compute prediction (standard deviation)	0.05	0.02	0.05

5.3 Parallelization using R packages parallel, doParallel and foreach

Creating the prediction models and the predictions are almost completely independent tasks – the only point where these tasks interfere are the IO operations: reading and writing from the underlying MongoDB database. Historically, several packages were developed to enable parallelization within R. Finally, the packages
parallel (https://stat.ethz.ch/R-manual/R-devel/library/parallel/doc/parallel.pdf), doParaller (https://cran.r-project.org/web/ packages/doParallel/doParallel.pdf) and **foreach (https://cran.r-project.org/web/packages/foreach/foreach.pdf)**
adopted most of them and are now the packages of choice for performing R parallelization using parallel versions of apply functions or parallel version of loops.

We have tested:

- classical sequential for loop
- parallel for loop using library foreach and doParallel
- parSapply and mclapply functions, which are different parallel alternatives for lapply from package parallel and are based on socket and forking types of parallelization, respectively.

These scripts were run on data for 80 consumers on a computing node 48 computing cores available. The benchmarking results are in Table 3.

Table 3: Comparison of computing times to build 80 models and predictions using sequential code and different parallelization scripts.

	user.self	sys.self	elapsed	user.child	sys.child
Sequential for loop	1.320,92	68,90	1.472,61	0,78	3,19
Sequential foreach-do loop	1.308,25	63,31	1.409,18	0,71	3,26
Parallel foreach-dopar loop	0,47	3,17	91,87	2.499,76	289,79
Mcapply	0,52	3,68	96,71	2.439,49	297,05
parSapply	0,42	1,89	94,47	0,25	1,78

We can see that for our type of problems, best choice for parallelization if using parSapply from library parallel, since it is most efficiently implemented. The total running time is the shortest as well the burden on child cores is the smallest.

6 CONCLUSIONS

In this paper, we present the results of an applied research to predict future electricity consumption. We identified key influencing factors, collected data on these factors features and on electricity consumption data for each 15-minute interval, and stored them in MongoDB databases. Finally, we developed AI models based on cluster analysis, neural networks, random forests, and generalized linear models to predict future electricity consumption for each 15-minute interval and for each measurement point. Since all these calculations were very time-consuming, we also performed a time complexity analysis, including the investigation of a possible parallelization using R libraries parallel and doParallel.

The prediction models that we have developed are on one hand time-consuming, but they also show good predictive power. They directly incorporate calendar, weather and historical consumption data. The testing phase has shown that the models do not yet perform as well as desired on certain days. Future work will therefore aim to find a good combination of individual forecasts and introduce solutions in the real environment for real-time forecasting. We also plan to develop prediction models based on multivariate time series analysis [3], especially with autoregression models.

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ON USING HYPERMETRIC INEQUALITIES IN A CUTTING-PLANE ALGORITHM FOR MAX-CUT

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

Keywords: semidefinite programming, cutting-plane method, augmented Lagrangian method, max-cut problem

1 INTRODUCTION

Max-Cut is a fundamental NP-hard combinatorial optimization problem that has attracted the scientific interest during the past decades [10, 11, 13]. For a given undirected and weighted graph $G = (V, E)$, the task is to find a bipartition of the vertices such that the sum of the weights of the edges across the bipartition is maximized. Let $A \in \mathcal{S}_n$ denote the adjacency matrix of the graph G with n vertices. Encoding the partitions by vectors $x = \{-1, 1\}^n$, the Max-Cut problem can be formulated as unconstrained binary quadratic optimization problem

$$\max \ \frac{1}{4} x^T L x \quad \text{such that} \quad x \in \{-1, 1\}^n, \tag{1}$$

where L denotes the Laplacian matrix of the graph defined by $L = \operatorname{diag}(Ae) - A$.

Deza and Laurent [5] introduced a class of *hypermetric inequalities* that provides a rich source of cutting planes for the Max-Cut problem. In particular, the hypermetric inequalities include the important class of triangle inequalities as special case. Due to a large number of hypermetric inequalities, the computational overhead to evaluate all of them is prohibitive for larger instances. It is the main purpose of this paper to describe an efficient way to separate a subset of hypermetric inequalities and show how to use them within an SDP-based cutting-plane algorithm.

We finish this introductory section with some notation. The inner product on the space of symmetric matrices is given by $\langle X, Y \rangle = \operatorname{tr}(XY) = \sum_i \sum_j X_{ij} Y_{ij}$. For the given symmetric matrices A_i, $i = 1, \ldots, m$, let $A \colon \mathcal{S}_n \to \mathbb{R}^m$ denote the linear operator mapping $n \times n$ symmetric matrices to $\mathbb{R}^m$ with $A(X)_i = \langle A_i, X \rangle$. Its adjoint is well known to be $A^T(y) = \sum_i y_i A_i$. We use the notation $X \succeq 0$ to denote that symmetric matrix X belongs to the cone of positive semidefinite matrices.

2 SEMIDEFINITE RELAXATION OF MAX-CUT

Over the decades, many methods have been proposed for finding exact solutions of Max-Cut. Some of them are LP-based methods [4], while other algorithms combine semidefinite programming (SDP) with the polyhedral approach [10] to strengthen the basic SDP relaxation with cutting planes. The semidefinite program optimizes a linear objective function of the matrix over the intersection of the cone of positive semidefinite matrices with an affine space [15]. To obtain the basic semidefinite relaxation of Max-Cut, observe that for any $x = \{-1, 1\}^n$, the matrix $X = xx^T$ is positive semidefinite and its diagonal is equal to vector of all ones. This leads to

$$\max \ \frac{1}{4}\langle L, X\rangle \quad \text{such that} \quad \operatorname{diag}(X) = e,\ X \succeq 0. \qquad (\mathrm{MC}_{\mathrm{BASIC}})$$

The bound from $\mathrm{MC}_{\mathrm{BASIC}}$ is not strong enough to be efficiently used within a branch-and-bound (B&B) framework to allow to solve the Max-Cut problems to optimality. In order to improve the quality of the bound, we tighten it by adding valid inequality constraints known as cutting planes to the relaxation. One such popular class of cutting planes are the triangle inequalities [10, 13] defined for $1 \le i < j < k \le n$ by

$$\begin{aligned} X_{ij} + X_{ik} + X_{jk} &\ge -1, \\ X_{ij} - X_{ik} - X_{jk} &\ge -1, \\ -X_{ij} + X_{ik} - X_{jk} &\ge -1, \\ -X_{ij} - X_{ik} + X_{jk} &\ge -1. \end{aligned}$$

Let $\mathcal{I}$ be a subset of the triangle inequalities and $A_{\mathcal{I}} \colon \mathcal{S}_n \to \mathbb{R}^{|\mathcal{I}|}$ be the corresponding linear operator. Adding such valid constraints to the relaxation gives an improved bound on the value of the maximum cut:

$$\max \ \frac{1}{4}\langle L, X\rangle \quad \text{such that} \quad \operatorname{diag}(X) = e,\ A_{\mathcal{I}}(X) + e \ge 0,\ X \succeq 0. \qquad (\mathrm{MC}_{\mathrm{TRI}})$$

Interior-point based approaches are among the most efficient methods for solving general SDP problems. These methods are only aplicable to instances for which n is reasonably small and the number of constraints is not larger than, say 10 000. However, for special cases like the relaxation ($\mathrm{MC}_{\mathrm{BASIC}}$), the interior-point method tailored to this problem scales well, since the matrix determining the Newton direction can be efficiently constructed [7].

A number of alternative algorithms have been proposed to handle large number of cutting planes in semidefinite relaxations. In particular, the BiqMac [13] and BiqBin [6] solvers use the bundle method from nonsmooth optimization to minimize the partial Lagrangian dual function, the BiqCrunch solver [10] applies quadratic regularization approach to produce a family of dual problems that are minimized by using a quasi-Newton method, while the newly developed state-of-the art `MADAM` solver [9] utilizes the alternating direction method of multipliers (ADMM) [2] to solve the dual problem.

3 HYPERMETRIC INEQUALITIES

In the following we explain how to tighten the basic semidefinite relaxation ($\mathrm{MC}_{\mathrm{BASIC}}$) by adding a subset of hypermetric inequalities, valid for any matrix X from the convex hull of rank-one matrices xx^T, for $x \in \{-1, 1\}^n$. For every integer vector b such that $e^T b$ is odd, the inequality $|x^T b| \ge 1$ holds for all $x \in \{-1, 1\}^n$. Therefore, we have $\langle bb^T, xx^T\rangle \ge 1$. The hypermetric inequality specified by the vector b is the inequality

$$\langle bb^T, X\rangle \ge 1.$$

We consider the subset of hypermetric inequalities generated by choosing b with elements $b_i \in \{-1, 0, 1\}$ and by fixing the number of non-zero entries to 3, 5, 7, 9 or 11. These correspond to triangle and higher order hypermetric inequalities, respectively. By adding the subset $\mathcal{J}$ of these inequalities we obtain the strengthened relaxation:

$$\max \ \frac{1}{4}\langle L, X\rangle \quad \text{such that} \quad \operatorname{diag}(X) = e,\ B_{\mathcal{J}}(X) \ge e,\ X \succeq 0, \qquad (\mathrm{MC}_{\mathrm{HYP\text{-}P}})$$

where $\mathcal{B}_{\mathcal{J}}\colon \mathcal{S}_n \to \mathbb{R}^{|\mathcal{J}|}$ denotes the linear operator corresponding to hypermetric inequalities in $\mathcal{J}$. The dual to this problem is given by

$$\min\ e^T y - e^T z \quad \text{such that} \quad \frac{1}{4}L - \operatorname{Diag}(y) + B_{\mathcal{J}}^T(z) + Z = 0,\ z \geq 0,\ Z \succeq 0. \qquad (\mathrm{MC}_{\text{HYP-D}})$$

4 THE COMPUTATION OF SDP-BASED BOUNDS

The goal of this paper is to get good bounds on the optimal Max-Cut by solving the dual problem ($\mathrm{MC}_{\text{HYP-D}}$). We use the cutting-plane approach where multiple hypermetric inequalities are iteratively added and purged after each computation of the upper bound. The problem with an updated set of inequalities is solved and the process is iterated as long as the decrease of the upper bound is sufficiently large. In order to complete the description of the bounding routine we describe how violated hypermetric inequalities are separated and how to solve the resulting SDP.

4.1 Finding violated hypermetric inequalities

There are $4\binom{n}{3}$ triangle inequalities, but for a given X, we can enumerate all of them and identify the most violated ones. Due to a large number of higher order hypermetric inequalities, the computational overhead to evaluate all of them is prohibitive for larger instances and the separation has to be done heuristically.

Suppose we are searching for hypermetric inequality defined by vector b of length $k \in \{5, 7, 9, 11\}$ with $b_i \in \{-1, 1\}$. Then the separation problem can be formulated as a quadratic assignment problem of the form

$$\min\ \langle H, PXP^T \rangle \quad \text{such that} \quad P \in \Pi, \tag{2}$$

where bb^T is embedded in $n \times n$ matrix H and Π denotes the set of all $n \times n$ permutation matrices. We propose to use the simulated annealing heuristic to approximately solve this problem to obtain hypermetric inequality with a potentially large violation. If the minimum value of (2) is less than 1, we add the cutting plane to $\mathcal{J}$.

4.2 Dual regularization by augmented Lagrangian

Quadratic regularization techniques for semidefinite programs with equality constraints were studied in [12]. We propose to use the augmented Lagrangian method to solve ($\mathrm{MC}_{\text{HYP-D}}$). We introduce a Lagrange multiplier X for the dual equation and consider for $\alpha > 0$ the augmented Lagrangian function $\mathcal{L}_\alpha$:

$$\begin{aligned}
\mathcal{L}_\alpha(y, z, Z; X) &= e^T y - e^T z + \left\langle X, \frac{1}{4}L - \operatorname{Diag}(y) + B_{\mathcal{J}}^T(z) + Z \right\rangle \\
&\quad + \frac{1}{2\alpha} \left\| \frac{1}{4}L - \operatorname{Diag}(y) + B_{\mathcal{J}}^T(z) + Z \right\|_F^2 \\
&= e^T y - e^T z + \frac{1}{2\alpha} \left\| \frac{1}{4}L - \operatorname{Diag}(y) + B_{\mathcal{J}}^T(z) + Z + \alpha X \right\|_F^2 - \frac{\alpha}{2} \|X\|_F^2 .
\end{aligned}$$

This is the usual Lagrangian with an additional redundant quadratic term. The augmented Lagrangian method to solve ($\mathrm{MC}_{\text{HYP-D}}$) consists in minimizing $\mathcal{L}_\alpha(y, z, Z; X)$ to get y, $z \geq 0$ and $Z \succeq 0$. Then the primal matrix X is updated $X \leftarrow X + \frac{1}{\alpha}\left(\frac{1}{4}L - \operatorname{Diag}(y) + B_{\mathcal{J}}^T(z) + Z\right)$, see [1]. Then as $\alpha \to 0$ the whole processes is iterated until convergence.

The inner minimization problem

$$\min\ e^T y - e^T z + \frac{1}{2\alpha} \left\| \frac{1}{4}L - \operatorname{Diag}(y) + B_{\mathcal{J}}^T(z) + Z + \alpha X \right\|_F^2 \quad \text{such that}\ \ y \text{ free}, z \geq 0,\ Z \succeq 0 \tag{3}$$

can be further simplified by eliminating Z as follows. Define $M = \frac{1}{4}L - \mathrm{Diag}(y) + B_{\mathcal{J}}^T(z) + \alpha X$. For fixed y and z the problem

$$\min_{Z \succeq 0} \|Z + M\|_F^2$$

is a projection of $-M$ onto the cone of positive semidefinite matrices. It is known that the solution $Z = (-M)_+$ can be computed from the eigenvalue decomposition of M, see [8]. More specifically, if the eigenvalue decomposition of M is given by $X = S\mathrm{Diag}(\lambda)S^T$ with the eigenvalues $\lambda \in \mathbb{R}^n$ and orthogonal matrix $S \in \mathbb{R}^{n\times n}$, then we have $X_+ = S\mathrm{Diag}_+(\lambda)S^T$.

By substituting Z into (3) we arrive

$$\min\ e^T y - e^T z + \frac{1}{2\alpha}\left\| \left(\frac{1}{4}L - \mathrm{Diag}(y) + B_{\mathcal{J}}^T(z) + \alpha X\right)_+ \right\|_F^2 \quad \text{such that} \quad y \text{ free},\ z \geq 0 \tag{4}$$

Note that the objective function is convex and differentiable. The function value and gradient are evaluated by computing partial spectral decomposition. This enables that for a fixed α and X, the function is minimized using the L-BFGS-B algorithm [3]. Finally, by using $Z = (-M)_+$ the update on X is given by

$$X \leftarrow \left(X + \frac{1}{\alpha}\left(\frac{1}{4}L - \mathrm{Diag}(y) + B_{\mathcal{J}}^T(z)\right)\right)_+. \tag{5}$$

To make the algorithm efficient in practice we do only one iteration of augmented Lagrangian method and proceeed with adding cutting planes. During each separation step we add 500 most violated triangle inequalities to the relaxation while for higher order inequalities we run 300 trials of simulated annealing. We monitor the number of violated triangle inequalities and as soon as this number drops bellow 50, we decrease the penalty parameter α. The idea is to reduce the tightness parameter α when we can no longer make good progress by adding inequalities.

4.3 Valid upper bound

In order for the value of the dual function to be a valid upper bound for the maximum cut, the constraint $\mathrm{Diag}(y) - B_{\mathcal{J}}^T(z) - \frac{1}{4}L \succeq 0$ has to be satisfied. However, since we only do 1 iteration of augmented Lagrangian method, the dual feasibility is not necessarily reached. In the following, we describe the post-processing step we do after each computation of the bound.

After the algorithm L-BFGS-B terminates, define $L' = L - \mathrm{Diag}(y) + B_{\mathcal{J}}^T(z)$. Note that the variable y is unconstrained. We are searching for correction vector Δy such that

$$L - \mathrm{Diag}(y + \Delta y) + B_{\mathcal{J}}^T(z) = L' - \mathrm{Diag}(\Delta y) \succeq 0.$$

The vector will add the term $e^T\Delta y$ to the upper bound. To get the smallest possible upper bound we solve

$$d^* = \min\ e^T\Delta y \quad \text{such that} \quad L' - \mathrm{Diag}(\Delta y) \succeq 0 \tag{6}$$

This is a dual problem of the basic SDP relaxation ($\mathrm{MC}_{\mathrm{BASIC}}$) and can be efficiently solved by interior-point methods. From the optimal value we compute a valid upper bound $e^T y - e^T z + d^*$ on the maximum cut.

We summarize our bounding routine in Algorithm 1.

5 COMPUTATIONAL RESULTS

Let HYP_k denote the bound obtained with Algorithm 1 when hypermetric inequalities up to order k are used, *i.e.*, vector b that defines the inequality has only k non-zero elements. For example, when $k = 3$ we strengthen the basic SDP bound only with triangle inequalities.

We first consider Billionnet and Elloumi instances from [14] with $n = 250$. In Table 1 we compare the HYP_3 (column labeled 3) with the HYP_{11} (column labeled 11). Using the

Algorithm 1: Semidefinite bounding procedure for Max-Cut

$\alpha > 0$, $\mathcal{J} = \emptyset$
while *upper bound decreases significantly or α sufficiently small* **do**
    get an approximate minimizer of (4) by using L-BFGS-B method
    compute the optimal value d^* of (6) and produce a valid upper bound $e^T y - e^T z + d^*$
    update X using (5)
    remove inactive hypermetric inequalities from $\mathcal{J}$
    add violated hypermetric inequalities of X of order $k = \{3, 5, 7, 9, 11\}$ into $\mathcal{J}$
    if *number of new violated triangle inequalities is bellow threshold* **then**
        reduce α

fact that we know that the optimal cut z_{mc} is an integer, we stop the bounding routine if the condition $\text{HYP}_k < z_{mc} + 1$ is satisfied. In all cases we observe a substantial gap reduction going from $k = 3$ to $k = 11$. Computational results show that our new bounding procedure is strong enough to prove optimality for all these instances right at the root node.

Table 1: Max-Cut results for Billionnet and Elloumi instances with $n = 250$.

Graph	Opt. cut	3	11
be250.1	24076	24081.6	**24076.9**
be250.2	22540	22550.2	**22540.7**
be250.3	22923	**22923.9**	*
be250.4	24649	**24649.9**	*
be250.5	21057	21142.3	**21057.9**
be250.6	22735	22760.8	**22735.1**
be250.7	24095	**24095.9**	*
be250.8	23801	23830.3	**23801.9**
be250.9	20051	20110.2	**20051.9**
be250.10	23159	23194.1	**23159.8**

Next we consider graphs from the Beasley collection [14] with $n = 250$. These 10 instances were used in [10] within a branch-and-bound setting. The hardest instance 250-8 resulted in 325 nodes in the branch-and-bound tree, while other 9 instances resulted in branch-and-bound trees having between 1 and 17 nodes. We recomputed the root bound HYP_{11} for all these instances and present our results in Table 2. Again, we find it remarkable that we could prove optimality for all these instances right at the root node with the exception of problem 250-8. Furthermore, for this problem we could reduce the root gap by 53.2%.

6 CONCLUSIONS

This paper presents a computational study of a cutting-plane scheme for the Max-Cut problem based on hypermetric inequalities. Our computational approach based on heuristic separation of hypermetric inequalities and using augmented Lagrangian method is very efficient in handling large number of contraints and solving the underlying SDP relaxations. The minimization of the dual function is carried out by using a quasi-Newton method. Computational results show a promising way to tighten the bounds for the Max-Cut problem. Future work will examine the incorporation of the proposed method inside a branch-and-bound algorithm to solve the Max-Cut problem to optimality.

Table 2: Max-Cut results for Beasley graphs with $n = 250$.

Graph	Opt. cut	# B&B nodes [10]	Root bound [10]	Our bound
bqp250-1	45607	1	**45607.9**	**45607.8**
bqp250-2	44810	3	44812.0	**44810.0**
bqp250-3	49037	1	**49037.8**	**49037.4**
bqp250-4	41274	3	41275.2	**41274.9**
bqp250-5	47961	1	**47961.9**	**47961.8**
bqp250-6	41014	17	41215.3	**41014.5**
bqp250-7	46757	1	**46757.9**	**46757.9**
bqp250-8	35726	325	36392.1	36038.7
bqp250-9	48916	3	48952.5	**48916.6**
bqp250-10	40442	3	40506.7	**40442.1**

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BIBLIOGRAPHIC DATA CLUSTERING BASED ON SYMMETRIC NON-NEGATIVE MATRIX TRI-FACTORIZATION

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Abstract: As a result of a vast expansion of the scientific knowledge the need has arisen to efficiently mine scientific literature in order to better understand and organize current knowledge. In this paper clustering of biomedical terms is performed by using only the number of co-occurrences of terms present in the scientific literature indexed by MEDLINE/PubMed database. In order to cluster discrete objects solely on similarity data non-negative matrix tri-factorization model was extended to reinforce clustering interpretation. Model training was performed by customized multiplicative update rule algorithm. Three methods were tested for extracting clusters from matrix factorization factors and analyzed.

Keywords: non-negative matrix tri-factorization, bibliographic data clustering

1 INTRODUCTION

Automatic document summarization (ADS) is one of the important tasks in text mining. The main aim of ADS is to generate a condense synopsis of the text, while loosing as little information as possible [16]. Researchers have proposed a variety of approaches to ADS, including machine learning [14] and deep neural networks [9]. Despite the maturity of the research field, ADS is still challenging. For a comprehensive overview of ADS, we refer the interested reader to recent surveys [5, 11]. In this work, we mimic the process of ADS as a clustering task, where we exploit the power of matrix factorization to describe complex relationships among biomedical documents.

During the last decade, we have witnessed the rise of methods to reduce data dimensionality and complexity. Among them, non-negative matrix tri-factorization (NMTF) has received extraordinary attention due of its ability to: (i) fuse several sources of data, (ii) extract sparse and easily interpretable factors, and (iii) predict new associations overlooked by other methods.

The main idea is to factorize a given input data matrix D into the product of three non-negative matrices, G_1, S, and G_2, with much lower dimensions. These are used for co-clustering of the concepts underlying the data and to generate the predictions (recommendations, hypotheses) for new associations between the concepts. The mathematical core of the basic variant of this method can be formulated as an optimization problem

$$\min \{\|D - G_1 S G_2^T\|^2 \colon G_1, G_2, S \geq 0\} \tag{NMTF}$$

The majority of the results about non-negative matrix factorization are related to the basic two-factor formulation. The book [6] contains a great overview of up-to-date theoretical and algorithmic advances pertained to this variant of the problem. The NMTF, which is formulated and depicted above is theoretically less understood, but its applications in machine learning are significant and well justified.

Experimental network biological data was fused using NMTF in [7, 17] to uncover new pan-cancer genes and to identify the most rewired genes in cancer. New algorithms and codes for simplified variants of NMF were recently developed in [1, 10, 17].

In a similar context, a social matrix tri-factorization model with two auxiliary matrices was developed in [21] to significantly improve the accuracy of prediction in micro-blogging. These models also capture user interests more precisely and give better prediction interpretability. A correntropy based the orthogonal NMTF algorithm was developed in [18], which turned out to be robust to noisy data contaminated by non-Gaussian noise and outliers, and has outperformed the state-of-the-art methods in clustering real world image and text datasets.

From the computational point of view, the basic non-negative matrix factorization problem, NMTF and the generalizations are all instances of hard optimization problems (NP-hard [20]). Moreover, due to the large size of datasets, these problems contain a huge number of variables, typically in the order of millions. Therefore, we cannot expect to solve such problems to optimality, but we can strive to obtain solutions that are as good as possible (local optimum) using state-of-the-art techniques from non-linear optimization, and best available computing machines (supercomputers).

The state-of-the-art approach to solve these problems relies on the Fixed Point Method (FPM) with a different variant of the multiplicative update rules, see [2, 3, 4, 17, 18]. Apart from FPM, some other methods have been applied to NMTF, like the Projected Gradient Method [15], the Least-Squares Algorithm with the active-set method [13] and the Alternating Direction Method of Multipliers (ADMM) [8]. Extensive computational studies in [1, 10] show that beside FPM, the Adaptive Moment Estimation Method (ADAM), initially developed for training the deep neural networks, is also a very efficient method for NMTF, especially if we add orthogonality constraints for factors G_1, G_2 and if we use high performance computers and libraries like TensorFlow.

This conference paper has two main sections: Section 2 describes our methodology which is based on symmetric non-negative matrix tri-factorization, the data acquisition process and the measures to evaluate the performance of our methodology. Section 3 contains the results of the clustering obtained by our novel methodology. Conclusions contains final remarks and ideas for future work.

2 METHODS

In this section, we first introduce the computational core of the approach, describe the data preparation process, and present the evaluation strategy. Further details on reproducibility and the programming code are available in the project's repository[1].

2.1 Orthogonal symmetric non-negative matrix tri-factorization

The first phase of our methodology consists of finding lower dimensional representations of the matrices D^i, constructed in the previous section, by NMTF. More precisely, we solve the following optimization problem, called orthogonal symmetric NMTF, shortly OSNMTF:

$$\min \quad \left\{ \|D^k - GSG^T\|^2 \;\mid\; G, S \geq 0,\ G^T G = I. \right\} \tag{OSNMTF}$$

We can see that the objective function represents our goal to find good factorization of matrices D^i as products of three non-negative matrices. The constraint $G^T G = I$ implies together with the non-negativity constraint $G \geq 0$ that the matrix G, which is unique for all D^i, has at most one non-negative entry in each row. This will be used to find good clustering of concepts underlying the input matrices.

[1] `https://github.com/akastrin/sor-2021`

The objective function and the set of feasible solutions of OSNMTF are not convex. Even more, the objective function is polynomial of order 6 and from the complexity theory [20] it follows that we can not expect to find efficient algorithms that will compute optimum solutions of OSNMTF for every triple of the input matrices D^i.

However, for data modeling purposes, it is usually good enough if we can compute very good feasible solutions, a kind of local optima. Therefore, we adapt and extend the Fixed Point Method (FPM), which were developed in [1, 10, 17] to solve OSNMTF. This algorithm has turned out to be the method of choice for similar problems and it scales well on state-of-the-art supercomputers. We use MATLAB framework with parallel toolbox. The core of FPM can be summarized into Algorithm 1.

Algorithm 1: FPM to solve (OSNMTF)

Input : $D \in \mathbb{R}_+^{n\times n}$, $m \in \mathbb{N}$, $\alpha > 0$.
Output: G, S.
Initialize: *Generate* $G \geq 0$ *as an* $n \times m$ *random matrix and* $S \geq 0$ *as a* $m \times m$ *random matrix.*
repeat

$$G \leftarrow \sqrt{\frac{4DGS + \alpha G}{4GSG^\top GS + \alpha GG^\top G}} \tag{1}$$

$$S \leftarrow \sqrt{\frac{G^\top DG}{G^\top GSG^\top G}} \tag{2}$$

until *convergence or a maximum number of iterations or maximum time is reached*;

We use the following measures of the quality of solutions of OSNMTF:

- mean square error, which measures the quality of factorization: $\text{MSE} = \frac{\|D-GSG^T\|^2}{\|D\|^2}$
- feasibility $\|S_-\|^2 + \|G_-\|^2 + \|G^TG - I\|^2/m$, where a minus in the subscript denotes that we take only the negative values in the matrix (the projection to the non-positive orthant).

All the internal parameters will be set such that the expected value of the feasibility measure will be below a threshold value, which will be set to approx. 10^{-4}. The internal dimension m was selected to be much smaller than n (we tested valued between 5 and 50).

Once we have a good (locally optimum) solution of OSNMTF, we exploit the G part of the solution. It will consist of n rows and m columns. Each row will have values between 0 and 1 and in each row there will be at most one element significantly larger than 0 (this follows from the orthogonality constraint $G^TG = I$.) This matrix is used to cluster the concepts into groups of similar concepts, where the similarity measure can be obtained as the Euclidean distance between the rows of G (and therefore classical clustering algorithms like k-means and hierarchical clustering (hlcust in Table 1 can be applied) or by using the maximum non-zero elements in each row of G as the indicator to which cluster the concept underlying the row should be assigned ($G_{\max}$ method in Table 1). The clusters reveal new groups of similar concepts, which can not be observed by other methods, as was the case in similar research in other domains [17]. The matrix S is be symmetric of dimension $m \times m$ and describes relations between the groups identified by G in networks D.

2.2 Data acquisition

Data for this study were obtained from the MEDLINE/PubMed bibliographic database and related resources, which are briefly described below.

PubMed is the largest bibliographic database in the biomedical domain. We queried PubMed for all bibliographic citations with *hypersensitivity* as the main topic. We only retrieved records that contained the full text of the abstract and were written in English. Next, we normalized the collected corpus of titles and abstracts using semantic predications (i.e., subject–relation–object triples) [19]. Subject and object arguments of each predication correspond to concepts from the Unified Medical Language System (UMLS) Metathesaurus, while relations coincide with links from the UMLS Semantic Network. For example, the predication `Hypersensitivity - process_of - Hymenoptera` was extracted from the sentence "An association between mastocytosis and hymenoptera allergy has been observed". In this study, we used the SemMedDB database with pre-extracted semantic predications [12]. Finally, the obtained data were presented in the form of a co-occurrence matrix (i.e., a weighted adjacency matrix), where the nodes denote concepts and the links between them are extracted semantic predicates. The weights corresponded to the number of relations between pairs of concepts.

2.3 Performance evaluation

We adopted an evaluation strategy introduced by Zhang et al [22]. First, the semantic predicates in each cluster were mapped to a shorter list of meta-predicates, which allows us to summarize the thematic meaning of the predicates in a cluster. Second, validity in terms of cohesiveness and separability was calculated and compared across clusters. Cohesion measures the purity of the objects within a cluster, while separation measures the isolation of the objects between clusters. Cohesion (*Coh*) and separation (*Sep*) of a cluster i are formally defined as:

$$Coh(C_i) = \frac{x}{x+y} \quad \text{and} \quad Sep(C_i) = \frac{x}{x+z},$$

where x is the number of predications that match the most frequent meta-predication in the cluster i, y denotes the number of predications that do not match the most frequent meta-predication in the same cluster, and z refers to the number of predications in other clusters that match the most frequent meta-predication of the cluster i. In addition, we summarized the mean validity of the cluster i as the harmonic mean of cohesion and separation. Performance was evaluated only on clusters in which the frequency of meta-predications was greater than 3.

3 RESULTS

Table 1 shows a summary of the clustering performance in terms of cohesion and separations across the selected values of parameters (method, K, and k). Regarding the cluster partitioning strategy, the k-means partitioning performs best on average (0.32 ± 0.21), followed by $G_{\max}$ (0.25 ± 0.18) and hierarchical clustering (0.20 ± 0.17). Comparing the results with respect to the parameter K, we observed no differences among solutions with $K = 30$ (0.25 ± 0.19) and $K = 120$ (0.25 ± 0.19). It is also worth noting that the mean validity of the clustering solutions decreases as the number of clusters increases (overall validity equals (0.30 ± 0.20), (0.25 ± 0.25), and (0.22 ± 0.18) for $k \in \{10, 20, 30\}$, respectively).

The column k_c in Table 1 summarizes the number of complete clusters for each clustering solution. (As described above, validity was only evaluated on clusters with more than three meta-predicates.) Comparing the number of induced clusters in column k with the number of complete clusters reveals a large discrepancy between both distributions. For each partitioning strategy, a total of 120 clusters (i.e., aggregated by both k and K) were originally induced. However, the proposed partitioning approach generates the largest number of complete clusters (111/120), while the k-means solution returns only 46/120 complete clusters.

4 CONCLUSIONS

This paper presents a methodology for clustering discrete objects using only similarity data. It is shown that NMTF model can be extended to achieve clustering interpretation by imposing orthogonality using a simple penalization term in the objective function. Model training was

Table 1: Summary of the clustering solutions

method	K	k	k_c	*Coh*	*Sep*	Overall
$G_{\max}$	30	10	10	0.53 ± 0.23	0.29 ± 0.18	0.33 ± 0.17
		20	19	0.53 ± 0.20	0.20 ± 0.17	0.24 ± 0.18
		30	25	0.61 ± 0.27	0.16 ± 0.15	0.21 ± 0.17
	120	10	10	0.50 ± 0.21	0.28 ± 0.20	0.32 ± 0.21
		20	20	0.63 ± 0.29	0.19 ± 0.18	0.25 ± 0.21
		30	27	0.65 ± 0.25	0.17 ± 0.16	0.22 ± 0.17
hclust	30	10	9	0.60 ± 0.30	0.20 ± 0.20	0.25 ± 0.21
		20	14	0.55 ± 0.28	0.18 ± 0.16	0.24 ± 0.18
		30	22	0.57 ± 0.28	0.13 ± 0.14	0.17 ± 0.17
	120	10	9	0.59 ± 0.25	0.14 ± 0.17	0.17 ± 0.17
		20	17	0.55 ± 0.25	0.15 ± 0.16	0.20 ± 0.17
		30	24	0.59 ± 0.27	0.16 ± 0.17	0.19 ± 0.17
k-means	30	10	4	0.62 ± 0.35	0.38 ± 0.22	0.39 ± 0.23
		20	9	0.84 ± 0.29	0.24 ± 0.24	0.28 ± 0.26
		30	11	0.80 ± 0.31	0.27 ± 0.18	0.34 ± 0.20
	120	10	3	0.64 ± 0.33	0.50 ± 0.00	0.54 ± 0.13
		20	8	0.67 ± 0.34	0.29 ± 0.19	0.32 ± 0.19
		30	11	0.74 ± 0.28	0.23 ± 0.18	0.27 ± 0.18

Note: K = dimension of matrix G, k = number of clusters, k_c = number of complete clusters, *Coh* = cohesion, *Sep* = separation. Results are presented as (mean, std. deviation) tuples.

performed by using customized multiplicative update rule algorithm which is especially suitable for sparse matrices and results to fast training. Method was tested by clustering biomedical terms using only the number of co-occurrences of those terms present in the scientific literature. To acquire this similarity data PubMed bibliographic database was used. Three methods were tested for extracting clusters from matrix factorization factors. With regards to cohesion and separation of clustering k-means was proven to have the best performance. On the other hand k-means returned the smallest number of complete clusters.

We remind the reader that the presented results are exclusively preliminary. The results demonstrate the main idea of the NMF-based ADS and provide promising evaluation performance. Further work requires evaluation of the generalization error on various datasets, appropriate evaluation on synthetic data, and rigorous statistical assessment. Behavior of cluster partitioning strategy will also be further explored in future work in order to balance the quality of clustering with regard to the number of complete clusters and the validity of clustering (cohesion and separation).

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On the didactic value of crossing critical graphs

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Abstract: Csikszentmikhalyi has introduced the concept of *flow* as a description of a psychologically optimal experience while working. Following the introduction of a mathematical model of emotional states while working and learning by Bokal (SOR 2017), later combined into a model of task-based time allocation by Bokal and Steinbacher, we formalize a problem structure that allows for the task challenge level to be iteratively adjusted to the growth of skills while working or learning, thus allowing for the performer of the activity to remain in flow during the whole process. We call such a structure a *dense challenge domain*, akin to a dense topological set. We show that large 2-crossing-critical graphs are an example of such a domain for several invariants, thus aligning the intuition of this model with experiences of a case study and linking this emerging theory with practice of adjusting course curriculum to induce flow in participants.

Keywords: course curriculum, problem based learning, 2-crossing-critical graphs

1 Introduction

Csikszentmikhaly has studied human emotional states arising while performing activities and characterized eight emotional states that occur, depending on the skill level and the challenge level perceived by the person engaging in the activity. These emotional states are apathy, worry, anxiety, arousal, flow, control, relaxation, and boredom, as displayed in Figure 1.

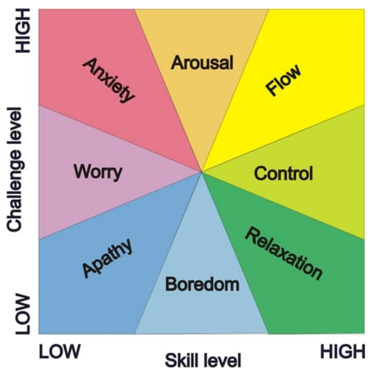


Figure 1: Csikszentmihalyi's characterization of emotional states while working. Source: [3].

Duckworth et al. [5] studied grit as a human trait and found it is based on two more basic character traits, passion and perseverance. She combined their perspective with the perspective of flow, and exposed the problem of the relationship between grit and flow [6]. Bokal and Steinbacher have proposed to model this relationship as a distinction between personal characteristics (of grit, passion, perseverance, and learning ability) which are an input into the process of working and learning; this process results in emotional states the individual experiences. Tertinek and Bokal have identified that the same model can be used for observing an optimal number of tasks for a process/person to perform, identifying several phenomena that could be explained by overloading the cognitive process [4].

While the model of Bokal and Steinbacher still requires validation, some aspects of it have been tested in pedagogical practice. A first step towards validation is to identify which learning and working problems satisfy the assumptions of the model, thus allowing for the learning process to follow the description of the model. While reflecting upon a course *Introduction to graph theory research* as conducted at the University of Osnabrück in October 2019, we observed that the structure of that course reflected closely the traits that could be abstracted to a general structure of a problem allowing for the learning process identified by Bokal and Steinbacher, consequently leading to flow and avoiding anxiety. In this contribution, we propose the concept of a *dense challenge domain*, which is a problem space parameterized by ordinal numbers. Under the assumption that the finite parameter subspace of that problem is solvable by elementary methods, problems associated with higher ordinal numbers call for applications of advanced mathematical tools or even introduction of new concepts. Should the complete problem be understandable to the practitioners, yet only elementary problems be immediately reachable for them, the parameterization allows the mentor to simplify the problem into smaller problems when needed and rise the challenges when suitable. This allows the course participants to slowly build upon their understanding of the problem and its solution. The result is an experience of the creative process that goes beyond learning from textbook examples.

The proposed formalization is an illustration of applied problem solving in a flipped course context in which we rather than focusing on introducing the concepts and past results, the concepts are presented to a level significant enough to understand the (yet unsolved and scientifically significant) problem, and the students then work towards solving this problem. The density of the challenge domain allows them to train the concepts required to be understood for a passable or even excellent grade at the course. However, the novelty of the challenge combined with the mentor's skill to observe the need to simplify or raise the challenge level (including the introduction of new concepts) provides the experience of actual, not simulated research. This setting thus satisfies the following preconditions for flow, identified by Csikszentmihalyi. The list needs to be understood both as desiderata defining the complete challenge domain, as well as the list of observations from the actual experience. Intuitively, if the students satisfy the preconditions, the process will converge to flow. The following three need to be satisfied by the tasks and the mentor proposing it: *Clarity of goals:* this clarity is provided through a mathematical definition of the problem for each instance, and by the students' understanding of the challenge as well as the expanse of the challenge domain. *Efficient feedback:* this is achieved by the accessibility of the mentor; his passive involvement with the projects turns active when he observes that students are spinning their wheels or heading towards anxiety, relaxation, or apathy. *Control is not a problem:* for mathematicians, the rigor of mathematical logic is the most ultimate form of control that they accept voluntarily. Should learning this rigor be part of the course experience, the presence of an advisor well-versed in mathematical rigor acts as such a control. The following conditions need to be satisfied by the environment in which the students are solving the task, i.e., participating in the course: *Deep concentration:* during the course, the students shall have no other significant obligations and no other lectures. Hence, this type of a course is only possible as a block course or an off-semester workshop. *Focus on the present:* during the course, future problems and issues should be kept in mind during planning and evaluation phases, yet the students should focus on the task at hand during the problem solving phases. As the (future) grade is a significant part of students emotional perception, this assumption requires the students to quickly reach a level that will with certainty lead to achieving a grade they are comfortable with, yet will still show possibility of improvement and increased challenge and skill. The last requirement arises from the dense challenge domain and the skill of the students as well as the mentor to navigate it: *Alignment of challenge and skill:* The challenge of the task being solved needs to be aligned with the student's current skill. While the complete problem is initially clearly beyond the reach of the students, the density of the challenge domain allows for students to pick a relevant solvable problem at each step of their learning. The awareness of the novelty of the solution induces alertness for seeking new concepts and tools, thus contributing to the desire for raising the challenges as well as to the realism of the research experience. With the above six conditions satisfied, Csikszentmihalyi's research predicts the following type of experiences: *Insensibility to the passing of time:* people in flow report both feelings of time passing quicker than they realized or not noticing it passing at all. *Loss of ego:* people in flow report not paying attention to the impression their activity left on other observers. *Autotelic experience:* people in flow report on their task being a significant enough award per se, without the need for external awards. We conjecture that while in flow, individuals do not have significant levels of attention left for reflecting time, the reactions of others to their activity, nor its usefulness.

In our case study, instances of all the above predicted experiences were observed. Due to the small sample size, we are unable to identify the scale of the effect. However, we believe that further research as well as the formalization of the context using the concept of the dense challenge domain would allow further validation of the concepts and the learning.

To further this, we structure the rest of the paper as follows: Next, we define 2-crossing-critical graphs which were used in our case studies. In Section 3, we formalize the concept of a dense challenge domain and prove that, for several graph invariants, the aforementioned graphs form a dense challenge domain for the problem of computing each of these invariants. Finally, we sketch a process of converting a dense challenge domain into a feasible curriculum and conclude with a discussion in which contexts such a curriculum can be applied.

2 Crossing critical graphs

The crossing number $cr(G)$ of a graph G is the smallest number of edge crossings in a drawing of G into the plane. For a positive integer c, we say that a graph G is c-crossing-critical if $cr(G) \geq c$ but $cr(H) < c$ for every proper subgraph $H \subset G$. In 1930, Kuratowski [8] showed that $K_{3,3}$ and K_5 are the only two minor-minimal nonplanar graphs. In contrast, fixed crossing number realizable graphs are known to have a richer structure of topologically minimal obstruction graphs, which was first demonstrated by Širan by constructing infinite families of c-crossing-critical graphs [10] and later extended by Kochol with simple, 3-connected graphs [7]. Kuratowski's theorem implies that $K_{3,3}$ and K_5 are the only 3-connected 1-crossing-critical graphs and describes all 1-crossing-critical graphs as their subdivisions. The logical next step was to investigate the structure of 2-crossing-critical graphs. The complete characterization was established only in 2015 by Bokal, Oporowski, Richter and Salazar [2], showing that 2-crossing-critical graphs are either (i) "small" or (ii) 2-connected and obtained from 3-connected ones using subdivisions and similar operations, or (iii) 3-connected and obtained similarly as Kochol's 2-crossing-critical graphs [7] but using 42 different structures called *tiles* (of which Kochol used only one). They showed that unlike just two 3-connected 1-crossing-critical graphs, the 3-connected 2-crossing-critical graphs already exhibit infinite families of topologically minimal obstruction graphs.

Definition 2.1. *A tile is a triple $T = (G, x, y)$, consisting of a connected graph G and two sequences $x = (x_1, x_2, \dots, x_k)$ (left wall) and $y = (y_1, y_2, \dots, y_l)$ (right wall) of distinct vertices of G, with no vertex of G appearing in both x and y. If $|x| = |y| = k$, T is a k-tile.*

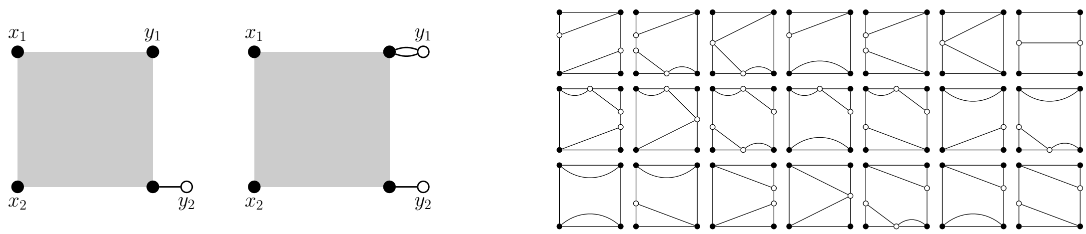
Definition 2.2. *Tiled graphs are cyclic joins of tile sequences, formalized as follows:*

- *The tiles $T = (G, x, y)$ and $T' = (G', x', y')$ are compatible whenever $|y| = |x'|$. Their join $T \otimes T' := (G'', x, y')$ is a new tile, where G'' is obtained from the disjoint union of G and G' by identifying y_i with x'_i for each $i \in \{1, \dots, |y|\}$.*
- *For a k-tile $T = (G, x, y)$, the cyclization of T is the graph $\circ T$ obtained from G by identifying x_i with y_i for each $i \in \{1, 2, \dots, k\}$.*

Definition 2.3 (based on [2])**.** *The large 2-crossing-critical graphs are defined as follows:*

1. *For a sequence x, let $\overline{x}$ denote the reversed sequence. The right-inverted (left-inverted) tile of a tile $T = (G, x, y)$ is the tile $T^{\updownarrow} := (G, x, \overline{y})$ (and ${}^{\updownarrow}T := (G, \overline{x}, y)$, respectively).*
2. *Let $\mathcal{S}$ be a set of 2-tiles obtained as combinations of two frames and 21 pictures, shown in Figure 2, in such a way that a picture is inserted into a frame by identifying the gray area with it; the picture may not be rotated.*

3. *Let $\mathcal{C}_L$ denote the set of all graphs of the form* $\circ(T_0^{\updownarrow} \otimes T_1^{\updownarrow} \otimes T_2^{\updownarrow} \otimes \cdots \otimes T_{2m-1}^{\updownarrow} \otimes T_{2m}^{\updownarrow})$[1] *with* $m \geq 1$ *and with* $T_i \in \mathcal{S}$*. We call* $\mathcal{C}_L$ *the set of large 2-crossing-critical graphs.*



(a) The two available frames. (b) The 21 available pictures.

Figure 2: Left wall vertices of the 2-tiles obtained from frames are x_1, x_2 and right wall vertices are y_1, y_2. The black vertices of the pictures are identified with black vertices of the frames.

3 Dense challenge domains and their relation to 2-crossing-critical graphs

The above allows us to define a *challenge domain* $\mathbb{C}$ as a set of *tasks*. A *task* is a 2-tuple $T = (P, I) \in \mathbb{C} = \mathbb{P} \times \mathbb{I}$, where $\mathbb{P}$ is a *problem space* and $\mathbb{I}$ is an *instance space*. Given a task $T = (P, I)$, I is a *family* of instances under consideration when tackling the problem P. Each task T poses a specific level of challenge and requires a specific level of skill.

Intuitively, a challenge domain is *dense* if it allows for a fine-grained selection of tasks $T \in \mathbb{C}$ with respect to (a) the complexity of the tasks, (b) the similarity between tasks, and (c) the preferences of the student. In a dense challenge domain, after closing a task, we can thus efficiently find a suitable next task, either leading into more complex realms, or via simplifications. This allows the mentor to identify tasks that bring and keep the student into flow according to the process identified by Bokal and Steinbacher in [3]. Essentially, the mentor can raise the challenge when the task should be more difficult, or suggest an easier task if the challenge proved too difficult. As such, a dense challenge domain should contain tasks close to trivialities and reach up to the current frontiers of knowledge.

The utilization of an explicit instance space is of utmost importance: changing between different problems does in general not lead to smooth transitions between tasks. A fine-grained and at the same time meaningful parameterization of instances on the other hand allows student to progress up to a point where a careful problem shift can hold them in or bring them into flow, followed by another progression through increasingly complex instance families.

It cannot be stressed enough that the existence of a dense challenge domain cannot be ascertained out of context: The necessary span between simple and hard tasks in $\mathbb{C}$ is intrinsically dependent on the student or group of students.

We propose to capture the above density concept formally; recall that $\aleph_0$ denotes the cardinality of the infinite set of all natural numbers:

Definition 3.1. *A challenge domain $\mathbb{C}$ is* dense *if there exists a mapping μ from tasks in $\mathbb{C}$ into ordinal numbers such that the image of μ has size at least $\aleph_0$. Thereby, the mapping μ is to encode the tasks' complexities: for two tasks T_1, T_2, a relation $\mu(T_1) < \mu(T_2)$ indicates that T_1 is easier than T_2 (for some notion of complexity). The ordinal number describing the infimum of μ over the set $\mathbb{C}$ is called the* density *of μ.*

Note that density is only defined for a specific mapping μ, but a given challenge domain can have several mappings witnessing its density, hence for a specific dense $\mathbb{C}$, its density may not be well defined. We can improve on this understanding as follows. Given a task $T = (P, I) \in \mathbb{C}$, there can be several *facets* that contribute to the task's complexity (for example instance size, density of the graph instance, maximum vertex degree, etc.):

[1] combinatorially equivalent to $\circ((T_0 \otimes {}^{\updownarrow}T_1^{\updownarrow} \otimes T_2 \otimes \cdots \otimes {}^{\updownarrow}T_{2m-1}^{\updownarrow} \otimes T_{2m})^{\updownarrow})$ as defined in [2].

Observation 3.2. *Given a challenge domain $\mathbb{C}$, assume that for each task $T \in \mathbb{C}$ there are ℓ different facets of complexity, and each facet $f_i(T)$, $1 \le i \le \ell$, is encoded via an ordinal number. Consider the mapping $\mu(T) := \prod_{i=1}^{\ell} f_i(T)$. If, over all tasks in $\mathbb{C}$, k facets each yield infimum $\aleph_0$, $\mathbb{C}$ has density at least ${\aleph_0}^k$. In particular, if $k \ge 1$, $\mathbb{C}$ is dense.*

For example, by allowing arbitrarily large instances in the challenge domain, one attains only density $\aleph_0$, the bare minimum, while we prefer higher densities.

Theorem 3.3. *The challenge domain of identifying a graph theoretic measure over 2-crossing critical graphs has density at least ${\aleph_0}^{42}$.*

Proof (Sketch). The core of the argument lies in the encoding of large 2-crossing-critical graphs, i.e., the infinite family of graphs composed by a (cyclic) arbitrarily long sequence of tiles from a set of 42 different tile types. Given any $G \in \mathcal{C}_L$, we may count the number of occurences of each tile type, yielding a 42-dimensional vector of integers. Over all large 2-crossing-critical graphs, each entry in the vector can yield arbitrarily large values and can be understood as one facet of complexity. By Observation 3.2 we thus obtain the claimed density. $\square$

We claim that restricting the number of tiles per type in fact corresponds to simplifying tasks from the graph-theoretic viewpoint. Furthermore, it is easy to see that the challenge domain's density can easily (and meaningfully) be raised further, by considering further facets of complexity: E.g. we may count the longest subsequence (i) of identical tiles, (ii) of two tiles alternating, (iii) without some predefined tile type, etc. Each such facet can be exploited in proof attempts and thus yields a meaningful measure of complexity. The more such facets with unbounded image we have, the (formally) denser our challenge domain becomes and the (intuitively) more possibilities for the mentor arise to finetune a task to the specific skill or interest of a student.

4 Turning a dense challenge domain into an university course curriculum

We conclude the paper with a discussion of an approach that converts a dense challenge domain into a course curriculum, as we did with 2-crossing-critical graphs for the course *Introduction to graph theory research* (IGTR). There are multiple steps:

Identification of a dense challenge domain and course preparation. In this step, a parameterization of the instance space and the problem space take place. They are introduced using a series of tasks showing the necessary concepts. This series starts with simple, elementary tasks. Later tasks, once the core concepts are understood by the course participants, are more demanding. For each task, a hint and independently a solution is provided. For IGTR, tasks were prepared as a paper [12] and solutions as an independent PDF. The course was prepared adhering to 6 ECTS guidelines. The course was elective, and all the material was presented to students before enrollment.

Introductory lecture. In the first day morning lectures, the mechanisms of learning, innovation, and accompanying emotional experience are presented to the level that allows the students to reflect upon their progress and evaluate their emotional state. This is followed by afternoon lectures introducing the concepts required to understand and navigate the selected challenge domain. For 2-crossing-critical graphs, the introduction consists of explaining graph planarity, linking crossing-critical graphs to Kuratowski's theorem, explaining tiled graphs, the theorem characterizing 2-crossing-critical graphs and their construction, and finally reviewing graph invariants that constitute the problem space. The students were then given the tasks prepared in the previous step as homework and told to try the presented invariants on a few small graphs and pick their favourite invariant.

Solving prepared tasks. In the next day morning lectures we review the solutions of the previous day homework. In the case study, the students solved most of the exercises themselves, and one even computed some elementary invariants thus reaching into the next step.

Solving selected problem instances. Solving the pre-prepared tasks sets the stage for the start of the creative part of the process, working on different invariants. This takes up the remaining contact hours. In this period, it is crucial for the mentors to work on establishing the preconditions for achieving flow, utilizing the density of the domain to find a task of suitable challenge level for the students to address. The mentor uses the aforementioned process of raising and lowering the challenge level to adjust to the students' progress. In our case the proposed theory is applied by starting with small graphs (of fixed length with one tile), to families of graphs (with few tiles) to the general results for the whole family.

Writing the results. After the end of the previous step, students write up the solutions to the problems they have solved. During this time, they periodically meet with the mentors to resolve any occurring misunderstandings and maintain feedback. Communication can be facilitated through group instant messaging channels. For 2-crossing-critical graphs, the writing up of the results took up a semester and resulted in the submission of a paper to a scientific journal.

Evaluation of the report. After the students submit their reports, these are evaluated by the mentor. The students may be given some iterations to improve their results according to the comments.

The presented case study and a formalization of the dense challenge domain concept show the possibility to systematically (try to) manage the emotional states of the participants of the problem investigation process. This (a) facilitates learning, but (b) can also be applied to challenging problems in research.

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INCREASING EFFICIENCY OF HEALTH CARE MANAGEMENT WITH THE ONLINE SCHEDULING FOR MEDICAL SERVICES: IMPACT OF AGE AND OCCUPATION

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Abstract: Online scheduling for medical services has various benefits, such as less administration work for the medical staff, time optimization, and transparency and its success depends on the individual perception of citizens about the value of utilization of such systems. This paper investigates those perceptions for the Croatian citizens and examines is there a difference of perception between demographic groups. The Correspondence analysis and Chi-square analysis were utilized to explore the data. The managerial and theoretical implications were discussed. The knowledge that emerged from the paper could help to develop strategies on how to educate and inform specific demographic groups on the topic.

Keywords: health care management, e-government, online medical scheduling, correspondence analysis, efficiency

1 INTRODUCTION

The pressure on the health care system is extremely high due to longer life expectancy and the aging population, and the pandemic accelerated the problem even more [9]. Appointment scheduling is complex especially in pandemics where the pressure on the health system is incredible. The organization is the key factor of its success and the ICT-enabled solutions such as online scheduling. The purpose of this paper is to explore how Croatian citizens perceive online scheduling for medical purposes. It investigates is there a connection between demographic characteristics such as age and occupation with the level of acknowledgment of the online scheduling systems, using the Chi-square and Correspondence analysis.

The paper is organized as follows: After the Introduction, the Literature review is presented where the key topics related to the research were discussed. The methodology chapter describes and explains the sample, research instrument, and statistical analysis. After Methodology, the results of the investigation were presented in the Results chapter. The final section of the paper is the Conclusion where the key findings were outlined.

2 LITERATURE REVIEW

2.1 Efficient healthcare management

The implementation of ICT in healthcare made it easier to manage global health systems, they emphasized universal access to health services and prominent quality of information [2].

Furthermore, they enabled overcoming geographical distance, connecting, and proactive action of physicians, consumers, and other stakeholders within the supply chain [6]. Greater consumer involvement in the health system creates a sense of greater security and trust, but it also carries great responsibility. Nevertheless, effective health management achieves consumer satisfaction through codes, regulations, and standards [17]. The local authority integrates complex systems analysis and technological-behavioral components into one synergistic whole. It ensures a balance of formality between different subjects, establishes a relationship between counseling and delegation, and creates a balance between individual and collective patterns of behavior [13]. On the other hand, one of the biggest challenges for healthcare management is how to ensure a fair distribution of resources. Very often, the technological instance entails an increasing discrepancy between rich and poor, between developed regions and less developed ones [7]. This creates an additional gap and deepens dissatisfaction that needs to be alleviated, concealed, and tried to eliminate.

Appointment scheduling is very challenging and shows how effective healthcare management is. The main challenge involves achieving synergies between a wide range of very different predictable but also unplanned circumstances [15]. There are various benefits of online scheduling, such as less administration work for the medical staff, time optimization, and transparency but its success depends on the, among other factors, individual perception of citizens about the value of utilization of such systems.

Aware of the limitations of their ability to provide quality services and a detailed approach to each patient in the short term, several different models of appointment scheduling in health care have been established [5]. This is achieved by dispersing decision-making at more adequately specialized levels or by providing multiple choices to patients to decide independently on potential solutions to their problems [18]. It establishes the order in the organizational distribution of health care staff, fixed capacities and investment flows, and ultimately achieves the satisfaction of all stakeholders in the system, especially patients.

2.2 Online scheduling for medical purposes

Online scheduling for medical purposes is a complex e-government system. Different authors already addressed the issue from different perspectives. For instance, some authors such as concentrated on the specific machines [11]. Authors examined patients perspective and suggested an optimization problem solution with reservation policy that minimises the non-utilization of resources subject to an overtime constraint [8]]. Others provided an heuristic search for medical service facility with two servers [14]. The same authors propose a simulation model which include logic for online scheduling.

The most accepted strategies predicted future requests by statistical model utilization with sampling the observations on the history [12]. The traditional model includes n jobs and number of m machines. Each job has to be processed on the each machine at the defined run [19]. Numerous algorythms were presented in order to solve the system. On the two parallel workstations, the 1.5+e01.5+e-approximation technique was developed after studying scheduling with release times and task rejection. [21] used a scheduling model to solve the challenge of single-day surgical scheduling in a single operating room (OR). offer a simulation framework that uses patient appointment control logic. Patients are scheduled using the authors' algorithm, which is structured on a simulation framework [16]. As the technology advances, the systems are much more sophisticated, faster and easier to use. Online scheduling systems of the modern world are based on AI, robotics, big data and other disruptive technology solutions [4].

3 METHODOLOGY

This research was undertaken on a sample of 3 268 respondents in Croatia. The respondents were divided by their demographic and occupation characteristics. The respondents fell into the five age groups: 16-24 (9,9%), 25-34 (33,8%), 35-44 (27,3%), 44-54 (16,0%) and older than 55 years old (13%). The respondents were divided by their occupations into knowledge and service-based occupations group, manual-based occupations where more than 60% respondents fell into, students and pupils (7%), retired (8%), and unemployed group (12%).

The respondents answered the questions which were measured by the Likert scale. The majority of the respondents acknowledge the relevance of the topic, as presented in Table 1.

Table 1: Research instrument measuring interest in online scheduling for medical services

Variable	Measurement / Percentage	Descriptive statistics
Scheduling for medical services	(1) not relevant (0,4%) (2) quite irrelevant (0,8%) (3) undecided (2,2%) (4) quite relevant (20,2%) (5) relevant (76,4%)	min=1 max=5 n= 3268 $\bar{x}$ = 4,71 σ= 0,585

The Chi-Square and Correspondence Analysis (CA) methods were utilized to explore the data. Chi-square is statistical which provides the confidence correlation between categorical variables [10]. The purpose of the Chi-square is to evaluate the large nominal datasets to test the hypotheses if the population is consisted of two or more categories as well as investigate the disparity of the data [3]. The Chi-square is calculated as follows:

$$\lambda^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(fo_{ij} - fe_{ij})^2}{fe_{ij}} \tag{1}$$

CA is a multi-way graphical representation of the incidence data which explores relationships between categorical variables [1]. CA is used to distinguish the most important relationships between the variables from the selected dataset [20]. They are presented as the dots on the map, where closer distributed dots represent the stronger relationship between variables [16]. In this investigation, CA will be used to reveal the concealed correlations between variables.

4 RESULTS

4.1 Chi-square analysis

Chi-square analysis results regarding the age and scheduling for medical services are presented in Table 2. The relationship is confirmed since the Chi-square value is 49,876 at 5%. All the age groups distinguish the scheduling for medical services as relevant or quite relevant, with more than half of respondents answered with one of the answers. Age group 35-44 have the most answers “Relevant” 27,4%. The age group 16-24 showed the least interest in online scheduling for medical services.

Table 2: Relationship of age and scheduling for medical services

Scheduling for medical services	**Age**				
	16-24	25-34	35-44	45-54	55+
(5)	23,1%	24,0%	27,4%	10,7%	9,0%
(4)	23,1%	28,0%	32,9%	31,8%	34,5%
(3)	15,4%	16,0%	15,1%	26,2%	28,1%
(2)	15,4%	16,0%	13,7%	19,5%	15,1%
(1)	23,0%	16,0%	11,0%	11,8%	13,3%
Total	100,0%	100,0%	100,0%	100,0%	100,0%
Chi-square (p-value)	49,876 (0,000***)				

Note: ** statistically significant at 5%

Chi-square analysis results regarding the relationship of age and scheduling for medical services are presented in Table 3. The Chi-square value is 50,722 so the relationship is confirmed at 1%. More than half of respondents from each occupation group marked the topic as "Relevant" were from knowledge and services (68,2%) The occupation group who answered the "Not relevant" the most is the manual based which could indicate the need for ICT skills improvement selected group.

Table 3: Scheduling for medical services and occupation

Scheduling for medical services	Occupation				
	Knowledge and serviced-based occupations	Manual-based occupations	Students and pupils	Retired	(Unemployed)
(5)	69,2%	56,0%	49,3%	59,8%	67,5%
(4)	7,7%	4,0%	8,2%	9,8%	9,3%
(3)	7,7%	16,0%	21,9%	7,3%	6,3%
(2)	0%	8,0%	6,8%	8,6%	6,4%
(1)	15,4%	16,0%	13,7%	14,5%	10,5%
Total	100,0%	100,0%	100,0%	100,0%	100,0%
Chi-square (p-value)					50,722 (0,000***)

Note: *** statistically significant at 1%

4.2 Correspondence analysis

Table 4 shows inertia per dimension of the selected variables which display the decomposition of the total inertia along each dimension. For age, the four dimensions were drawn from the analysis. The two dimensions account for the proportion of 96,1% of the total inertia which means they explained 96,1% of the variance of the cumulative solution. The third and fourth dimensions add 3,9% so they were excluded from the further investigation. Therefore, the two-dimensional representation was accepted for the research. The same conclusion refers to the occupation, in which the first and the second dimensions account for the proportion of the 98% variance of the cumulative solution.

Table 4: Inertia per dimension for age, occupation and scheduling for medical services

Dimension	Singular Value	Intertia	Chi Square	Sig.	Proportion of interia			
					Accounted for	Cumulative	Standard Deviation	Correlation 2
Age								
1	0.110	0.012			0.798	0.798	0.024	0.030
2	0.050	0.002			0.163	0.961	0.018	
3	0.024	0.001			0.039	1.000		
4	0.000	0.000			0.000	1.000		
Total		0,015	49.867	0.000	1.000	1.000		
Occupation								
1	0.107	0.011			0.736	0.736	0.024	0.203
2	0.060	0.004			0.232	0.967	0.019	
3	0.018	0.000			0.022	0.989		
4	0.013	0.000			0.011	1.000		
Total		0,016	50.722	0.000	1.000	1.000		

The CA provides a graphical representation of associations between dimensions of age and occupation with scheduling for medical services by giving a comprehensive view of the data. Figure 1 shows the relationship with the dimension of age. The age groups 25-34, 35-44, and 55+ are furthest away from the origin, so they show the most important differences from the expected proportions. The same age groups show a strong relationship to the „Relevant" value which indicates that selected age groups recognize the benefits from the online schedules for medical services. Those are either older citizens (55+) which are the group who often uses medical services, either the 25-44 age groups which have advanced ICT skills, who want to optimize their schedule and use the system for their children or older parents as well. The age group 16-24 is connected to „Irrelevant", „Undecided" and „Partially irrelevant" variables which are expected due to their lack of need and interest in medical services altogether.

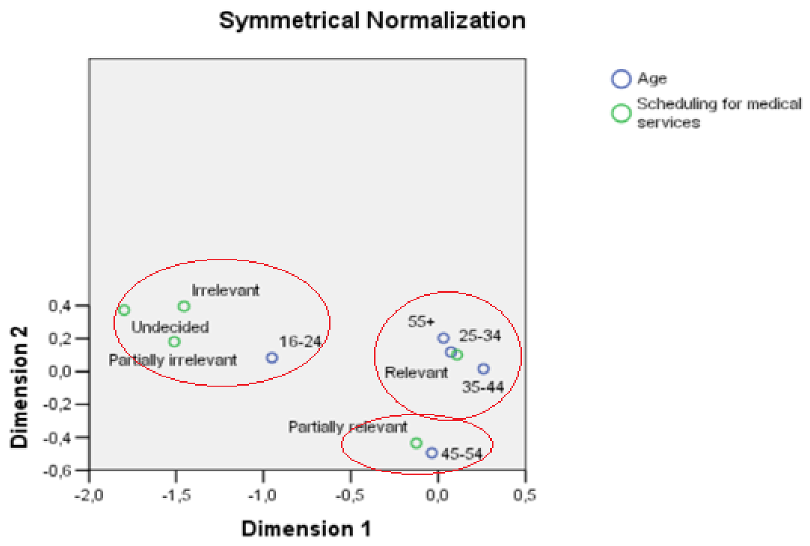

Figure 1: Correspondence analysis of age and scheduling for medical services

Figure 2 shows the CA between occupation and schedule for medical services. The knowledge and service occupation have the strongest correlation with the “Relevant" variable from all datasets. This is because the group has ICT skills and is aware of the importance of the topic. Manual-based occupation respondents also recognize the importance of online scheduling for medical services and mark the topic either as relevant either as partially relevant. Retired and unemployed mark the topic as partially relevant which can be due to the lack of information and ICT literacy. Students and pupils mark the topic as partially irrelevant as for the lack of interest in medical services altogether.

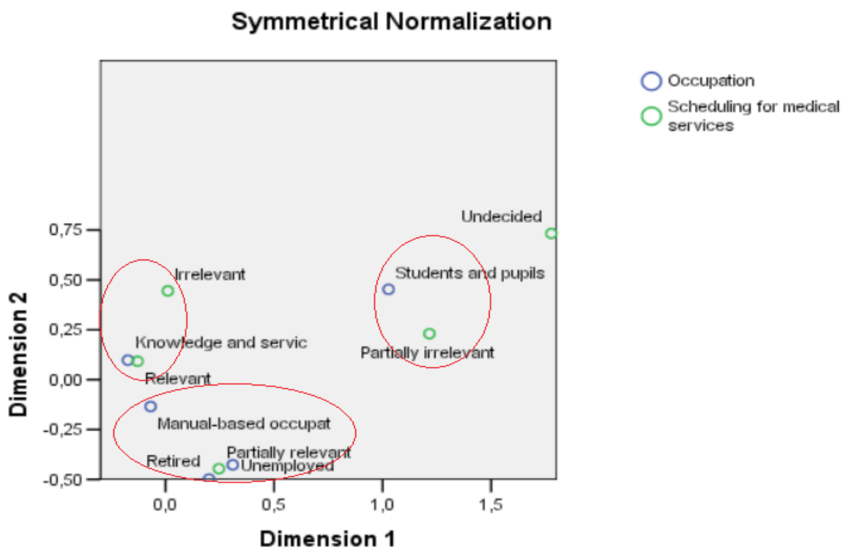

Figure 2: Correspondence analysis of occupation and scheduling for medical services

5 CONCLUSIONS

The prerequisite of online scheduling for medical services to succeed and function optimally all demographic groups need to acknowledge the importance of the system. The paper identified two categories that need a different approach to optimize the system overall: people with lower ICT skills such as the older population, who need education, and the younger population who need to raise awareness and information about the importance of the topic.

These findings should be useful for strategy development for managerial purposes, also can serve as useful investigations for the researchers. Future investigations should concentrate on other demographic characteristics, such as regions and cities, and should compare to the international findings, especially EU which are the limitations of this research. Lastly, this paper outlined CA as an excellent tool for data exploration so it could be utilized in a wide array of similar investigations.

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SMART HOUSE FOR OLDER AND PEOPLE WITH DISABILITIES

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Abstract: The article discusses a smart house model for the care of the elderly and people with disabilities. The future is in our hands and we need to take care of those who are not capable of taking care of themselves. We will present a model of a smart house which cares for the elderly and people with disabilities while providing the family members and health professionals with valuable data about its residents. The model raises and addresses numerous questions about the use of such data.

Keywords: smart house, IoT, Wi-Fi, health, BLE, smart systems

1 INTRODUCTION

On the surface, a smart house is not so different from a regular everyday house, the difference is only in the technology within its walls. A smart house is embedded with smart devices that allow for the automatization of everyday tasks. A smart house offers its inhabitants better quality of life with less worry. Smart houses enable us to live more comfortably. They save electricity, allow for better security, and can also take care of us.

As stated by Tanabe et al. (2019) the idea started with a project titled "Robotic smart home" (abbreviated RSH), which is targeted at the elderly and people with disabilities. The project presented a model that allowed for the development of a safe home environment. The biggest problem with introducing robots into the home is the space. The project RSH plans the development of robots based on creating the optimal home environment, which will allow the elderly to live independently for longer. RSH proposes three robotic subsystems: A system that will assist with mobility and transport, a system that will assist with general functioning, and a system that will assist with information.

Gjesten et al. (2020) suggest the use of electronic healthcare to monitor and treat illnesses with the use of sensors, alarms, reminders, etc. Through these methods, we can prevent potential hospitalization of the elderly and people with disabilities, that live in a home environment or are in community care. The model of using technical applications to monitor a patient's illness is gaining recognition around the world. As such the model must be useful and adequate for its purpose.

Transforming regular houses into smart houses is on the rise in the last couple of years. This trend can be attributed to the so-named technology "Internet of Things" (further abbreviated to IoT), which enables sensors, smartphones, and computers to all coexist in the cloud and be controlled through various means such as by voice commands. Mtshali and Khubisa (2019) describe a system, that uses smart plugs, smart chargers, smart cameras, and smart assistants employing voice control from Amazon Alexa, Google Home, Google Assistant, Apple Siri, and Microsoft Cortana. The system is targeted at people with disabilities and aims to make household tasks such as toggling appliances on and off as easy and as natural as possible.

The study is based on the technology IoT and presents an application system that uses soft control of devices, to ensure comfortably warm indoor spaces. The system uses a dispersion method to determine the best location for measurements. It assesses the stability with minimal variations, reliability with the lowest average deviation and uses a user questionnaire or an external conversation with the user to determine if the test data differs from the user's feelings. (Sung, Hsiao, 2020)

1.1 The problem

We will go over the use of smart systems for the control of everyday objects. This subject gives rise to many ethical questions, such as protection of personal data, the abuse of personal data, unauthorized access, control over one's privacy, and violation of their right to privacy.

Smart houses don't only automate everyday processes (regular, technological) they also have a psychological effect on people, by making them feel safer. Besides allowing for total control over the house and the things that go on inside it, it also allows for many other things.

Older people and people with disabilities have a harder time tending to everyday tasks or they may be completely unable to do them at all. Often they are unable to care for themselves or, with older individuals, they may be forgetful and can forget that they started an activity. With analysis we determined the key problems of older people and people with disabilities:

1. They often forget what they were doing. They may start cooking and leave the house for just a moment. In that short period, they may have forgotten that they were cooking and can accidentally start a house fire.
2. They have difficulty or are unable to perform basic everyday tasks (turning on lights, opening the blinds, opening the door).
3. They may fall and hurt themselves inside the house, outside, on a walk, or even in the shower. They may even be unable to call for help.
4. They may feel sick and sometimes, because of their endangered state, it may already be too late. Because they don't know, if they are sick and they don't want to wait at the doctor's, they often don't seek help at all.
5. They may feel unsafe if they live alone.

1.2 Objective and intent

The objective of this article is to discover and suggest a smart house model, that will best support the needs of older people and people with disabilities. The intent of this article is to in the simplest way possible describe and show, that smart houses are more than just sensors (temperature, moisture, luminosity, ...) and that there are many fields here, that are extremely important. We will describe 6 key elements of a smart house, which are necessary to allow the house to care for older people and people with disabilities. The goal of this research is to discover and suggest a model, which will best satisfy the following requirements: to create an accessible, simple, revived, and effective model; to notify close family members and health workers in due time; to allow for a prompt overview of privacy of people within their home; suggest a cost-effective and efficient solution of smart house deployment.

1.3 Methods of research

We will go over existing literature in various world databases such as Web of Science, Scopus, Google Scholar, and Research Gate. We will search for literature with the following keywords and their combinations: skill acquisition: IoT, health care, Wi-Fi, smart house.

Based on critical analysis of secondary sources, we will learn the technological needs and requirements of houses and the needs and requirements of older people and people with disabilities, so that they may live in these houses with utmost comfort.

2 ELEMENTS OF A SMART HOUSE

2.1 Blinds

The system would allow for simple control of blinds with a mobile phone, tablet, or computer. The blinds can be controlled from anywhere and at any time, regardless of the location or time. The application would offer many functions, which include the opening and closing of blinds with a single touch, opening and closing of blinds at a predetermined time, and automatic adjustments of blinds based on when the sun rises and sets. The user also has the added option of a "security mode" and various other scenarios. The blinds can also adjust themselves based on the current weather, which the device gets based on the location of the house. The controller allows for control of all types of blinds: roller shutters, window blinds, awnings, insect screens, and textile screens. For the controller to operate electricity and a Wi-Fi network is required. The application allows for control of individual blinds as well as user-defined groups of blinds, which the user opens and closes at the same time. If the Wi-Fi network collapses the blinds could still be controlled over Bluetooth or they may be controlled directly.

2.2 Lights

Smart lights would also work with a mobile phone. The connection between the device and the application is established over the Wi-Fi network and Bluetooth. We would enable switching the light on and off by merely entering or exiting a room. The lights may be controlled with the application.

The application also allows for a "security mode" which, would semi-randomly toggle the lights, which increases security from break-ins, when we're away from home for a longer period of time (vacation). By randomly toggling the lights we can give the impression that someone is home and therefore reduce the chances of a break-in. The user can also set a schedule, which will turn the lights on and off at a set time. Similarly, the user can enable a feature that will turn the lights off after a set amount of time. This prevents the lights from staying on all night if we happen to fall asleep before we turn the lights off.

Smart lights would also have a light regulating function, which can also be set in the schedule. By decreasing the intensity of incoming light we could make the house more pleasant to live in. The biggest advantage would be in the automatic toggling of lights, since the application could recognize each light, and communicate with it. In practice, this means the person can walk into a room, and the light would automatically turn on and after the person leaves the room the light would automatically turn off.

2.3 Heating and air conditioning

With air conditioning and heating devices, we make our lives more comfortable by cooling or heating spaces. Traditional heating can use a lot of energy (and with it money), especially if we live the device turned on even when we're not at home.

Smart air conditioning and heating devices would be controlled by the application. To control them we require a working Wi-Fi network, over which we connect to the device with our smartphone. The application allows for controlling the devices from anywhere and at any time. So we do not have to worry, about leaving an air conditioning or heating device turned on and then wanting to turn it off. We can also turn the device on before we get home, and hence increase the level of comfort of our home. The devices can also be put on a schedule, that will turn them on and off. For example: The air conditioning should work every day between 9:00 and 16:00 or the air conditioning should not work between 22:00 and 9:00.

2.4 Access control

Access control would be comprised of the front door and the garage door. It represents a smart way to enter your house or apartment. By clicking on an icon in the application, locking and unlocking the apartment would be possible. The front door and the garage door would automatically unlock/open and lock/close based on the user's location. The door would unlock and open when we get within a certain proximity of it. The owner of the house is connected via their phone to the control unit, which recognizes the owner based on a generated key and opens the door for them. By using a generated key we avoid duplication of traditional keys and lower the chance of a break-in. If the owner is not home, and someone rings the doorbell, the owner is notified and is offered the option of checking the intercom's camera, to see who is at their entrance. The application also allows for answering the intercom.

The intercom also has an integrated movement sensor, which would, when it detected movement, notify us and show us an image on our phone, that is also saved for later viewing. This would increase the safety of our home, while also giving us a better overview of the happenings around our house or apartment.

2.5 Smart wristband

With a smartwatch, we would have constant overview of key life functions of the person. Vital signs are at the forefront: heartbeat, temperature, blood pressure. These would be measure with a sensor embedded on the inner side of the wristband. The wristband would replace more traditional methods of measurement, which are usually slower and require their own instruments. Besides the vital signs, the wristband would also measure movement, which includes counting of steps, distance, calories, and GPS location. The wristband would also have a fall sensor, which would detect all falls. All of these functions can be reviewed in the application. The measurements are written automatically to the application by use of synchronization and the Wi-Fi network. The application allows us an overview of both past and present measurements. This foregoes the need to write these measurements down by hand, as it happens automatically and thus prevents mistakes and illegible writing.

The display of the wristband would display large numbers and letters, which would help older persons with reading. The display would show the time, date, and battery percentage. The wristband would also have the function of vibrating. Vibration would be used with incoming calls and SMS messages. The name of the caller would also be displayed on the wristband during an incoming call or SMS.

2.6 Voice control

Lights, blinds, climate control, and access control can all be voice-controlled as well with the help of spoken commands. This is useful when our phone is out of reach or our hands are busy. Voice control eases controlling of all devices in the house and even allows people with some more prohibitive disabilities to control everything in their house. This also improves our quality of life, since we can open doors, control blinds, toggle lights, ..., all without even leaving the comfort of our chair or interrupting our current activity. Controlling devices this way is also a lot more natural and personal, which contributes to the feeling of a true caring smart home.

3 MODERN MODEL OF A SMART HOUSE FOR OLDER PEOPLE AND PEOPLE WITH DISABILITIES

The model of the house would be designed to care for older people and people with disabilities. As we equip the house with the required technology, we will connect them into a comprehensive system. The house must in every moment, care for the user and allow them a safe and comfortable living.

We can see that in our model, everyday tasks that the user does in everyday life are automated. Above we outlined 5 key problems, however in practice there exist many more.

When the user of the smart house cooks lunch and leaves the room for a minute, an alarm in the system triggers. If the user leaves the room while cooking our model detects this, specifically this is done with the wristband since it provides us with the user's location. In this case, after a couple of minutes have passed, the user's wristband starts vibrating and alerts the user, that the stove is on. If the user is not responsive, the system can turn the stove off by itself, to prevent extended damage or even a house fire.

Everyday household tasks, such as turning the lights on, opening and closing blinds, and opening doors, have never been this easy. The user can control all of this from their phone or by voice control. This way the user can be lying in bed and still control the blinds, turn off the light or lock the front door, all by use of his smartphone or voice control.

The user can have an accident at any time. Our model allows us to detect this accident and, in the case of the user falling, be it in the house, in the garden, in the store, or the forest, the smart wristband detects the sudden change in height and sounds the alarm. This way it can immediately notify close family members about the accident, specifically what had happened and the location of where the family member is currently lying.

The smart wristband would allow for measuring of basic life functions, such as temperature, sleep quality, step counting, oximeter, etc... If the user's temperature is elevated or their heart rate is elevated, or anything else is off, our model would detect that the user is not in his normal life functions. Our model would immediately notify close family members and the user's assigned doctor. This way we can quickly and effectively know what's going on with the user and we can take the appropriate measures.
The user would feel safe in the smart house since they would feel like they aren't alone in the house. The house would care for them, correct their mistakes, control everyday devices and care for the user's health, as well as ensure that the user can live as undisturbed as possible in their smart house.

The smart house model is shown in Figure 1.

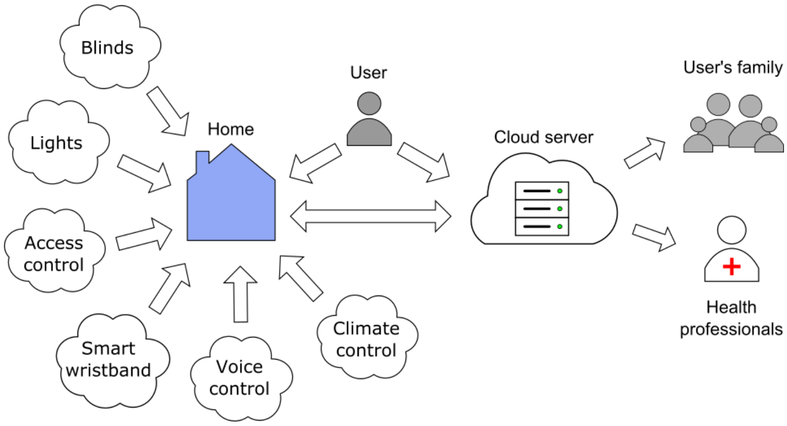

Figure 1: Smart house model

4 CONCLUSION

Smart houses used for caring for older people and people with disabilities need to be modern, since only modern smart systems can enable efficiency and flexibility. Information needs to be precise and delivered on time. People play an essential role in setting up a smart system, as they are the experts and the users. If the system is set up by experts, it will allow for better utilization and better utilization of information.

Every day technology improves, and since time is money, we need to enable users to get the most out of it in the shortest amount of time. If the user wants to live safely and comfortably in his house they need an effective smart system. A smart house needs to: adapt to trends in the technology market, be competitive with other technologies, and needs to connect and automate as many processes as possible. Minimizing the amount of time the user spends on their basic life needs is instrumental to the success of a smart house.

With the new model, we will enable other researchers to explore the details of each segment of smart homes for the care of the elderly. With the obtained data, we will determine the needs and requirements of people in need of care. We will also use the resulting model to change the course of nursing care, which will depend on IoT technology.

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LONGITUDINAL DYNAMICS BETWEEN LINEARLY ORDERED CLASSES

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Abstract: A longitudinal study monitors a cohort of subjects over a period of consecutive tests. When each test assigns the tested subject a class from a linearly ordered set, the dynamics of subjects can be presented using a sequence of bar-charts, each displaying the proportions of subjects in each class, and a graph drawing with vertices drawn on these bar-charts, such that the edges are drawn as lines representing the state transitions of each subject between tests. In the paper, we observe that the graph resulting from the above representation belongs to the family of tiled graphs, and that the drawings induced by two consecutive tests induce a tile drawing as introduced by Pinnontoan and Richter. We use this observation to develop an algorithm to produce drawings of the above graphs with the provably smallest number of crossings, and propose several applications of the structure resulting from such optimal drawings in studying such longitudinal processes.

Keywords: longitudinal study, crossing number, tile crossing number, optimal drawing.

1 INTRODUCTION

Longitudinal study designs have a long history in many scientific disciplines [3]. In such designs, the outcome is measured repeatedly over time for each individual in the study where continuous or repetitive tests or observations can be used. The longitudinal study aims to obtain information on changes in the process being monitored. Additionally, it can be used to anticipate risks or predict future developments. They are primarily used in health sciences, but also in biomedical research, psychology, sociology, education, etc.

In medicine, this study type is beneficial for evaluating the relationship between risk factors and the development of disease and the outcomes of treatments over different lengths of time. Similarly, because data is collected for given individuals within a predefined group, appropriate statistical testing may be employed to analyze change over time for the group as a whole or for particular individuals [2]. Psychologists are also making increasing use of such models to delineate the dynamic properties of psychological mechanisms, understood as a sequence of causal effects that govern the psychological functioning of human behavior. Apart from being an end in itself, understanding psychological mechanisms can also be an important step toward developing effective interventions [5].

Depending on how time is treated in the analysis, we can roughly distinguish between two different longitudinal models: static models and dynamic models. In static models, time is treated as a predictor in the model equation, just like any other predictor (e.g., in a standard regression model). In contrast to static models, dynamic models try to capture the actual mechanisms of a change process. In these models, time is considered implicitly by order of the measurement occasions but is not explicitly used as a predictor. A similar shift in preference can be observed regarding whether time should be treated discretely or continuously [6]. In the former, time is treated as a discrete variable that may only take on values from a countable set, whereas in the latter, time is treated as a continuous variable that may take on a continuum of values [5]. Several statistical methods may be used in the analysis of longitudinal data. The most commonly applied approaches are univariate (ANOVA) and multivariate (MANOVA) analysis of variance, mixed-effect regression model (MRM), and generalized estimating equation (GEE) models that are in more detail presented in [2].

The goal of this paper is to present longitudinal observations with graphs from a family of tiled graphs with the provably smallest number of crossings, and propose several applications of the structure. A key entity in a longitudinal study is a subject from a set of subjects S, who is periodically examined regarding traits related to the study. Each of these examinations constitutes a test. The methodology, applied in [7] is relevant for any longitudinal study that uses tests to place subjects in linearly ordered classes. Because of that, tests and subjects do not need to be specified, similarly to an abstract vector space, in which we wouldnt define the contents of its coordinates. For our model, we assume all individuals are tested at the same time instances, or at least the tests can be attributed to timestamps from a discrete set T. We further assume that the tests assign each individual at each timestamp a class from a discrete set of classes C. In this model, each individual traverses a path in the Cartesian product of $T \times C$, induced by the linear ordering of timestamps of T. If there is another linear ordering on the set of classes C, the paths of the subjects can be interpreted in the grid graph on the set of vertices $T \times C$. This allows for tools of graph theory to be applied to the investigated longitudinal process. The key contribution of our paper is linking longitudinal observations to (tile) crossing number of these observed graphs.

Our primary interest in the subject arises from observing emotional states of students during a project based learning course including a hackathon for key content development, as described in [7]. In there stated context, we investigate the role of crossing minimization in understanding the relative progress dynamics of subjects along a linearly ordered list of classes–their emotional states while working on the course. Our primary interest was understanding student progress in their project at the course. However, the same methodology can be used to study risk factors for disease development, such as cancer [8]. Abstracting from these instances, the approach is suitable for identifying intra-subject progress in any longitudinal study in which subjects are periodically tested and assigned to a set of linearly ordered classes. We observe that in order to display the relative progress of students during the course, we need to solve an abstract problem of optimizing the number of crossings in the longitudinal display of results. The algorithm produces a graph drawing from an abstract tiled graph in which tile's wall vertices are assigned equivalence classes, and these classes are linearly ordered. In Section 2, we explain the mathematical background of the algorithm, in Section 3 we present the algorithm, and in Section 4, we share the initial results and plans for further research.

2 MATHEMATICAL BACKGROUND

This section presents the mathematical background of the studied problem. The basic definitions and notations needed to prove the minimal number of crossings in the graph of an abstract longitudinal study are presented. This result is the basis of the optimization algorithm presented in Section 3 and is based on the theory of tiles initiated by Pinontoan and Richter [4] and further developed by several authors in the crossing number community.

A graph G is a structure consisting of two sets: $V(G)$ are the vertices of G and $E(G)$ are the edges of G. Each edge from $E(G)$ connects two vertices from $V(G)$ (endvertices of an edge). In our case, we will connect the individual subject from S in two consecutive tests and thus illustrate the change in the assessment of the state. A graph $G = G(V(G), E(G))$ is a *bipartite* graph if its vertex set can be partitioned into two disjoint subsets $V(G) = A + B$ such that every edge of $E(G)$ connects a vertex in A to a vertex in B (for *bipartite multigraph* multiple edges are allowed). We say that the sets A and B form a bipartition of G.

Let S be the set of considered elements, C a set of linearly ordered classes, and T a sequence of tests, where each $t \in T$ gives a mapping of S to C. Let $S(t,c) = \{s \in S \mid t(s) = c\}$ be the set of subjects who are assigned class $c \in C$ by test $t \in T$. For each consecutive t, t', we define a bipartite multigraph $G_C(t,t')$ with the bipartition $V(G_C(t,t')) = \{(t,c) \mid c \in C\} + \{(t',c) \mid c \in C\}$. Each subject $s \in S$ with the property $t(s) = c$ and $t'(s) = c'$ constitutes an edge between (t,c) and (t',c'), hence $E(G_C(t,t')) = \{(t,c)(t',c') \mid \exists s \in S \ni: (t(s) = c) \wedge (t'(s) = c')\}$. The label $b((t,c)(t',c'))$ of the edge $(t,c)(t',c')$ is equal to s existing to witness the edge.

Let G be a graph and let $L = (\lambda_0, \lambda_1, \ldots, \lambda_l)$ (*left-wall*) and $R = (\rho_0, \rho_1, \ldots, \rho_r)$ (*right-wall*) be two sequences of distinct vertices of G, such that no vertex of G appears in both. The triple (G, L, R) is called a *tile*. For $u, v \in L$ or $u, v \in R$, we use $u \leq v$ or $u \geq v$ whenever u precedes or succeeds v in the respective sequence. A tile (G, L, R) is *compatible* with a tile (G', L', R') if $|R| = |L'|$. A sequence of tiles $(T_0, T_1, \ldots, T_n)$ is compatible if T_i is compatible with T_{i+1} for $i = 0, 1, \ldots, n-1$. The *join* of two compatible tiles (G, L, R) and (G', L', R') is defined as $(G, L, R) \otimes (G', L', R') = (G \otimes G', L, R')$, where $G \otimes G'$ is the graph obtained from the disjoint union of G and G' by identifying ρ_i with λ'_i for $i = 0, 1, \ldots, r-1$. Since this operation is associative, we can define the join of a compatible sequence of tiles $(T_0, T_1, \ldots, T_n)$ as $T_0 \otimes T_1 \otimes \cdots \otimes T_n$.

For each consecutive $t, t' \in T$, we define a tile $T_C(t,t') = (G_C(t,t'), L, R)$, where L is the sequence of vertices $\{(t,c) \mid c \in C\}$ induced by the linear ordering on C. Similarly, R is the sequence of vertices of $\{(t',c) \mid c \in C\}$ induced by the same ordering. Note that each vertex of $T_C(t,t')$ is either a left or right wall vertex and that $|L| = |R|$. Hence, a sequence of tests $(t_0, t_1, \ldots, t_n)$ defines a compatible sequence of tiles $T_C(t_0,t_1), T_C(t_1,t_2), \ldots, T_C(t_{n-1},t_n)$.

A drawing of G in the unit square $[0,1] \times [0,1]$ that meets the boundary of the square precisely in the vertices of $L \cup R$ so that the vertices of L occur in the line $x = 0$, with the y-coordinates $\lambda_0, \lambda_1, \ldots, \lambda_l$ decreasing and the vertices of R occur in the line $x = 1$, with the y-coordinates $\rho_0, \rho_1, \ldots, \rho_r$ decreasing is a *tile drawing* of T.

A tile drawing of $T_C(t,t')$ is obtained by positioning the wall vertices on their respective sides of a unit square respecting the sequences L and R.

Let C be a linearly ordered class set. A *class-longitudinal graph* $T_C(t_0, t_1, \ldots, t_n)$ for the sequence of tests $T = (t_0, t_1, \ldots, t_n)$ is obtained by joining a compatible sequence of tiles $T_C(t_0,t_1), T_C(t_1,t_2), \ldots, T_C(t_{n-1},t_n)$: $T_C(t_0, t_1, \ldots, t_n) = T_C(t_0,t_1) \otimes T_C(t_1,t_2) \otimes \cdots \otimes T_C(t_{n-1},t_n)$. A *class-longitudinal drawing* of the class-longitudinal graph $T_C(t_0, t_1, \ldots, t_n)$ is a drawing $D_C(t_0, t_1, \ldots, t_n)$, such that each subdrawing induced by $G_C(t_{i-1}, t_i)$, $i = 1, \ldots, n$, is a tile drawing of $T_C(t_{i-1}, t_i)$.

For each consecutive t, t', we define a graph $G_S(t,t')$ with the bipartition $V(G_S(t,t')) = \{(t,s) \mid s \in S\} + \{(t',s) \mid s \in S\}$. The edges of this graph include $(t,s)(t',s)$, but in addition, the vertices of each $S(t,c), S(t',c)$ are joined by a path joining the vertices in each of these sets. We call the edges of these paths ordering edges, as the paths induce an ordering on the vertices in $S(t,c)$. The label $b((t,s)(t',s'))$ of the edge $(t,s)(t',s')$ is equal to s. By contracting all the ordering edges of $G_S(t,t')$, one obtains the graph $G_C(t,t')$. Hence, $G_C(t,t')$ is a minor of $G_S(t,t')$.

We define a tile $T_S(t,t') = (G_S(t,t'), L, R)$, where L is the sequence of vertices $\{(t,s) \mid s \in S\}$ induced by the linear ordering on $t(S) \subseteq C$, and the vertices of $S(t,c)$ are ordered respecting the ordering paths of the previous paragraph. Similarly, R is the sequence of vertices of $\{(t',s) \mid s \in S\}$ induced by the respective ordering. Note that each vertex of $T_S(t,t')$ is either a left or right wall vertex.

We obtain the *subject-longitudinal graph* $T_S(t_0, t_1, \ldots, t_n)$ from the class-longitudinal graph $G_C(t_0, t_1, \ldots, t_n)$ by expanding of the vertices (t,c) into paths induced by $S(t,c)$. This is the inverse operation of the above contraction, and by performing it in $T_C(t_0, t_1, \ldots, t_n)$ we assure expansion is done consistently for each pair of tiles $T_C(t_{i-1}, t_i)$ and $T_C(t_i, t_{i+1})$, $i = 1, \ldots, n-1$.

After the expansion, we double the newly obtained ordering edges, hence $T_S(t_0, t_1, \ldots, t_n)$ is obtained as a join of appropriate tiles $T_S(t_0, t_1, \ldots, t_n) = T_S(t_0, t_1) \otimes T_S(t_1, t_2) \otimes \cdots \otimes T_S(t_{n-1}, t_n)$.

A *subject-longitudinal drawing* $D_S(t_0, t_1, \ldots, t_n)$ is a drawing of $T_S(t_0, t_1, \ldots, t_n)$, such that each induced drawing of $T_S(t_{i-1}, t_i)$ is a tile drawing. An optimal subject-longitudinal drawing of $T_S(t_0, t_1, \ldots, t_n)$ has smallest number of crossings among all subject-longitudinal drawings of $T_S(t_0, t_1, \ldots, t_n)$. Its number of crossings is subject-longitudinal crossing number of T_S.

Let $i = 0, 1, \ldots, n$. We say that a subject s:

- is below subject s' at test t_i, if $t_i(s) < t_i(s')$.
- is above subject s' at test t_i, if $t_i(s) > t_i(s')$.
- is level with subject s' at test t_i, if $t_i(s) = t_i(s')$.
- overtakes a subject s' at test t_i, if s is below s' at t_{i-1}, but is above s' at t_i.
- overtakes a subject s' after test t_i, if s is level with s' at t_i, but is above s' at t_{i+1}.
- catches up with subject s' at test t_i, if s is below s' at t_{i-1}, but is level with s' at t_i.

Lemma 2.1 *Suppose a subject s overtakes s' at test t_i. Then, there is a crossing between the edge $(t_{i-1}, t_{i-1}(s))(t_i, t_i(s))$ and the edge $(t_{i-1}, t_{i-1}(s'))(t_i, t_i(s'))$ in the tile drawing of $T_X(t_{i-1}, t_i)$ for $X \in \{C, S\}$ (or $T(t_{i-1}, t_i)$ for short).*

We say that a pair of subject s, s' *strongly forces a crossing* in $T(t_{i-1}, t_i)$ if a subject s overtakes s' at test t_i.

Lemma 2.2 *Suppose the following three conditions hold:*

(i) *a subject s catches up with s' at test t_i,*
(ii) *s overtakes s' after t_j, and*
(iii) *s is level with s' for t_k, $k = i, \ldots, j$.*

Then, for some k, $k = i, \ldots, j+1$, there is a crossing between the edge $(t_{k-1}, t_{k-1}(s))(t_k, t_k(s))$ and the edge $(t_{k-1}, t_{k-1}(s'))(t_k, t_k(s'))$ in the tile drawing of $T_S(t_{k-1}, t_k)$.

We say that a pair of subject s, s' *weakly forces a crossing* in $T_S(t_{i-1}, t_i, \ldots, t_j)$, whenever the conditions of Lemma 2.2 are met with s, s'.

Theorem 2.3 *There exists a drawing D of $T_C(t_0, t_1, \ldots, t_n)$, such that every crossing in D is strongly forced. This drawing is an optimal class-longitudinal drawing of $T_C(t_0, t_1, \ldots, t_n)$.*

Theorem 2.4 *There exists a drawing D of $T_S(t_0, t_1, \ldots, t_n)$, such that every crossing in D is either strongly forced or weakly forced. This drawing is an optimal subject-longitudinal drawing of $T_S(t_0, t_1, \ldots, t_n)$.*

3 ALGORITHM

Theorems 2.3 and 2.4 have constructive proofs that we outline in this section. The described algorithms are illustrated on the data of [7].

First, we introduce some notation. Let $D_C(t_i, t_{i+1})$ be the tile drawing of $T_i := T_C(t_i, t_{i+1})$ in $[0, 1] \times [0, 1]$, obtained as follows: The vertex (t_i, c_j) is represented as the point $(0, 1/(n - j))$, and the vertex (t_{i+1}, c_j) as $(1, 1/(n - j))$. Each edge is drawn as either straight line between the points representing the edge's endvertices, if there is precisely one subject testing as the respective classes, or as a given number of lines parallel to this line, whenever there are several such subjects. These parallel lines can be connected to respective endvertices without introducing any crossing between them, so any crossing in $D_C(t_i, t_{i+1})$ results from Lemma 2.1. By gluing together the drawings of consecutive tiles $T_0, T_1, \ldots, T_n$, the resulting drawing D_C

satisfies the conditions of Theorem 2.3. We continue by explaining how D_C from the previous paragraph can be converted into a drawing D_S satisfying the conditions of Theorem 2.4. For this conversion, we use the fact that $T_C(t_0, t_1, \ldots, t_n)$ is a minor of $T_S(t_0, t_1, \ldots, t_n)$ and apply some approaches developed in studying minor crossing number [1].

Note that in D_C, the paths of an individual subject cross either at strongly forced crossings or at vertices. In D_S, any crossing at vertices of D_C representing classes of C that cannot be avoided in the expansion into vertices representing individual subjects in D_S is converted into a single new crossing, and each such crossing is shown to be weakly forced.

To achieve this desired outcome, we structure the multiple edges of T_C into subject bundles. A *bundle* in a tile $T_C(t_i, \ldots, t_j)$ is a set of subjects s that have the same class $t_k(s)$ assigned in each test t_k, $k = i, \ldots, j$. For later applications, we call $j - i$ the length of the bundle. For a bundle in a tile, the tile does not force any ordering of its subjects when expanding the classes, and they can be ordered arbitrarily. The bundles (dis)form dynamically as the time progresses. Whenever a bundle splits into several bundles, this may result in weakly forced crossings depending on the relative ordering of the classes the subjects had before they formed a bundle. An algorithm respecting this ordering hence yields a drawing D_S in which each crossing that is not strongly forced is weakly forced.

4 RESULTS AND FURTHER RESEARCH

Figure 1 displays the class-longitudinal drawing of $T_C(T1, \ldots, T11)$ for the data from paper [7]. The tests are interpreted as consecutive week numbers $T1, \ldots, T5, T8, \ldots, T11$, and as tests relating to the hackathon that was performed in the middle of the course in the weekend between $T6$ ($H1$) and $T7$ ($H4$). $H2$ and $H3$ denote the test after the first and the second day of hackathon, respectively. The emotional states (linearly ordered using their numeric representations) are interpreted in the figure caption.

The subject-longitudinal drawing of $T_S(T1, \ldots, T11)$ is displayed in Figure 2a. Here, each subject's path is displayed entirely, with colors matching the colors in Figure 1. We observe that the drawing is heavily distorted by the missing data. For this reason, we produce another crossing minimal drawing with no edges to missing data vertices (see Figure 2b).

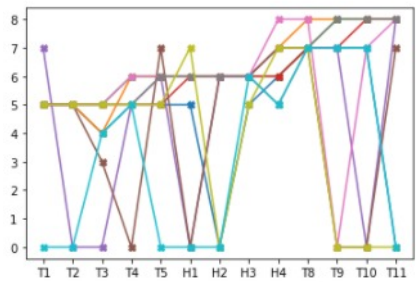

Figure 1: A drawing T_C for the data from [7]. Note that due to current code limitations, which will be resolved before the final version of the paper, parallel lines are drawn on top of another. Interpretation of emotional states (y-axis): 0-no data, 1-boredom, 2-apathy, 3-worry, 4-anxiety, 5-arousal, 6-flow, 7-control, 8-relaxation. Interpretation of weeks (x-axis) is in the text.

Note that each crossing of D_S is a result of a subject overtaking another (or a subject falling behind) another. Hence, in a longitudinal study, the agility of subjects with respect to the investigated ordering of the group could be measured by counting the positive crossings when they overtake and the negative crossings when they fall behind. Similarly, the total number of crossings could be interpreted as a measure of turbulence of the longitudinal process, with laminar processes having low subject-longitudinal crossing numbers and turbulent processes having high subject-longitudinal crossing numbers. Laminar longitudinal processes can be considered understood and predictable, and turbulent processes conversely unpredictable, with possibly unidentified parameters influencing the process. Identifying long bundles in a tile and understanding the mechanism that distinguishes them from the rest of the subjects would contribute to understanding the process and its influencing parameters. An example of such an understanding of the process is presented by comparison in Figure 2.

Most of the turbulence of the Figure 2a is caused by missing data. This may be justified by the fact that subjects, who do not have time to respond to questionnaires, may be unreliable in determining their response, and thus justifiably interpreted as turbulent. On the other hand, when missing data results from other causes and the process can be assumed laminar, the approach of minimizing the crossing number can be exploited to estimate the missing data. Each subject missing a test can be for that test assigned a class resulting in the smallest number of crossings. There may be several such classes and the likelihood of each class being assigned can be determined by the number of extra crossings induced by each class. Investigation of this method is planned for further research.

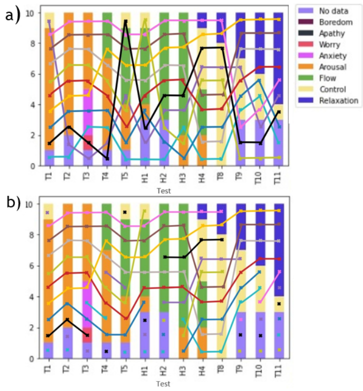

Figure 2: **a)** A drawing of T_S resulting from a drawing of T_C in Figure 1. Each of 10 students is represented by a single polygonal line. **b)** A drawing of T_S with no edges to missing data vertices.

5 Acknowledgements

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INFLUENCE OF NATIONAL CULTURE IN SUPPLY CHAIN INTERNAL INTEGRATION

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Abstract: Nowadays, the extremely competitive global market calls for complex global supply chains which makes it necessary for companies to establish relationships with a culturally diverse set of employees, partners, and customers. To effectively manage these relationships, organizations need to understand the critical role of national culture in supply chain management. Particularly, Culture has a huge impact on internal integration with 30 percent of cross-cultural mergers and acquisitions failing due to poor cultural management. To study the influence of national culture in supply chain internal integration literature was reviewed to identify factors affecting cross-cultural internal supply chains. By identifying these factors, organizations will have the opportunity to prevent cultural misunderstandings when extending internationally.

Keywords: National Culture, Supply chain, Internal Integration

1 INTRODUCTION

Cultural misunderstandings are an issue in global value chains and many enterprises place significant resources in preparing employees to avoid cultural misunderstandings. Studies show that a lack of intercultural competence results in enormous losses and frictions in negotiations, sales, and customer relationships [1]. National culture brings a contextual difference that can have an impact on the efficacy of supply chain management efforts [2].

Therefore, decision-makers in international companies face the challenge of dealing with a wide knowledge about cross-cultural management along the supply chain to successfully interact with their global partners. Particularly, Culture has a huge impact on internal integration with 30 percent of cross-cultural mergers and acquisitions failing due to poor cultural management [3].

Research shows that national culture factors are not neglectable in the supply chain management context [4]. However, literature on the influence of national culture in supply chain management is still limited. This paper will focus on identifying factors affecting cross-cultural internal supply chain integration to afterward design a questionnaire to analyze the impact of cultural differences in the internal supply chain of a multinational Dutch company. The questionnaire will be applied to the supply chain planners because they are responsible for integrating the site with the mother company every day, therefore, experiencing first-hand the challenges of cross-cultural internal supply chain integration.

2 CULTURAL FACTORS INFLUENCING SUPPLY CHAIN INTERNAL INTEGRATION

To design the questionnaire, literature was reviewed to understand which factors affect cross-cultural workplace and integration. To select the factors that would be included in the study, case studies of integration between companies operating in different countries were analyzed as well as personal experiences from employees working in a cross-cultural environment. The factors selected for the study were communication styles, structure and hierarchy, attitudes about time, giving feedback, decision-making styles, language, communication tools, beliefs regarding personal success, trust and commitment (Figure 1). Each factor will be discussed in detail, explaining why it is included in the study as well as how it affects cross-cultural internal supply chain integration.

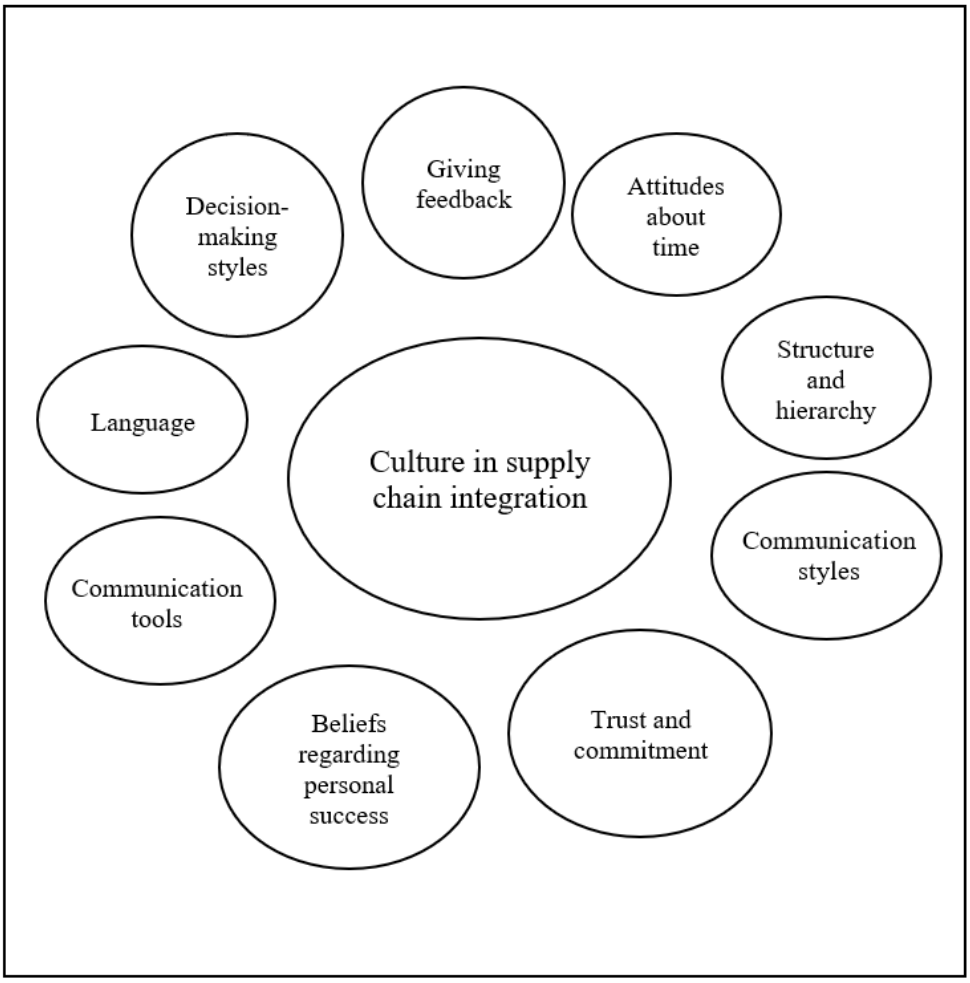

Figure 1: Cultural Factors influencing supply chain internal integration

2.1 Communication styles

A common challenge mentioned in cross-cultural integration is the differences in communication styles. This factor concerns the usage of non-verbal (implicit) communication. Societies like the USA are task-centered and the primary purpose of communication is to exchange information, facts, and opinions. Conflict is dealt with directly and openly and individuals will not hesitate to say “no” or criticize others in public. This direct style of speech may be interpreted by foreign visitors as rude and may cause embarrassment to those who are unaccustomed to such explicit communication. In these societies is common to make a recap at the end of the meeting and send written conclusions to the participants as well as assign tasks to everyone.

On the other hand, in countries like China or Japan, communication is implicit. In other words, people often imply and infer rather than verbalize directly. It is also placed high importance on the impact of body language, relationships, emotion, and other non-verbal communication, in short, the listener is expected to read between the lines. Conflict and criticism are best dealt with in private and indirectly. As a result, individuals from societies with different communication styles are sometimes left confused and struggle to achieve their business objectives if they don’t possess the required information [5]–[7].

2.2 Structure and hierarchy

This factor concerns the extent to which people in an organization are required to show respect for seniority. In some countries like Russia and Germany, status is an important part of business culture is linked to age and position. While in order countries like USA status is mostly based on achievement. Therefore, in more hierarchical societies co-workers are expected to treat their superiors with respect addressing them by their titles or last name and using formal language, while in less hierarchical societies co-workers are expected to treat each other by their first names and using informal language. Neglecting this factor can cause friction between relationships because people might feel disrespected if you don’t correctly address them [5], [7]–[11].

2.3 Attitudes about time

This factor concerns if a society is time flexible or not, in other words, if you are expected to be on time and strictly respect schedules and deadlines or if there is some flexibility concerning time. For example, in Switzerland, Germany, and Japan – countries which respect the idea of linear time and believe in sequential steps, promptness, and strict adherence to deadlines- being late for appointments or interrupting a meeting is considered rude and inappropriate. However, that is not the case with Saudi Arabia, Nigeria, Kenya, Russia, and India, where adaptability is much more important, and time is flexible. In these cases, being late can be acceptable or even expected, meetings may not follow a linear agenda and may be interrupted by phone calls or people coming in [7], [8].

2.4 Giving feedback

This factor concerns how individuals give feedback to their co-workers. In some cultures, such as the Dutch and the Germans giving feedback, particularly negative feedback, is done in a very direct way telling exactly what is wrong and what needs to be improved. However, in Anglo cultures, for example, negative feedback is given indirectly. In these cultures, negative feedback will be sugarcoated and phrases like “That is an original point of view” which will mean “Your idea is stupid!”.

The differences in giving feedback between cultures can cause misunderstandings and conflict therefore this is a very important factor. In direct cultures, indirect feedback can cause people to think their work is good when needs to be improved, and the other way around in indirect cultures direct feedback can be perceived as rude and disrespectful [7], [10].

2.5 Decision-making styles

There are two main decision-making styles consensus contrasted with top-down. In a consensus approach, managers attempt to understand people's perspectives and needs to ensure they're affirmed and pleased, to avoid employees becoming angry or upset, and prevent discouragement. On the other hand, in cultures experiencing a top-down approach, an executive or other top person makes the decisions of how something should be done and the others simply follow [10], [12]. Different decision-making styles can lead to slow decision-making, failure to make decisions, or failure to implement decisions [3].

2.6 Language

Language has been perceived as a barrier in cross-cultural supply chain integration, even though English is mostly used in international work environments miscommunication due to language is still common, particularly in expressions and specific vocabulary. Language interfaces in these businesses will trigger problems of miscommunication, uncertainty, mistrust, and conflict and unless these problems are professionally managed, they will bring detrimental consequences for the business and its relationships [13], [14].

2.7 Communication tools

A study between U.S. manufactures and Brazilian distributors found significant differences in communication preferences. They found that the high context party (Brazilian stakeholders) preferred more personal forms of contact such as telephone calls and visits while the low-context party (American enterprises) preferred technology-mediated communication like email [15].

With the growing use of computer-mediated technologies in supply chains[4], [16] potentiated by the Covid-19 pandemic, it would be interesting to investigate the influence of national culture in the choice of the tools to mediate cross-cultural stakeholder communication.

2.8 Beliefs regarding personal success

In individualistic cultures like the US, Individual initiative and personal achievement are emphasized and valued. Whereas in collectivistic societies like Russia affinity for the group can be seen in everyday life. This sense of co-operation and togetherness must be considered when doing business in collectivistic countries, especially when communicating. For example, it is important to remember to address the group rather than the individual. Therefore, in an individualistic society success is celebrated primarily focusing on individual “stars”. On the other hand, in collectivistic societies success is mostly celebrated as teamwork. These differences can lead to breakdowns in getting work done. If people who believe they have to achieve goals as a team integrate with people whose notion of "success" emphasizes individual performance, the resulting situation is often characterized by personal dislike and lack of support for getting the job done [3], [5], [8].

2.9 Trust and commitment

Personal dynamics [17] and employee continuity [18] also can affect cross-cultural relationships therefore this factor should also be taken into consideration in the supply chain context.

3 CONCLUSION

The topic of national culture in supply chain offers substantial promise as a topic for further researcher. The current study provides greater detail through analyzing the literature, factors influencing cross-cultural supply chain internal integration. The factors identified were communication styles, structure and hierarchy, attitudes about time, giving feedback, decision-making styles, language, communication tools, and beliefs regarding personal success. Identifying these factors is a crucial step to understand how culture affects the internal supply chain. By addressing these factors in the organizational context, organizations will have information on how these factors should be addressed according to different cultural backgrounds to successfully integrate the organization across the globe. This way, enterprises will be aware of cultural differences and be able to avoid cultural misunderstandings when expanding their organization internationally.

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GUIDELINES FOR AGILE CONCURRENT PRODUCT DEVELOPMENT IN SMEs

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Abstract: Constantly changing project environment and a new paradigm shift to a more human-centred and sustainable Industry 5.0 has also brought about a need for a new project management style. Over the last decades, more flexible and people-oriented agile project management (APM) approaches have emerged. Due to its many benefits, APM has already become a mainstream in software industry, and is now increasingly being transferred to other industry sectors. In this paper, we present some basic guidelines for manufacturing SMEs on how to increase their agility without having to undergo a complete agile transformation that requires high financial and non-financial resources. The guidelines are based on three key pillars: concurrent product development, APM, and modern technologies, and are focused on achieving both high project efficiency and stakeholders' satisfaction.

Keywords: product development, concurrent engineering, agile project management, SMEs

1 INTRODUCTION

While companies are becoming more and more successful in leveraging advanced technologies such as Internet of Things, Big Data, Digital Twins, etc., the society is becoming increasingly aware of the importance of humans in the industrial environment. In the last years, a new paradigm shift to a more human-centred and sustainable industry can be observed.

In accordance to this new paradigm called Industry 5.0, the companies must also adapt their project management approach and perception of project success. Originally developed for the software industry, agile project management (APM) could present a promising solution also for manufacturing companies. Embracing change, shifting from process-oriented to people-oriented management style and focusing on project stakeholder's success, APM can help in establishing not only economically and environmentally, but also socially more sustainable workplace [23].

APM in manufacturing represents a relatively young research field, and there is still a great need for further research, in-depth case studies, and statistical analyses of larger samples of projects [3, 4, 18]. There is an especially big lack of literature regarding APM in manufacturing small and medium-sized enterprises (SMEs) [9, 23]. The existing hybrids are mostly appropriate for larger companies that can afford to undergo a complete agile transformation and address various demanding challenges related to it.

The main objective of this paper is therefore to present an alternative for SMEs and provide some basic guidelines for a more effective way of managing product development projects in todays' unpredictable environment. The guidelines are based on three key pillars: concurrent product development, APM, and modern technologies. While concurrent product development principles enable SMEs to increase project efficiency, APM and modern technologies allow for a faster and more effective response to change, and thus lead to higher stakeholders' satisfaction.

The rest of the paper is composed as follows. Section 2 presents a brief literature review on concurrent product development, APM, and APM in manufacturing. In Section 3, the key pillars and the main guidelines for agile concurrent product development in SMEs are presented. The paper concludes with some final remarks and ideas for future work.

2 LITERATURE REVIEW

2.1 Concurrent product development

In order to successfully enter and survive in a highly competitive global market, SMEs must overcome a number of challenges, the most important one being to ensure the shortest possible time-to-market [12]. To achieve that, SMEs need to transition from sequential to concurrent product development [12, 13].

In concurrent product development, the development stages overlap, which means that each stage can start before the previous one is fully completed. The overlapping stages are combined into development loops (track-and-loop approach [15]), which enables efficient interaction and constant exchange of information. Project team in concurrent development is multidisciplinary and its composition changes depending on the loop underway [12].

Concurrent development focuses on three main goals: shortening development time, reducing costs, and ensuring the required product functionality and quality [12, 13]. Research has shown that the use of appropriate concurrent development strategies, i.e. parallelism, standardisation and integration [8], and various engineering tools such as quality function deployment (QFD), failure mode and effects analysis (FMEA), computer-aided technologies (CAx), design for manufacturability (DFM) and design for assembly (DFA) [12], allows 30-60% shorter development time, 15-50% lower costs and 55-95% less necessary changes and corrections [10].

Despite many benefits brought about by the introduction of concurrent product development, companies still face number of challenges, mostly related to the unpredictable and rapidly changing environment, incomplete information and unstable requirements. Detailed upfront planning, methods such as critical path method (CPM) or detailed Gantt charts, and strict adherence to the initial plan are no longer efficient. Whereas in the past the aim was to reduce complexity and the rate of change and to strictly follow the plan, companies today are increasingly aware of the fact that changes represent new opportunities and high added value, and that they need to be accepted as such and effectively managed [3, 17]. For this purpose, more flexible and value-focused APM approaches have been introduced [4].

2.2 APM

APM first emerged in software industry in the 1980s as an alternative to the traditional plan-driven project management approaches [20] that could no longer face the challenges of constantly changing environment. It became widely popular with the release of the Manifesto for Agile Software Development in 2001 [2]. The manifesto contains the main values and principles of agile development, which give priority to: (1) individuals and interactions over processes and tools; (2) working software over comprehensive documentation; (3) customer collaboration over contract negotiation; and (4) responding to change over rigidly following a plan [2].

APM approaches are based on iterative and incremental product development and active customer collaboration. After each iteration, customer tests the product increment (a working software code) and provides feedback information [17]. This allows for a faster design of final requirements, early detection of discrepancies, and development of product the customer actually needs. Some of the most frequently used APM practices are: iterative planning, time boxing, daily meetings, small self-organized teams, fully dedicated team members, user stories, retrospectives, continuous integration, and others [4, 7]. Based on these practices, many structured agile methods have been developed, the most popular one being scrum [16].

There are many benefits to APM, such as rapid and effective response to change, fast detection of errors, greater productivity and motivation, and improvements in teamwork [11, 21]. Due to its many advantages and good results in software industry, many other industry sectors are also starting to recognize APM as a promising new management approach.

2.3 APM in manufacturing

Due to specific characteristics of software development, a direct transfer of APM approaches to other industry sectors (e.g. manufacturing) is not possible and would also not be effective [16]. The most obvious challenge of APM in manufacturing companies is the constraint of physicality. The reason for that lies in the incremental and iterative nature of APM that is characterized by frequent delivery of a working intermediate product that the customer can already use. While realizing functioning and potentially shippable software code every few weeks is challenging yet feasible, delivering physical products this often is practically impossible [5]. In manufacturing, the idea of a protocept therefore emerged: a version of a product that can represent anything from the initial concept to a working prototype and allows for a feedback from the customer [6].

Some other important challenges related to constraints of physicality are modularisation of product, production of necessary tools, required greater specialisation of team members, synchronisation of different domains, and others [1, 22]. When undergoing agile transformation, there is also a need for a full management support [6] and willingness of the customer to be actively involved throughout the project [1]. Another thing that proved to be very demanding in manufacturing companies is ensuring dedicated project team [6, 9]. Finding fully dedicated team members is especially challenging in SMEs, where individuals often have to take on multiple roles and work on multiple projects concurrently [9].

To address all these challenges, companies need to effectively adapt APM approaches to suit their needs and capabilities. In the last decade, the so called hybrid models have emerged, which combine APM elements with traditional development models. Companies can thus exploit the benefits of agility without sacrificing the stability of traditional models [3, 14]. The adoption of APM elements in manufacturing has largely been made possible by modern technologies such as powerful computer tools, simulations, virtual and mixed reality, rapid prototyping, and 3D printing [5].

Studies have shown that combination of agile and traditional approaches can have significant benefits for manufacturing companies, such as increased design flexibility, higher productivity, improved internal and external communication, better focus, raised team morale, and others [6, 19]. There is also evidence that implementing APM elements in traditional models can positively affect project success, both in terms of project efficiency and stakeholders' satisfaction [18, 23].

However, the existing hybrid models are mostly appropriate for larger companies, as they presume the adaptation and implementation of a certain APM method in full (usually scrum [19]). This means that some new roles must be introduced (e.g. scrum master, product owner), personnel needs to undergo lengthy trainings, teams need to be fully dedicated, and the company usually needs to employ agile experts to lead and manage the whole transformation [23]. This requires high financial and non-financial resources and most SMEs cannot afford it. SMEs therefore need an alternative approach that will still allow them to increase their agility, but without high investments and risks, related to a complete agile transformation and company reorganization.

3 GUIDELINES FOR AGILE CONCURRENT PRODUCT DEVELOPMENT IN SMEs

There have already been some attempts to develop agile hybrid models appropriate for SMEs, however, they still assume implementation of scrum as a whole [9, 24], which leads to the aforementioned high investments, lengthy trainings, and an extensive company reorganization. Study in one Slovenian SMEs has shown, though, that SMEs can relatively easily adopt only certain APM practices instead of the entire scrum, and still gain many benefits [23].

The analysed company implemented the following APM practices into their standard concurrent product development model: dedicated and co-located project team, daily stand-up meetings, active customer collaboration, weekly teleconferences where protocepts were analysed, supplier involvement, and iterative and adaptive planning [23]. As expected, a full dedication of team members could not be achieved, however a changing team composition according to concurrent development loop proved to be a very good alternative. Among the most important benefits, the project team listed: improved communication, faster response to change, greater flexibility, faster detection of errors, and more effective problem-solving. The combination of concurrent development principles and APM practices also proved to have a positive impact on project success [23].

Based on the literature review and the results of existing studies, we identified three key pillars crucial for successful development in SMEs: concurrent product development, APM, and modern technologies (Figure 1).

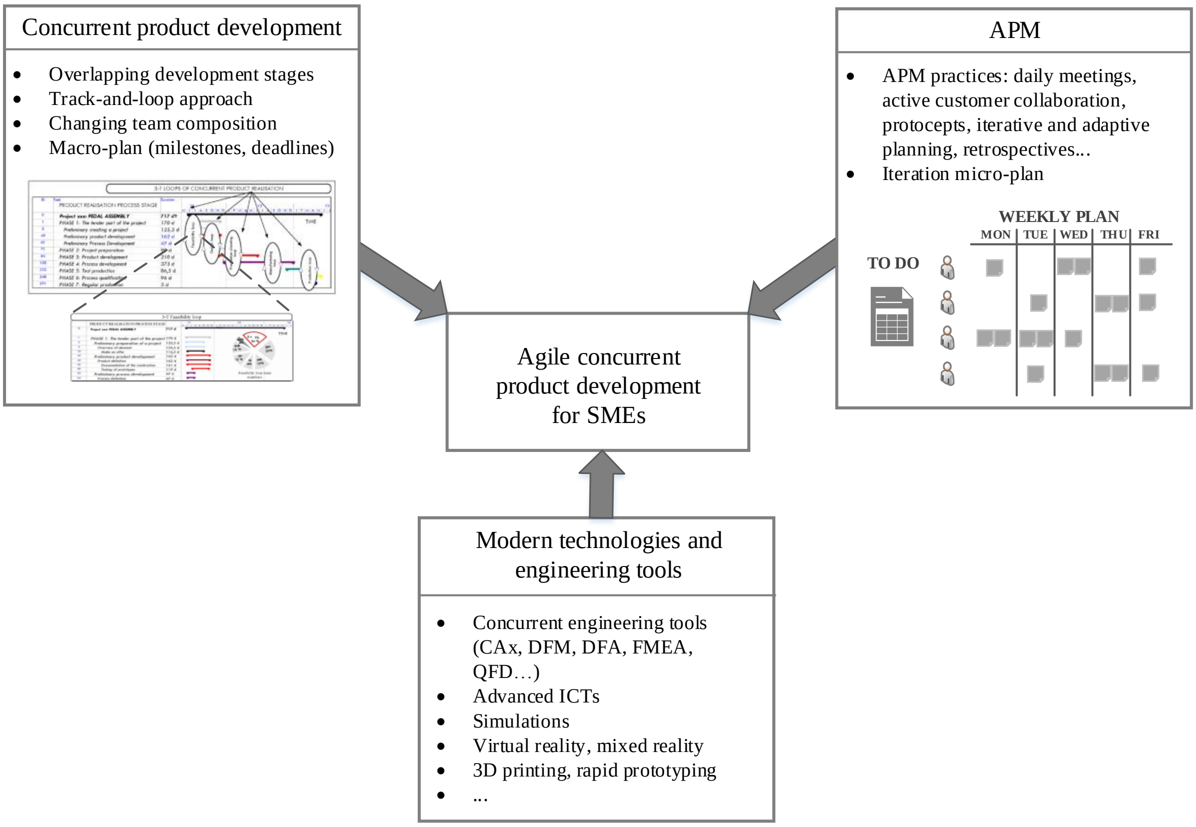

Figure 1: Key pillars of agile concurrent product development in SMEs.

Depending on its needs and capabilities, each SME should adjust its development approach and adopt those practices and principles they see fit, but in general, the following guidelines should be taken into consideration:

- SMEs need to adopt concurrent product development principles (overlapping stages, track-and-loop approach) to achieve greater project efficiency, and upgrade it with APM elements for more effective response to changes and greater stakeholders' satisfaction;
- due to limited resources, instead of adopting certain APM method in full, SMEs should adopt only some of APM best practices;
- in SMEs it is impossible to ensure fully dedicated project team members, therefore changing team composition according to concurrent product development loop underway should be adopted;
- to ensure that all team members are constantly up-to date with all relevant information and current project status, daily stand-up meetings should be introduced;
- a rough macro-plan including crucial milestones and deadlines should be prepared upfront according to concurrent product development model, whereas a detailed micro-plan should be prepared for one iteration upfront only, so that the newest information can be constantly taken into account;
- after each iteration, a protocept (drawings, 3D models, simulations, samples, prototypes, etc.) should be delivered to the customer, who needs to actively collaborate and provide frequent feedback information;
- for frequent protocept development, advanced modern technologies and engineering tools should be used (CAx, simulations, virtual and mixed reality, rapid prototyping, 3D printing, etc.);
- frequent retrospectives should be carried out to assure continuous improvements of project management process.

4 CONCLUSIONS

In todays' unpredictable and highly competitive environment, companies need to adopt more flexible project management approaches and combine them with good product development practices. SMEs, who are especially at risk, need different approaches for effectively managing projects than larger companies. We have identified concurrent product development, APM, and modern technologies as three crucial pillars of successful product development in SMEs. In this paper, we provide basic guidelines for SMEs on how to combine concurrent development principles with APM elements and thus achieve greater project success in terms of both project efficiency and stakeholders' success. The future work should focus on additional case studies and development of structured agile concurrent product development model for SMEs.

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PREDICTORS OF EMAIL COMMUNICATION SKILLS AMONG SLOVENIAN AND SERBIAN STUDENTS

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Abstract: Communication skills are among the most important 21st century skills. When it comes to written communication, a multitude of lateral differences in the way students communicate via email have been identitifed. The main focus of our research was to identify some of the key predictors that influence student-teacher email communication. Based on the literature review, we have identified six predictors as having an impact on student email communication skils, i.g., culture, digital literacy, social media use, country of origin, gender, and age. Students from two countries, Slovenia and Serbia, participated in the study. The multivariate regression analysis showed that all identified predictors except for age have a statistically significant impact on communication skills. This paper presents each identified predictor in more detail and discusses the key findings in regard to student email communication skills.

Keywords: student communication skills, email communication, culture, social media use, digital literacy, regression model

1 INTRODUCTION

According to the 21st century skills framework (Battelle for Kids, 2019), communication skills are one of the core skills since they are as important as learning, innovation, information, media, and technology skills. Iksan et. al (2012) have descibed email communication skills as a set of abilities to present ideas in written form clearly and effectively, and have identified them as components of generic skills which are essential among students in higher education. Moreover, academics and practitioners see communication skills (CS) as an important part of university education, commonly related to professionalism and employability, and playing a role in preparing students for future workplace communications (Lewin-Jones and Mason, 2014). Similarly, good communication skills are essential for students because professional ability and performance are strongly linked with communication competence (Mascle, 2013). Chen (2006) states that writing appropriate email messages to teachers requires high pragmatic competence and critical language awareness; this can oftentimes present a challenge to students due to their limited linguistic ability and unfamiliarity with the target culture's norms and values.

The main goal of this research is to identify the factors that impact student email communication skills. The research is based on email communication between students and teachers. Six factors were hypothesized as important in student-teacher email communication: culture (C), Social Media Use (SMU), Digital Literacy (DL), country of origin, gender, and age.

2 LITERATURE REVIEW

Many factors have been proposed to explain what affects student email communication (Danielewicz-Betz, 2013). In this review we focus on six key predictors (culture, digital literacy, social media use, country of origin, gender, age) and their application to student-teacher email communication.

Culture plays a central role in effective communication because it not only represents the sum total of shared experiences but also shapes the life experiences of individuals who occupy a particular culture as members of that community (Liu and Fang, 2017). The term itself carries multiple meanings that range from the idea of a complex social system that emerges through individuals' joint participation in the world to that of shared knowledge, beliefs, values, attitudes, and practices (Baker, 2015).

The definition of digital literacy differs and is sometimes referred to as digital competencies (Spante et al., 2018), or as using new technologies for the retrieval and processing of information, communication, and the production of content using information-communication technology (Jin et al., 2020). Digital literacy has become an essential capacity in the 21st century, and although digital natives are not necessarily information literate (Šorgo et al., 2017), digital literacy does affect email communication skills. Not only can it improve student writing ability and academic performance (Shao and Purpur, 2016), but it also has a positive impact on students' core competencies, among which communication and human relation are included (Kim, 2019).

According to the analysis performed by (Fatimawati *et al.*, 2020), social media is an effective tool to improve student communication skills about a specific topic and can therefore be used as an alternative way to teach science. In addition, Bal and Bicen (2017) show that incorporating social media in the study process improves cooperative learning skills and helps students to communicate with their teachers easily. As presented by AlSaleem (2018), oral communication skills of foreign students improved more in the group of students who were taught by Facebook activities. On the other hand, Hidayat and Pratama (2019) argue that the intensity of social media use is not related to interpersonal communication skills of students.

The country of origin affects the way people think, behave and communicate in different situations. As has been noted (UKEssays, 2018), people from different countries tend to have different ways of understanding the world around them, and are likely to also have different ways to exchange information and perform various activities that are unique to their countries. Since effective communication involves understanding both one's own linguistic and cultural identity, and that of the people with whom one is communicating, the effect of the student's origin (country) on communication is significant.

Various life skills, including communication, evolve with age. In the study by Chavda and Trivedi (2015), a sample of students belonging to different age groups was selected randomly from schools and colleges in India. A life skills test was administered to measure the types of life skills, including communication. The result showed a significant difference in skills development when the age of students is increasing from 11 to 20 years. In the study by Skoglund *et al.* (2018), student nurses in the final semester reported higher self-rated communication skills than the students in the second semester. This result was somewhat expected, which means that students perceive that they progressed in knowledge and skills during their education.

Higher education student's gender differences regarding email communication have also often been studied. The research of Punyanunt-Carter and Hemby (2006) confirmed differences between college male and female students regarding their email behaviours. Their findings reveal that female students were more likely to check their email and use shorthand in their email messages directed to a professor compared to males. At the same time, males reported that they were more likely than females to use emoticons regularly in emails and preferred emailing when they could not meet someone in person.

Gender differences in the student-teacher interaction were also statistically significant in the study of Kim and Sax (2009). Female students reported more frequent communication with faculty by email or in person for a course-related faculty contact than males. In contrast, males demonstrated more frequent interaction with teachers during lecture class sessions than females. Politeness is also considered an important aspect of communication. According to O'Neill and Colley (2006), there was no evidence that the females were using polite strategies more than the males. Rather, the use of politeness features varied according to the staff member's status supposedly sending an email. According to these findings, we consider that gender can be an essential variable in analyzing student communication skills in higher education.

3 RESEARCH METHODOLOGY

To analyse the influence of different factors on student communications skills, we propose the following research hypothesis:
RH: *Culture, social media use, digital literacy, country of origin, gender and age have an impact on student communication skills.*

To test the research hypothesis, a backward multivariate regression analysis was used (Field, 2018), where insignificant independent variables were sequentially removed from the model.

The data were gathered in a Slovenian-Serbian research project in the academic years of 2018/19 and 2019/20. Here only part of data gathered by an online questionnaire and answered by students is used. Detailed description of the data collection phase could be found at Tratnik *et al.* (n.d.).

4 RESULTS

The sample consists of 547 students, who fully completed part of the questionnaire included in the research hypothesis. 51.5% of the respondents were women, and 48.5% were men. Almost two-thirds (62.0%) of the students were from Serbia, while 38.0% of the respondents were from Slovenia.

Table 1 shows descriptive statistics of six independent variables included in the research hypothesis, as well as exact wording of the measured items. The variables (indicated in grey) C, DL, SMU, and CS were calculated as the average of the corresponding measured statements from the questionnaire. All listed items were measured on a 5-point Likert type scale of agreement.

Table 1: Descriptive statistics of the variables (constructs) included in the research hypothesis and the corresponding measured variables

Construct & Questionnaire items	**M**	**SD**
Culture (C)	4.18	0.668
I can identify with Serbian/Slovenian culture.	3.92	0.878
I respect Serbian/Slovenian culture.	4.39	0.638
I take pride in using the Serbian/Slovenian language.	4.32	0.800
Serbian/Slovenian cultural heritage is important to me.	4.03	0.927
I am proud to present Serbian/Slovenian culture to foreigners.	4.22	0.828
Digital Literacy (DL)	3.93	0.641
I keep up with important new technologies.	3.93	0.784
I can learn new technology easily.	3.98	0.721
I have good ICT skills.	3.78	0.853
I am familiar with issues related to web-based activities (e.g. cyber safety, search issues, plagiarism).	4.04	0.774
Social Media Usage (SMU)	4.14	0.844
I often use social media.	4.15	1.016
I often use emoticons, pictures or gifs when communicating on social networks.	3.96	1.104
I use messaging apps (e.g. Snapchat, Messenger, WhatsApp, Viber, etc.) to communicate with friends and family.	4.29	0.929

Communication Skills (CS)	4.35	0.493
When I write an email, I always properly introduce myself.	4.19	0.733
Before I write an email, I think about what the person needs to know (my name, course of study), and how best to convey it.	4.25	0.720
When I communicate, I consider what the purpose of communication is.	4.22	0.655
When I write an email, I pay attention to the understanding of my message.	4.46	0.574
When I communicate, I try to be polite.	4.61	0.552
Age [years]	24.1	6.485
	Percentage	
Gender (1 – M, 0 – F)		48.1
Country (1 – SI, 0 - SR)		37.8

[a] Percentage of category labeled by 1.

Six independent variables were included in the initial regression model, as shown in Table 1. The initial summary of the regression model R Square indicates that 7 independent variables are able to is 13.8% of the variance in the CS. The value of Durbin-Watson test is equal to 1.979 which indicates that the errors in the model are independent. ANOVA ($F = 22.263, df1 = 6, df2 = 540, p = 0.000$) indicates that the data fit the regression model well.

In the initial regression model all included independent variables except for age were found to be significant at a 5% level of significance. Next, the backward method (Field, 2018) was used where variable with the smallest insignificant contribution to the model (according to the t-statistics) is eliminated in the successive steps. The final model contains the variables that have a significant contribution to the model. In the procedure described, one step was required since only age was found to be an insignificant predictor.

The final regression model with five significant independent variables is shown in Table 2. With this model, we are able to explain 19.7% of the variance in CS. The value of the Durbin-Watson test is equal to 1.982, indicating that the errors in the model are independent. ANOVA ($F = 26.557$, $df1 = 5$, $df2 = 541$, $p = 0.000$) indicates that the data fit the final regression model well. Five predictors remain in the model because their regression coefficients are statistically significantly different from zero at the 5% significance level (all p-values in Table 2 are less than 0.05).

Table 2: Results of the final regression model predicting Student Communication Skills

Final Model	Unstandardized Coefficients		Standardized Coefficients		
Dependent Variable: CS	B	Std. Error	Beta	t	Sig.
(Constant)	2.814	.177		15.890	.000
C	.163	.029	.221	5.638	.000
SMU	.055	.023	.095	2.372	.018
DL	.199	.031	.258	6.316	.000
Country (1 – SI)	-.175	.040	-.173	-4.350	.000
Gender (1 – M)	-.193	.040	-.196	-4.839	.000

Research results are summarized in the following regression model equation [1]:

$$CS = 2.814 + 0.163 \cdot C + 0.055 \cdot SMU + 0.199 \cdot DL - 0.175 \cdot Country(SI) - 0.193 \cdot Gender(M) \quad (1)$$

As presented in Table 1, C ($\boldsymbol{\beta = 0.163, p = 0.000}$), SMU ($\boldsymbol{\beta = 0.055, p = 0.018}$), and DL ($\boldsymbol{\beta = 0.199, p = 0.000}$) have positive impact on CS. Slovenian students have lower CS than Serbian students ($\boldsymbol{\beta = -0.175, p = 0.000}$), and male students have lower CS than female students ($\boldsymbol{\beta = -0.193, p = 0.000}$).

4 DISCUSSION AND CONCLUSIONS

Advances in modern information technology and the rapid pace of change in the communications revolution are affecting the way students use information technology, develop their language communication skills and communicate via email. In our study, we postulated the hypothesis about the impact of six different factors on email communication skills of students.

The results show that five out of six factors impact communication skills of students. Culture, social media use and digital literacy have a positive impact on communication skills. Likewise, we identified the differences between students regarding the country of origin and gender. As assumed, Serbian students have higher communication skills than Slovenian students, whereas female students have higher communication skills than male students. Age was not found to be a significant predictor although we assumed that older students would write more appropriate emails and have better communication skills.

On a final note, there is a consensus among higher education teachers that students need guidance and training in their use of email which would encourage appropriate use of this modern mode of communication and further enhance students' email practice and written communication skills.

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THE INTENTION TO USE MICROCHIP IMPLANTS: MODEL EXTENSIONS AFTER THE PANDEMICS

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Abstract: Attitudes towards technology have changed due to the recent situation with pandemics. The primary research model of attitude towards microchip implants in the human body therefore needs to be updated. Not only the perceived usefulness of microchip implants during the time of pandemics, but also the revival of conspiracy theories and the abundance of fake news has influenced our perception of this technology. To identify this influence and determine changes in attitude towards microchip implants, three constructs were added to the primary model. Preliminary structural equation modeling analysis confirmed that the constructs could be included in the research model. The results also show that Slovenians and women have the lowest confidence in the usefulness of microchip implants.

Keywords: TAM, SEM, microchip implant, pandemics

1 INTRODUCTION

Advances in technology can make our lives easier, yet some technologies are treated as controversial. Microchip implants (MI) are among this group of technologies. Although MIs are used in healthcare (Cui *et al.*, 2019; Landaluce *et al.*, 2020), personal identification (Michael *et al.*, 2017; Rotter *et al.*, 2008), purchases (Landaluce *et al.*, 2020; Michael and Michael, 2010) or smart home (Cui *et al.*, 2019; Rotter *et al.*, 2008), most of us still have doubts that they are safe. These concerns relate to legal issues (Graveling *et al.*, 2018), ethical considerations (Moosavi *et al.*, 2014), health risks (Albrecht, 2010), and security (Huo, 2014).

The research team at the Faculty of Organizational Sciences, University of Maribor has been investigating the attitude toward MI since 2014 (Werber and Žnidaršič, 2015). The research model analysing the factors influencing the intention to use MIs has been composed and the proposed hypotheses were tested in an international study conducted in four European countries (Žnidaršič *et al.*, n.d.). Due to major changes in lifestyle and attitude towards technology related to the recent pandemics outbreak, the team decided to repeat the study to determine if the attitude has changed. Namely, the technology has evolved, particularly in relation to security issues (Masyuk, 2019), and more people are using MIs on a voluntary basis (Oberhaus, 2018), some even due to the requirements of their employers (Michael *et al.*, 2017). Perceived fear of COVID-19 (Al-Maroof *et al.*, 2020) and perceived COVID-19 risk (Aji *et* *al.*, 2020) have been identified to impact the perceived ease of use (PEU) and perceived usefulness (PU) of technology. The pandemics situation has revived conspiracy theories and fake news. Some of the conspiracy theories are related to MIs impact the credibility of fake news (Halpern *et al.*, 2019) and may even affect vaccination refusals (Ullah *et al.*, 2021) In general, conspiracy mentality decreases trust in official sources and therefore increases perceived threats to privacy (Imhoff *et al.*, 2018).

In this paper, we present the preliminary analysis of the three items added to the primary model of MI adoption. Our goal is to explore changes in the attitude towards MI resulting from experiences with pandemics (MP) and to determine whether beliefs in conspiracy theories (CT) and fake news (FN) influence perceived trust in MI. Based on the results of this research, we will extend the primary research model to include behavioural intention to use MI. Demographic differences in the attitude towards MI usefulness are also presented in the paper.

2 METHODOLOGY

The primary research model of behavioural intention to use MI based on the technology acceptance model (TAM) is presented in Žnidaršič *et al.* (n.d.). In addition to the basic components of TAM, age and constructs that include the specifics of the MI technology were added as antecedents: perceived trust, privacy right, technology safety, privacy threat, health concerns and painful procedure. Because individuals perceive technology and its benefits differently after the pandemic outbreak, we aim to extend the primary model. Three new constructs with hypothesised impact on the primary model were added to address the changes in the attitude. Based on previous research (Aji *et al.*, 2020; Al-Maroof *et al.*, 2020), we hypothesise that MP has positive impact on perceived usefulness (PU). Given the positive feedback loop between CT and FN was identified in previous research (Halpern *et al.*, 2019; Xiao *et al.*, n.d.), we hypothesise that CT will correlate with FN. Studies by Moscadelli *et al.* (2020) and Naeem *et al.* (2020) were used to formulate the items related to CT and FN. In addition, aligned with Imhoff *et al.* (2018), we hypothesise that CT has a negative impact on perceived trust (PT).

The analysis was conducted using the standard two-stage approach of Structural Equation Modeling (SEM) (Schumacker and Lomax, 2010). The first step is the validation of the measurement model, whereby the Confirmatory Factor Analysis (CFA) was conducted to determine how well the measured items reflect the theoretical latent variables. Within this step, the construct validity of the measurement model is examined through convergent validity and discriminant validity. The estimates of the standardized factor loadings should not exceed 0.5 indicating convergent validity. Composite Reliability (CR) and Average Variance Extracted (AVE) for each latent variable should exceed 0.5 (Fornell and Larcker, 1981; Koufteros, 1999). In a second step, SEM was used to test the structural relationships between the latent variables. The unstandardized B and standardized path coefficients β indicating the relationships between the latent variables, were calculated along with z-values and significance level. The overall fit of the measurement and structural model was assessed using a number of fit indices: the value of the comparative fit index (CFI (Koufteros, 1999) and the root mean square error of approximation ($RMSEA$) (MacCallum *et al.*, 1996).

In addition to the above research hypotheses, we used the t-test and ANOVA to test whether opinions about the perceived usefulness of MI in pandemics differed between countries, gender, status, and groups based on the highest level of education.

3 RESULTS

The preliminary analysis of data from the cross-sectional study was conducted with data collected in four European countries, Croatia, Poland, Slovenia and Ukraine, between February and May 2021. Only complete responses to the online survey questionnaire items were used, representing a convenience sample of 1.536 respondents. The characteristics of the sample are presented in Table 1.

Table 1: Sample characteristics

Variable	Group	f	%
Country	Poland	452	29.4
	Croatia	352	22.9
	Slovenia	372	24.2
	Ukraine	360	23.4
Gender	Female	873	56.8
	Male	663	43.2
Status	Student	583	38.0
	Employed	740	48.2
	Unemployed	50	3.2
	Pensioner	163	10.6
Level of formal education	Elementary school or less	29	1.9
	Vocational school	59	3.8
	Four-year secondary school	509	33.1
	College	124	8.1
	First Bologna level	258	16.8
	University or second Bologna level	305	19.8
	Science master's degree or a doctorate	254	16.5

The questionnaire items of the three constructs to be added to the research model and their descriptive statistics are presented in Table 2.

Table 2: Descriptive statistics of added constructs

Construct	Questionnaire item	M	SD
Conspiracy Theory (CT)	Authorities plan to use a corona virus vaccine to inject microchip implant.	2.17	1.136
	Governments have a secret plan to use microchips for unauthorised surveillance or supervision.	2.62	1.253
	There is a correlation between 5G technology and the spread of Covid-19.	2.07	1.120
Fake News (FN)	Drinking hot water, methanol or alcohol has been recommended as a proven cure for Covid-19.	1.77	0.923
	Coronavirus can be transmitted through houseflies, mosquito bites or domestic animals.	2.02	0.945
Microchips in Pandemics (MP)	In my opinion, global pandemic management could benefit from microchip implant usage.	2.79	1.173

3.1 Confirmatory factor analysis of the added constructs

We use CFA to check whether the proposed questionnaire items form the new constructs CT and FN. All standardized factor loadings for the items in the measurement model) exceed a threshold of 0.5 for convergent validity. AVE for four constructs exceed a threshold of 0.5 for convergent validity. The AVE for CT is 0.670, for FN 0.532, for PT is 0.733, and for PU is 0.787. CR for CT is 0.859, for FN is 0.687, for PT is 0.892, and for PU is 0.959. The obtained results prove the convergent validity for the set of latent variables and corresponding measurement items in the measurement model.

The overall fit of the measurement model was assessed based on a set of commonly used fit indices. The χ^2 was 730.428 with 71 degrees of freedom. Both, CFI ($CFI = 0.961$) and $RMSEA$ ($RMSEA = 0.078$) indicate a good model fit (MacCallum *et al.*, 1996). According to the set of calculated fit indices, the measurement model fits the sample data well.

3.2 Results of the structural model

The overall fit of the structural model was assessed using a set of commonly used fit indices. The χ^2 was 1216.995 with 85 degrees of freedom. Both, CFI ($CFI = 0.935$) and $RMSEA$ ($RMSEA = 0.093$) indicate an acceptable model fit. According to the set of calculated fit indices, the measurement model fits the sample data well.

The results of hypotheses testing are shown in Figure 1. There is a positive correlation between FN and CT ($r = 0.661$) and a negative impact of CT on PT ($\beta = -0.067$). The new measured variable MP has a positive impact on PU ($\beta = 0.365$).

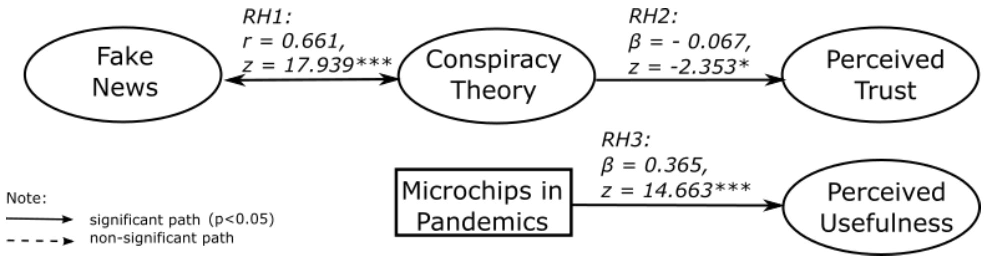

Figure 1: Hypothesized relationships in the extended part of the model

3.3 Usefulness of MI in pandemics

The results show that there are statistically significant differences in opinions about the usefulness of MI in pandemics according to country (ANOVA: $p = 0.0159$) and gender (t-test: $p = 0.002$) at 5% significance level (Table 3). There were no statistically significant differences considering status and level of formal education.

Table 3: Results of ANOVAs and t-test for opinion on usefulness of MI in pandemics

Grouping Variable		**Descriptive Statistics**			**ANOVA (or t-test)**		
	Group	***N***	***M***	***SD***	***F* (or *t*)**	***df1; df2* (or *df*)**	***p***
Country	Poland	452	2.84	1.190	5.827	1; 1534	0.0159
	Croatia	352	3.00	1.084			
	Slovenia	372	2.43	1.236			
	Ukraine	360	2.90	1.085			
Status	Student	583	2.87	1.170	2.125	1; 1534	0.1450
	Employed	740	2.75	1.186			
	Unemployed	50	2.84	1.131			
	Pensioner	163	2.73	1.121			
Level of formal education	Elementary school or less	29	2.28	1.066	0.853	1; 1534	0.3560
	Vocational school	59	2.90	1.348			
	Four-year secondary school	509	2.86	1.160			
	College	124	2.91	1.101			
	First Bologna level	258	2.77	1.229			
	University or second Bologna level	305	2.68	1.138			
	Science master's degree or a doctorate	254	2.82	1.168			
Gender	Female	873	2.70	1.121	-3.765	1354	0.0002
	Male	663	2.92	1.227			

4 CONCLUSIONS

The purpose of this research was to assess the fit of new constructs added to the primary TAM model used to determine behavioural intention to use MI. Three constructs were added to the primary research model: Usefulness of MI in pandemics, Conspiracy theory, and Fake news. Based on the preliminary analysis all three constructs fit the model well, so we can proceed with the evaluation of the extended research model when all data are available.

The perceived usefulness of MI in pandemics was analysed based on the demographic variables. We can see that there are statistically significant differences in terms of country of residence and gender. Among the countries studied, Croatians find MIs more useful in case of pandemics, while Slovenians have the lowest confidence in their usefulness. In addition, male respondents have higher confidence in the usefulness of MIs during pandemics.

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Special Session 8:

Lessons Learned from the COVID-19 Pandemic: Applications of Statistical and OR Methods

THE ROLE OF CRYPTOCURRENCIES IN THE PORTFOLIO OPTIMIZATION DURING THE COVID-19 PANDEMIC

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Abstract: The performance and diversification benefits of the cryptocurrencies during the economic downturn are yet to be explored. Previous evidence suggests that cryptocurrencies are effective portfolio diversifiers in normal times. This paper assesses risk-return profile of the portfolios with and without currencies, using the CVaR optimization. We used daily data from 1.1.2020 to 15.3.2021 on the ten cryptocurrencies and traditional assets and constructed efficient frontiers for the portfolios in question. Our results suggest that cryptocurrencies, even if only naively diversified, improved the risk-return performance of the portfolio during the pandemic.

Keywords: Cryptocurrencies, Portfolio diversification, Conditional Value at Risk (CVaR), Efficient frontier, Risk-return profile

INTRODUCTION

Cryptocurrencies are relatively new phenomenon within the financial markets. Research so far suggested that cryptocurrencies are relatively uncorrelated to the traditional asset classes and not exposed to the same factors. The tensions and the backdrop of the financial markets related to the pandemic of Covid-19 provided us with the possibility to assess the performance of the cryptocurrencies within the portfolios of other asset classes during the crisis.

To this end we have implemented CVaR methodology to optimize the portfolio construction with and without cryptocurrencies using Excel Solver Add-in and to compare the performance of the resulted portfolios with regards to their risk-return profiles. We used the data on the historical prices of the assets ranging from 1.1.2020 to 15.3.2021.

Our results suggest that adding cryptocurrencies to the portfolio may significantly improve its performance during the crisis times, when the traditional assets underperformed relatively to the cryptocurrencies. Even the naively diversified portfolio containing cryptocurrencies allows to improve risk-return profile of the portfolio relative to the CVaR optimized portfolio consisting only of traditional asset classes.

1 REVIEW OF THE LITERATURE

Although the word cryptocurrency evokes that they are used as a medium of exchange, Baur et al. [2] concluded that Bitcoin is used mainly as a speculative investment rather than a currency. Potential of the cryptocurrencies to enhance the risk-return trade-off of portfolio formation during the normal times, not influenced by pandemic is well established in the literature. Several studies focused on the most well-known cryptocurrency, Bitcoin. Its use within the portfolio construction was analysed by Bouri et al. [3], who with the use of the correlation coefficient analysis suggested that Bitcoin can serve as an effective diversifier. The diversification benefit of the Bitcoin is explained by the authors by its independency on the global macroeconomic and developments. On the other hand, study was much less conclusive on the role of the Bitcoin as the hedge or safe heaven asset, suggesting only limited hedging properties. Contrary to this ambiguity, hedging role of the Bitcoin is supported by Dyhrberg [5] and Guesmi et al. [6]. Same conclusions are derived by Platanakis et al. [14], concluding that Bitcoin should be included in the portfolio as it allows to reap higher risk-adjusted returns. Bitcoin exhibits different return, volatility and correlation patterns compared to other assets.

Other studies used CRIX, as a cryptocurrency index, or selected specific cryptocurrencies to derive the conclusions on the diversifying benefits of cryptocurrencies. With the aim to assess the diversification role of cryptocurrencies, as a specific class of assets, within the portfolio, Lee et al. [10] studied the comovements between CRIX and traditional asset classes. Their analysis based on the historical data from mid-2014 to beginning of 2017 showed, that the correlation of the CRIX and any traditional asset class is well below absolute value of 0.1. With regards to the returns, authors concluded that cryptocurrencies had higher average daily return than other asset classes. Adding CRIX to the portfolio expanded the efficient frontier significantly. Similar conclusions are drawn by Holovatiuk [8] who concluded that adding cryptocurrencies, represented by CRIX, to the investment portfolio led to its outperformance. The author also observed that cryptocurrencies as asset class are characterized by the high return and high standard deviation. This is also in line with Petukhina et al. [13], who concluded that cryptocurrencies improved portfolios risk-return profile, but pointed out potential risk arising from their illiquidity, which can potentially offset the higher returns. Illiquidity of the cryptocurrencies and their higher volatility compared to traditional assets is also pointed out by Trimborn et al. [16]. Even after recognizing these shortcomings, Liu and Tsyvinski [11] reported, that cryptocurrencies have no exposure to most common stock market, commodity, foreign exchange and macroeconomic factors.

Current Covid-19 pandemic and the pessimistic expectations of the investors led to the surge of the returns on the traditional assets and the search for the hedge and safe heaven assets. This brought attention to the cryptocurrencies as a potentially outperforming asset class. Faster re-bounce of cryptocurrencies compared to the stocks after the market turn-down at the beginning of the pandemic is emphasized by Vidal-Tomás [17], who has identified, that Covid-19 has negatively affected cryptocurrencies only in March 2020. This notion is supported also by Caferra and Vidal-Tomás [4], who, beside the re-bounce, reported that co-movements between stocks and cryptocurrencies are present only at low frequencies, suggesting the nonexistence of significant correlation in the short run. Similarly, Omanović et al. [12] concluded, that cryptocurrencies recovered from the market tensions faster than the traditional asset classes. With regards to the portfolio optimization their results, obtained by comparison of Sharpe ratios for different portfolios based on their returns between December 2019 till June 2020, showed that buy and hold was, during this period, desirable investment strategy for cryptocurrencies and gold, but not for stocks. Stocks affected portfolio returns negatively. Supporting this notion, study of the volatility of the cryptocurrencies conducted by Aysan et al. [1] showed their resilience with respect to the pandemic. The unidirectional return transition from stocks towards cryptocurrencies, during the Covid-19 pandemic was supported also by findings of Yousaf and Ali [18], who explored return and volatility spillovers during Covid-19 pandemic between S&P500 and cryptocurrencies represented by Litecoin, Bitcoin and Ethereum. Their findings also showed that the unidirectional volatility transition between these asset classes was not significant for 2 out of 3 cryptocurrencies. All these studies suggest that cryptocurrencies might perform better than the traditional asset classes in these trying times.

Within this paper we analysed the risk-return performance of the portfolios with and without cryptocurrencies. As a method of the portfolio optimization, we used the Conditional Value at Risk minimization. Further, the efficient frontiers are constructed and compared. Our results showed that including cryptocurrencies within the portfolio improves its risk-return profile significantly.

2 DATA AND METHODOLOGY

The aim of this paper was to assess the performance of the cryptocurrencies during the pandemic and their potential role in the portfolio diversification. As a beginning of the pandemic, and of our analysis, we chose 1.1.2020. We did so because the first case of Covid-19 in the US was reported on January 21. As the final day of our sample, we used 15.3.2021, which represents the day of the data collection. This period is divided into two parts: 1.1.2020 - 31.1.2020 used for the calculation of the Sharpe ratios and picking the cryptocurrencies for portfolio, based on them and 1.2.2020 - 15.3.2021 to assess the performance of the portfolios.

We picked the cryptocurrencies based on the website Coinmarketcap. As more than 5000 cryptocurrencies were listed on this website on the day of the data collection (15.3.2021), we have decided to filter those with the daily volume over 10 million USD and the price above 1 USD on 15 of March 2021. We did so to pick the cryptocurrencies which are traded relatively frequently, thus fulfilling the requirement of the liquidity of the investment. A bit over 200 cryptocurrencies passed these limits. As we did not have access to the data on Coinmarketcap, we then downloaded the historical daily quotes from 1.1.2020 to 15.3.2021 from the website Marketwatch. All the prices were in USD. After filtering out unavailable cryptocurrencies and those with uncomplete data for the chosen period, we ended up with 47 cryptocurrencies.

Out of these 47 cryptocurrencies we picked 10 cryptocurrencies with the highest Sharpe ratio for the period from 1.1.2020 to 31.1.2020. To calculate Sharpe ratio, we used formula:

$$Sharpe\ ratio = \frac{E(r) - r_f}{\sigma} \tag{1}$$

where $E(r)$ stands for the average return of the asset, r_f represents risk free rate of return and σ stands for the standard deviation of returns. As risk-free rate we used the return on the one-year US treasury bill of 1.45% published on 31.1.2020, which gave us daily risk-free return of 0.004%. The final sample of cryptocurrencies consists of Cardano, Aragon, Dash, ICON, Chainlink, Lisk, Litecoin, IOTA, Ontology and Zcash.

The indices used for traditional assets are based on Holovatiuk [8]. Composition of the sample and the Sharpe ratios are shown in the Table 1.

Table 1: Expected daily returns, standard deviations (1.1.2020-15.3.2021) and Sharpe ratio of the selected assets

Asset Class	**Asset**	**Mean**	**Standard Deviation**	**Sharpe ratio (1.1.-31.1.2020)**
Cryptocurrencies	**Cardano**	1.48%	0.080	0.455
	Aragon	1.48%	0.099	0.539
	Dash	0.48%	0.081	0.395
	ICON	1.35%	0.086	0.671
	Chainlink	1.25%	0.079	0.495
	Lisk	0.89%	0.074	0.409
	Litecoin	0.77%	0.066	0.406
	IOTA	0.99%	0.076	0.533
	Ontology	0.54%	0.070	0.368
	Zcash	0.82%	0.074	0.466
Stocks	**S&P500**	0.09%	0.020	-0.606
Foreign Exchange	**Dow Jones Dollar Index**	-0.02%	0.004	-1.931
Bonds	**Vanguard Total Bond Market Index**	0.00%	0.006	-1.953
Commodities	**Bloomberg Commodity Index**	0.03%	0.010	-1.898
Real estate	**Dow Jones Real Estate Index**	0.02%	0.022	-1.445
Risk-free rate	**1 Year Treasury Rate (1.45%)**	0.00402		

Source: own calculations on the base of data from Marketwatch.com

Even from the table, one can already see that traditional assets were, during its first month, hit by the pandemic more severely than the cryptocurrencies. Sharpe ratio for January 2020 daily returns was negative for the traditional asset classes. Although the mean return for the full period is, except for FX, positive, it is significantly lower than the return of the cryptocurrencies. In line with the literature, one can also see higher volatility of the cryptocurrencies.

Once the constituents were picked, we proceeded to the construction of the portfolios and their efficient frontiers. We constructed three portfolios with different sets of restrictions. As we want to test the performance of the cryptocurrencies in the investment portfolio and short positions are closer to the speculation than investing, we disregarded them. All the portfolios are constructed by using Solver function to minimize Conditional Value at Risk - CVaR 95 for the given rate of return. The CVaR, introduced by Rockafellar and Uryasev [15] is a measure of the expected loss in the left tail given a particular threshold on the percentile of the distribution of outcomes. In contrast to Value at Risk (VaR), CVaR fulfils the subadditivity condition, not allowing the portfolio to have higher risk than the sum of constituents itself. CVaR exceeds VaR measure and thus leads to the more conservative portfolios (Hafsa, [7]). Minimizing CVaR to construct the portfolio was used previously by Petukhina et al. [13] and Kajtazi and Moro [9].

First portfolio (Portfolio A) includes cryptocurrencies and indices for other asset classes and sets no conditions on the constituents other than sum of the asset weights must be equal 1:

$$Min\ CVaR_a(w)\ subject\ to\ \mu_p(w) = r_T, \sum_i w_i = 1,\ w_i \geq 0, \tag{2}$$

where $\mu_p(w)$ is the portfolio mean and r_T is a target return. Weights of the individual constituents are w_i. Because Portfolio A allocation is skewed towards two assets, Cardano and USDollar, we construct second portfolio (Portfolio B), which introduces naïve diversification with respect to the asset classes and brings the following restrictions on the weights: Cryptocurrencies = 0.2, Stocks = 0.2, Bonds = 0.2, Foreign exchange = 0.2 and Commodities and Real estate both equal to 0.1.

$$Min\ CVaR_a(w),$$

$$s.t.\ \mu_p(w) = r_T,\ \sum_i w_i = 1,\ w_{B,S,FX} = 0.2,\ w_{C,RE} = 0.1,\ \sum w_{CC} = 0.2,\ w_i \geq 0, \tag{3}$$

where $w_{B,S,FX,C,RE,CC}$ stands for the weights of bonds, stocks, foreign exchange, commodities, real estate, and cryptocurrencies respectively. Last portfolio (Portfolio C) disregards cryptocurrencies and allocates funds fully into traditional assets according to the mathematical programming model (2).

Once the weights are optimized for the given rates of return, we proceeded to the construction of the efficient frontiers for the portfolios including cryptocurrencies and for those which do not. These are built based on daily data from 1.1.2020 to 15.3.2021.

3 RESULTS AND DISCUSSION

Constructed portfolios are summarized in Table 2. Only the assets which had non-zero weight at least once are reported in the table. It can be seen, that Portfolio C consisting only of traditional assets allowed to investors to reach maximum daily return of 0.1% with the CVaR equal to 5%, in the case of investing in a single asset – stocks, driving it overexposed to the specific asset class. The same value of daily return can be earned by investing into mixed Portfolio A with the CVaR of only 1.4% and Portfolio B, with the limited weight of the cryptocurrencies allowed to reach 0.1% return with the CVaR of 3.5%. Even the naively diversified portfolio allowed to reach twice higher return with the lower CVaR value. Portfolio

A brought the return of 0.5% while CVaR being 5.3%, however the weights were distributed only between two assets – USDollar and cryptocurrency Cardano, making it relatively undiversified.

Table 2: Portfolio weights for min CVaR and given return, 1.1.2020-15.3.2021

Portfolio A							
Cardano	0	0.075	0.149	0.224	0.366	0.718	0.998
Aragon	0.001	0.001	0.001	0	0	0	0.001
Dash	0.006	0	0	0	0	0	0
Lisk	0.001	0	0	0	0	0	0
Litecoin	0.003	0	0	0	0	0	0
Stocks	0.001	0	0	0	0	0	0
FX	0.960	0.583	0.764	0.753	0.634	0.282	0.001
Bonds	0.012	0.243	0	0	0	0	0
Commodities	0.006	0.097	0.086	0.023	0	0	0
Real Estate	0.011	0	0	0	0	0	0
Return	-0.01%	0.1%	0.2%	0.3%	0.5%	1%	1.4%
St.dev	0.004	0.007	0.013	0.018	0.022	0.058	0.081
CVaR 95	0.008	0.014	0.023	0.033	0.053	0.105	0.147

Porfolio B							
Cardano	0	0	0.040	0.077	0.118	0.159	0.2
Dash	0.2	0.174	0.138	0.104	0.071	0.038	0
Link	0	0	0	0.004	0.001	0.001	0
Lisk	0	0	0	0	0.003	0.002	0
Zcash	0	0.026	0.022	0.151	0.001	0.001	0
Stocks	0.2	0.2	0.2	0.2	0.2	0.2	0.2
FX	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Bonds	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Commodities	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Real Estate	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Return	0.04%	0.05%	0.1%	0.15%	0.2%	0.25%	0.3%
St.dev.	0.018	0.017	0.017	0.017	0.017	0.018	0.020
CVaR 95	0.034	0.034	0.035	0.036	0.039	0.039	0.041

Portfolio C							
Stocks	0.025	0.010	0.031	0.110	0.590	0.831	1
FX	0.318	0.121	0	0	0	0	0
Bonds	0.393	0.293	0.118	0	0	0	0
Commodities	0.265	0.577	0.852	0.890	0.410	0.169	0
Real Estate	0	0	0	0	0	0	0
Return	0.01%	0.03%	0.05	0.06%	0.08	0.09%	0.1%
St.dev.	0.004	0.006	0.009	0.011	0.015	0.018	0.021
CVaR 95	0.010	0.017	0.024	0.029	0.040	0.047	0.053

Naïvely diversified	
Cardano	0.02
Aragon	0.02
Dash	0.02
ICON	0.02
Chainlink	0.02
Lisk	0.02
Litecoin	0.02
IOTA	0.02
Ontology	0.02
Zcash	0.02
Stocks	0.2
FX	0.2
Bonds	0.2
Commodities	0.1
Real Estate	0.1
Return	0.19%
St.dev	0.017
CVaR 95	0.042

Source: own calculations on the base of data from Marketwatch.com

Controlling the allocation among the assets and allowing only 20% share of the portfolio value to be allocated in the cryptocurrencies, gave three times higher maximum daily return with the lower CVaR than the riskiest only stock consisting investment. The naively diversified portfolio allowed to reap almost twice higher returns for the lower level of risk compared to the highest return portfolio of traditional assets.

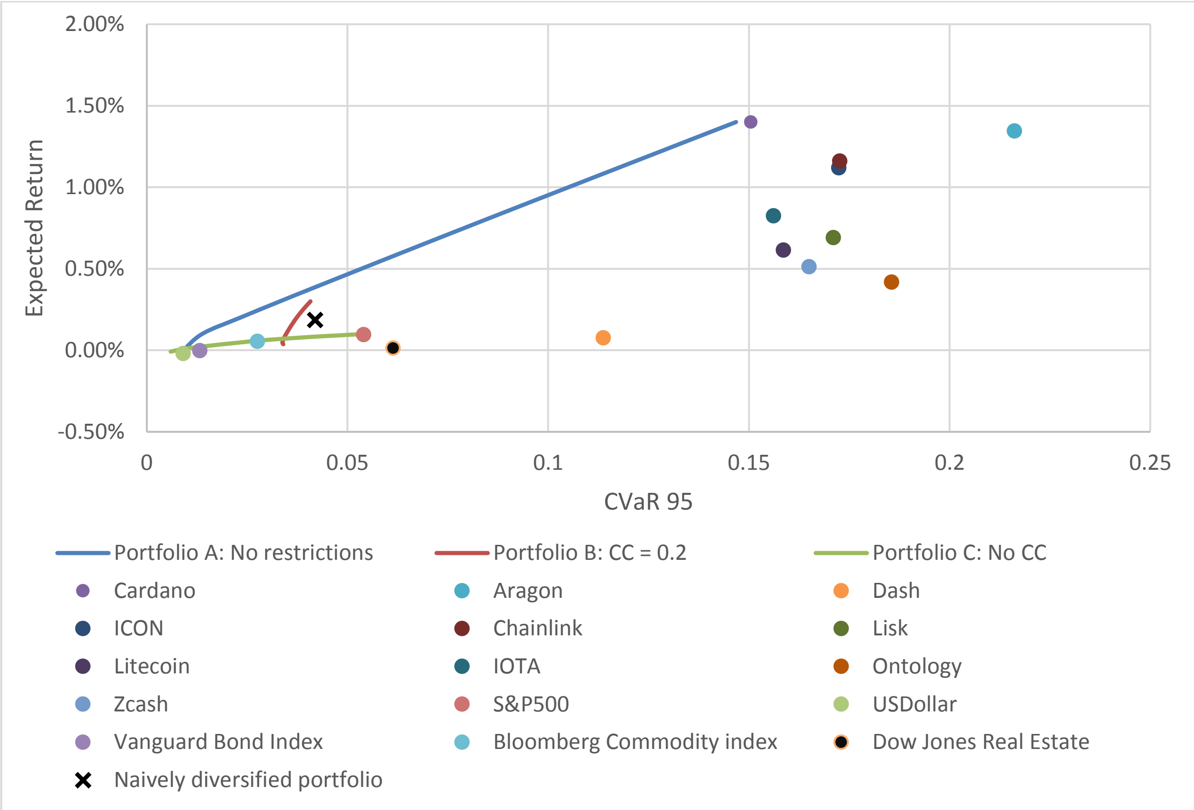

Figure 1: Efficient frontiers of the constructed portfolios, based on the data from Marketwatch.com

Figure 1 provides the visualisation of the efficient frontiers for the constructed portfolios, together with the location of the individual assets on the mean-CVaR 95 map. It clearly shows the outperformance of the portfolio with the cryptocurrencies included, based on the daily price data from the period from 1.2.2020 to 15.3.2021, suggesting that cryptocurrencies are considerably improving the performance of the portfolios during the crisis times. Even to the risk averse investor, the portfolio with cryptocurrencies allows to gather much higher returns with the same level of risk as the portfolios including only traditional asset classes.

4 CONCLUSION

Our analysis led us to the conclusion that cryptocurrencies improved the risk-return performance of the portfolio during the Covid-19 pandemic. Even from the analysis of their mean returns and standard deviations it seems obvious that they outperformed over traditional assets during the period from 1.1.2020 to 15.3.2021. Although in line with the literature, cryptocurrencies reported higher values of volatility, it seems that their role of an effective diversifier stays as well in the corona crisis period. Even the naively diversified portfolio allowed to reap almost twice higher returns for the lower level of risk compared to the highest return portfolio of traditional assets.

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IN-CLASS AND ONLINE TEACHING OF MATHEMATICS – A COMPARISON OF STUDENTS' OUTCOMES AT THE MIDTERM EXAMS

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Abstract: The paper describes the results of the case study where the students' outcomes in the mathematics midterm exams were compared regarding the type of teaching method used during the course: in-class or online. In the analyses, various factors such as prior knowledge of math from secondary school, engagement in learning activities, and success in e-lessons were taken into account. The results of the case study could not confirm any significant difference in the average outcomes of students from both groups. We can therefore conclude that the type of teaching method (in-class or online), as well as the method of knowledge examination, have no significant impact on students' outcome. Furthermore, the results also showed that the students who took the course online expressed a higher level of engagement in comparison to those who participated in class. Their greater engagement in learning activities can be explained through the fact that the online course took place during lock-down due to the COVID-19 pandemic in Slovenia. Namely, the strong lock-down measures disable the students to perform various extracurricular activities, which can result in their stronger motivation to perform study activities on a regular basis.

Keywords: mathematics, teaching methods, in-class teaching, online teaching, knowledge examination, outcomes comparison, case-study

1 INTRODUCTION

In March 2020 the whole world was heavily hit by the pandemic of COVID-19. The new extreme situation has completely changed our lives as well as educational processes at all levels. The new reality brought new challenges in different areas: how to efficiently teach the students, how to motivate them and how to establish safe and secure exam environment ehich would prevent the students' attempts of cheating.

At the Department of Methodology, Faculty of Organizational Sciences, we have decided to give the students comparable opportunities to pass the exams as they would have them in the "normal" situation. As in the pre-pandemic years, the midterm exams were offered to the students who did the homework at regular basis, while the exams were opened to all.

At the end of the study year we offered the students a questionnaire to get the feedback about their opinion on the following questions:

- Do the students get the same quality of information if the lessons are performed online if the lessons would held in the classroom?

- Are the results of the examination realistic since we are aware that it is easier to cheat while doing the exams from a remote position than in the classroom.

The research was conducted within the course "Fundamentals of quantitative methods I", which covers the basics of Calculus (functions, sequences, derivatives, integral calculus) and introductory Linear Algebra (three-dimensional vector space and matrices). The course is performed during the winter semester, with 51 hours of lectures and 39 hours of tutorials. Two generations of students participated in our study:

- The "pre-pandemic" generation of 2019/20, which participated the complete course in the classroom,
- the "pandemic" generation of 2020/21, which had all the lectures and tutorials online.

Our research was focused on the students' outcomes at the midterm exams where we especially focused on last of three midterm exams in total. Since we wished to examine if any statistically significant differences existed between the two generations under consideration, at this exam the students of both generations received identical problems to solve and identical questions to answer. We have to emphasize that the students were not aware of our experiment and all the data were processed anonymously.

2 LITERATURE REVIEW

There are a lot of scientific papers devoted to the topic of teaching and examining online. One of the recent comprehensive literature reviews is provided in [2]. The authors classified the papers based on different criteria: publication year, country of research, study method, number of participants, different aspect of examination (cheating, anxiety, results, etc.).

Since during the COVID-19 pandemic, distance learning became a new reality, several studies have been conducted analyzing experiences with re-designing the educational process from face-to-face to distance learning in mathematics courses [3, 4, 10]. The impact of distance learning on outcomes at mathematics for university students was studied [11]. The results show that distance learning does not affect excellent students and eliminates the number of students who do not pass.

Many authors discussed the possibilities of cheating in online examination (audio, video or both), and eventual differences in the achievements were supervised. As expected, the results showed that unsupervised examination provide significantly better results than supervised one [7-9].

Authors of [12] showed that students who feel more stress while doing exam in the classroom feel less stressed while doing it online and vice versa, but the correlation is stronger in the first case than in the latter one.

In the study [6] different ways of examination were tested and analysed. The authors concluded that the fairest approach is a question bank, where each student chose a number of questions at random. Sufficient number of questions in the bank assures that the probability of two students getting the same questions is negligible. Besides, we can even harden the students' ability to cheat by implementing the random order of questions.

Results of the study [5] discuss the possibility of implementation of automatic grading (e.g. TRUE or FALSE, 0% or 100%). We found the idea interesting but not really useful at math exams since we prefer to be able to award a student a part of points, when he provides a partially correct solution.

It is interesting that some authors examined also the influence of other factors, such as text size, text font, background colour, etc., on students' performance on the exam. For more on that, see [1].

3 RESEARCH DESIGN

Two consecutive generations of first-year students of the Higher Education Diploma course collaborated in our research. All the students under consideration were enrolled in the course “Fundamentals of quantitative methods I”. Furthermore, some of the students from previous generations (2. year of study), who how have not yet passed the exam, were also included. Our population includes all the students who took all three midterm exams, which in turn means that they also satisfied all the condition (some amount of homework is mandatory for the privilege of taking midterm exams and also their first and second midterm exams result had to be over 30%).

In the academic year 2019/20, 50 students were included in the study, while in 2020/21 85 students collaborated. The structure of both generations is explained in

Table *1*. We can conclude from the results that both generations are comparable from all the aspects.

Table 1: Characteristics of the populations in the study

		2019/20		2020/21	
		f	**%**	**f**	**%**
Gender	female	25	50	43	51
	male	25	50	42	49
Study year	1. year	48	96	84	99
	2. year	2	4	1	1
Program	OM KIS	21	42	39	46
	OM IS	23	46	36	42
	IPS	6	12	10	12

Moreover, both generations were compared according to the average mathematical achievements from high school (GPA in the final year, math grade in the final year, math grade at Matura), and no significant differences were approved.

4 RESULTS

4.1 Student’ engagement during the semester

There were 14 online activities for students to solve in both years of our study. Generation 2019/20 solved on average 12,9 of those activities (with the standard deviation of 1,9) and achieved on average 68,7% of available points (with a standard deviation of 13,9%). The average number of solved activities for the generation 2020/21 was the same (12,9 with s = 1,5), while their average success was 72,6 % (s = 13,0%).

The students were also given a chance for additional points, which allows them to improve their grade, but they were not able to turn the negative grade into a positive one. In generation 2019/20, 14% of students did not participate in the additional points scheme, while only 5% did not participate in 2020/21. The average number of additional points from tutorials of those who did participate in 2019/20 was 4,24 (s =2,3), while it was 5,75 (s =3,0) in 2020/21. For additional points from lectures (available only to the generation 2020/21) 14% choose not to participate, while the average of those who did, was 3,89 (s =2,7).

To summarize, if we only compare the additional points, which we were given on an almost weekly basis, it is possible to conclude that the students of generation 2020/21 were more motivated for studying during the semester.

4.2 Students' outcomes on midterm exams and final grades

For the purpose of our study we focused on the results of last (third) midterm exam, which was completely the same for both generations (identical problems, the same time limits, equal rules about the additional literature allowed). In the case of the students from the first generation, the exam was performed in-class, while the second generation of the students participated at supervised online exam (the students are required to have two cameras and unmuted microphone all the time during the examination). The third and final midterm exam was identical for both generations, while we also try to duplicate the other factors (time available, extra literature, etc.). The students were given four theoretical questions, each contributing 10% to the final score, and two problems from tutorials, each contributing 30%. Besides, the students from the second generation were given a 10 minutes' time frame at the end, to scan their solutions and submit them to Moodle.

The average results are presented in Figure 1. As seen, the students of generation 2020/21 were better on every task with the exception of problem 2 from the tutorial part. But in our opinion those differences are negligible. The only noteworthy differences are at theoretical questions 1 and 4. Taking all into account, we believe that the way the lectures and tutorials were done (live or online) does not influence the students' success. Even allowing for the greater possibility of cheating while doing the exam online and the chance that the exam was pre-known to students (although it was not published anywhere), the students' achievement seem comparable. This gives us a sort of confirmation that our hard work in teaching and planning of exams' procedure during COVID-19 pandemic was well worth it.

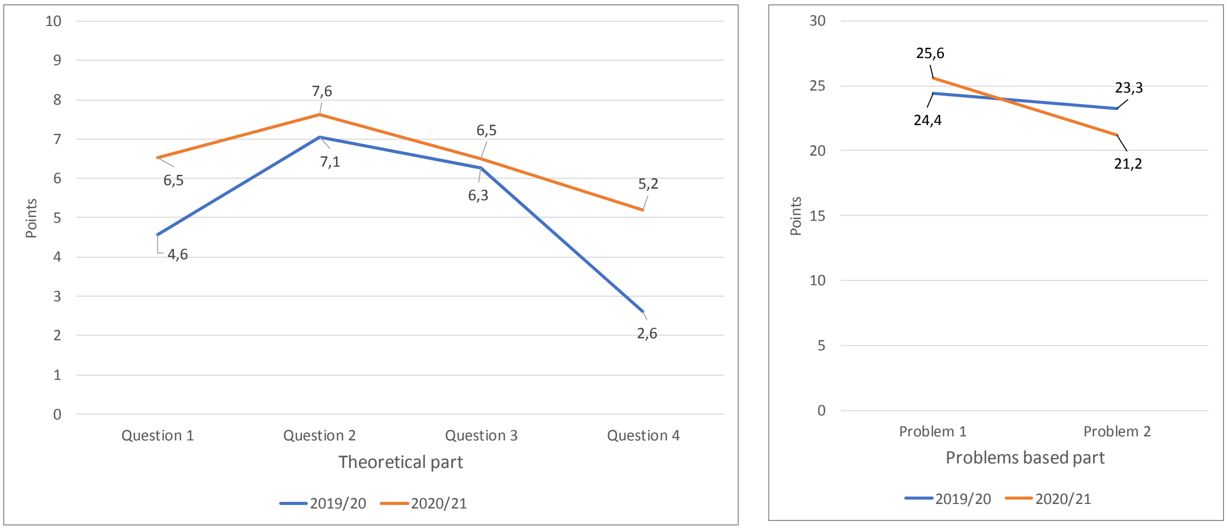

Figure 1: Comparison of both generations of students regarding their achievements on the theoretical part and problem based part of the 3rd mid-term exam

Besides the in-depth comparison of the last midterm exam, we also compared the points gain at the first two midterm exams. Of course, the comparison should be read with a bit of care since both the problems the students faced were different. The comparison is shown in Figure 2. The results of the first midterm exam argue that the students from the generation 2020/21 were more successful, while the result from the second midterm exam shows the opposite. Under the assumption that exams were equally challenging, we can state again that the method of teaching, whether face to face or online, has little or no effect on students' outcomes.

Finally, we compared the final grades the students received (in Slovenia, the positive grades are 6-10, while students that do not pass get the grade 5 or less). The distribution of grades in both years is presented in Figure 3.

It is interesting to point out that only 8% of students, who participated the last midterm exam in 2019/20, did not pass, while this percentage was 14% in year 2020/21. The average grade for generation 2019/20 was 7,7 (with s = 1,4), while it is 7,9 (s = 1,7) for generation 2020/21. If we concentrate only on those who passed, it rises to 7,91 (s = 1,2) for generation 2019/20, and to 8,21 (s =1,3) for the latest generation of the students.

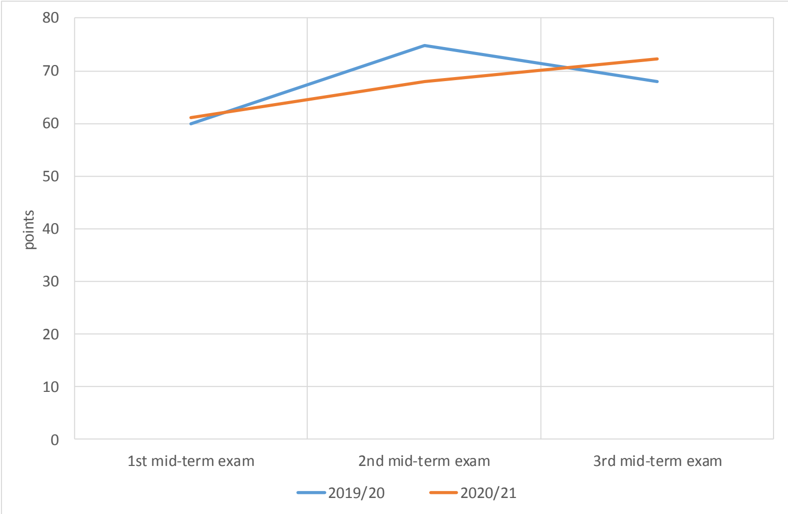

Figure 2: Average points in all mid-term exams together in both academic years

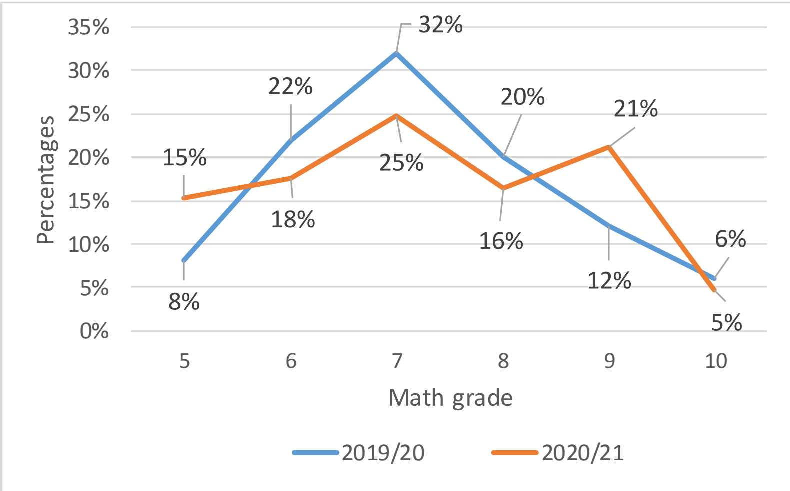

Figure 3: Frequency distribution of the final grades (with additional points) in both academic years

5 CONCLUSION

We can summarize our results as follows:

- There are no significant differences between the high school mathematical grades of generation 2019/20 and 2020/21, which implies that generations were comparable according to their mathematical background.
- Even though the course teaching methods among generations differed completely, with one year being face to face and one year being only online, there are negligible differences in students’ average outcomes. This is proved especially with the results of the third midterm exam, which was identical for both generations. This implies that it does not really matter to the students how the course is conducted.

- The generation 2020/21 had more opportunities to be actively engaged in the course. Some (or perhaps) all of this enthusiasm can be a result of the fact that a lot of our students are doing student work besides the studies, but due to pandemic, the students' work was badly hit last year.

Our results somehow confirm the outcomes of the previous studies. There was a general worry of so-called "lost generations" because of online schooling during the previous year. It seems that our results can deny those claims, at least at the university level.

However, during the pandemic period we also realized the many benefits offered by online education technology. We hope that we will be able to apply these good practices in the future as well. We also provided a lot of video material for our students, which they could use multiple times. The following generations will, hopefully, benefit from it as well.

Our study is limited to the students' achievements in math. It would be of course interesting to analyse the wider aspects of pandemic impact on study results in comparison to the older generation of students (e.g., general success, duration of the studies, etc.). So we look for that research at SOR '23.

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On the COVID effect for OT-ICU systems

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Abstract: How does the COVID-19 pandemic influence the congestion probability of the ICU? In this paper two models are given to capture the interaction and effect of COVID to non-COVID patients at the ICU and its possible effect on postponed surgeries for a single hospital. Particularly a coordinate convex interdependence is allowed. So-called product form expressions are derived that can be used to compute $\mathbf{B}^t$, the patient dependent congestion probabilities. It enables, as illustrated with real data, to calculate the congestion probabilities for the different patient types.

Keywords: COVID-19 · Intensive care units · Operating rooms · Finite tandem queues · Coordinate convexity · Erlang loss model ·

1 INTRODUCTION

In 2020 a new challenge for society arose, hospitals are severely impacted by COVID-19. As can be seen in Figure 1, the number of ICU beds needed for non-COVID patients is fairly stable, but the amount of beds needed for COVID patients fluctuates much more and can even increase drastically (e.g. between 27/02/20 and 27/04/20). The majority of recent OR related literature on COVID seems to be directed towards global aspects and effects rather than for one particular hospital, with some exceptions. As one example, in [2] forecasting methods are used to predict the ICU occupancy or queue length, that can be applied for individual hospitals. Further, the average Length of Stay (LOS) of COVID and non-COVID patients in the ICU differs substantially: the average LOS of a patient in the ICU is 3.46 days [8], while the average LOS of a COVID patient in the ICU was 10.8 days as in Dutch hospitals [5].

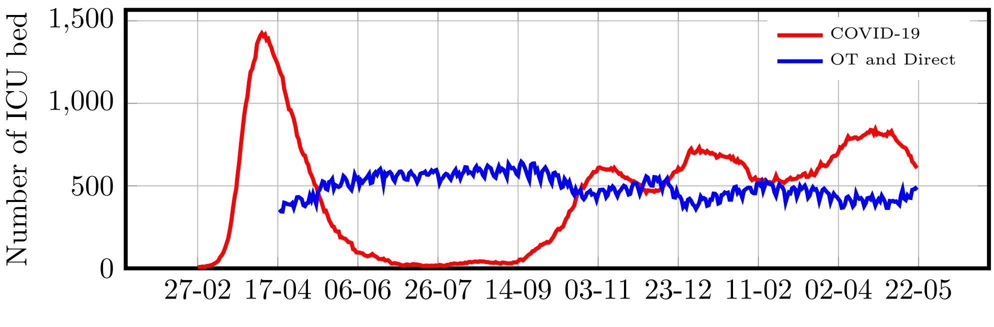

Figure 1: Number of ICU beds occupied during the COVID crisis 20/21 [4]

Accordingly, the ICU capacity also has to incorporate and distinguish non-COVID patients as from surgery and emergencies. As such, at individual hospital level, the demand by COVID patients should at least be modeled as by a finite tandem queue of an Operating Theater (OT) and an ICU distinguishing different patients.

This paper, therefore, reflects a tandem queue model for the OT-ICU (operation theater - intensive care unit) relationship for a singular hospital, in contrast to the newscasts in which usually is spoken about national levels. This model will differ from previously studied models as it will include more job types to also allow for COVID patients next to (OT patients and Direct ICU patients), which are distinct in both arrival rate and length of stay in the ICU. The ICU segment of the model will be coordinate convex (CC), particularly to study the effect of more general interdependencies of OT and COVID patients.

Finite tandem queues have long been known to be most useful for modeling practical challenges, such as in manufacturing, communications and healthcare. The COVID-pandemic provides a new challenge at individual hospital level. As COVID-patients may require an ICU bed, a contention for available bed capacity may arise with regular elective surgeries and emergency patients.

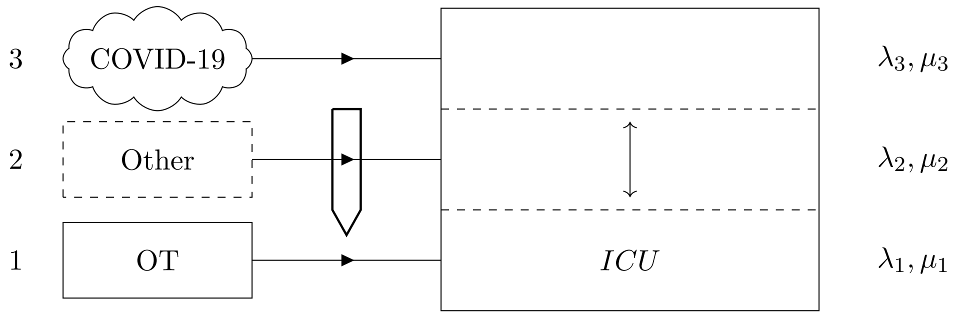

Figure 2: ICU and COVID flows for a single hospital

At the same time, also beyond this new ICU contention by COVID, finite tandem queues are also hard to analyze analytically. Clearly, for practical purposes, a simulation might be one option, but it would strongly rely upon the particular situation, detailed logistical assumptions, data and underlying distributions. A queueing theoretic analytic approach in contrast, could provide more generic support insights and replicable results.

In this paper, therefore, an analytic so called product form solution is developed with a finite generic patient interdependent structure at an ICU. As such the main objective and result of this paper is to illustrate the potential of classic queueing theory, particularly product form solutions, to capture the interaction and effect of COVID to non-COVID patients at the ICU and its possible effect for canceled operations.

From a theoretical point of view and referring to remarks 1-3 below, the results can be regarded as of interest as it includes:

i) a non-reversible (as serial from an OT into an ICU) routing,
ii) multiple job (patient)–types with different job-characteristics,
iii) interdependencies more than just by a total number of ICU beds.

From a practical point of view the results can be supportive for hospital management to

i) determine the capacity of an ICU with the current inclusion of COVID-patients,
ii) allocate these beds accordingly in a more distinctive manner,
iii) quantify the effect of COVID-patients on surgery cancellation.

A numerical illustration as based on realistic (Dutch hospitals) data will be incorporated.

2 MODEL DESCRIPTION

2.1 Description

Patients for surgery, either elective or by emergency, are brought over to an operating room. Directly after surgery a patient is shortly seen and kept at a recovery room to be monitored, and to let the first effects of anesthesia wear off. As we are particularly interested in ICU occupation while the recovery time is substantially shorter these recovery times are not included in this paper. For the same reason and as in [9], with reference to remark 2 below for possible extension, it is also assumed that all operated patients have to pass the ICU for a short period of time. Next patients are either discharged, directly brought to a regular (or medium) care nursing ward or to the ICU for necessary post operative care. In this model, we will only include surgical patients that need ICU care. Let η the patient arrival rate (per day) for operations. Hence η can also be seen as $\eta = \lambda_1$ the arrival rate of operated patients that should visit the ICU, if not canceled, as discussed below. For the different functions and possible extension as in remark 2, separate symbol η is kept. In order to study interdependencies more than by just a total number of IC beds, we need to incorporate and distinguish various ICU patients. There can also be ICU arrivals directly as by an emergency patient from outside or a deteriorating patient from a ward, say at an arrival rate λ_2. As third and new aspect we allow COVID-patients as their bed sojourn times are substantially longer, say at an arrival rate λ_3.

The arrival rates for 'Direct' and 'COVID' patients are assumed to be Poisson, that is to say 'homogeneously spread'. As for the operated patients these are determined by the surgery process. As we are interested in the interaction, the operating theater will essentially be included. The operating (surgery) times as well as the ICU bed sojourn times will first all be assumed to be exponential, as standardly done in literature for its analytic modeling purposes as a CTMC. Here, we refer to Theorem 3.3 later on, which allows to discard the exponential assumptions for the ICU.

The ICU will be finite and may incorporate interdependencies between the three patient types, as will be specified in section 2.3. In line with real-life practice, when no ICU bed is available for post-operative care, surgery for these patients is stopped, i.e. operations are stopped (with reference to remark 3 as if interrupted immediately, as justified by exponential assumptions) and new starting requests are "canceled", to be seen as 'temporarily' rejected and postponed.

2.2 Notation

The following parameters are used:

- Number of operating rooms	s	
- Number of IC beds at ICU	M	
- OT patients at ICU		type 1
- Direct patients at ICU		type 2
- COVID patients at ICU		type 3
- Operation Theater	n	number of patients at the OT
- Intensive Care Unit	m_t	number of patients of type t = 1, 2, 3 at the ICU
- Patient arrival at OT	η	number of operations for OT and ICU per day ($\lambda_1 = \eta$)
- Patient Arrival Rate	λ_t	number of patients of type t per day for the ICU
- Mean surgery time	ν	number of operations per day per operating room
- Mean ICU Sojourn time	$\tau_t = \frac{1}{\mu_t}$	days at the ICU by patients of type t = 1, 2, 3

2.3 Coordinate convex interaction

In order to allow for interdependencies at the ICU more than by just a total number of ICU beds M, we adopt (see e.g. [7], a so called notion of a coordinate convex set $\mathbf{C}$ for the ICU by:

$$\mathbf{C} = \{(m_1, m_2, m_3) \mid m_1 \geq 0, m_2 \geq 0, m_3 \geq 0, m_1 + m_2 + m_3 \leq M\} \quad \text{such that} \tag{1}$$

$$(m_1, m_2, m_3) \in \mathbf{C} \Rightarrow \begin{cases} (m_1 - 1, m_2, m_3) \in \mathbf{C}, (m_1 > 0) \\ (m_1, m_2 - 1, m_3) \in \mathbf{C}, (m_2 > 0) \\ (m_1, m_2, m_3 - 1) \in \mathbf{C}, (m_3 > 0) \end{cases} \tag{2}$$

Some examples are visualized in Figure 3, assuming that $M = 25$. $\mathbf{C}$ is coordinate convex since if there is either one COVID, Direct or OT patient less than that point is still contained by the blue mesh in Figure 3.

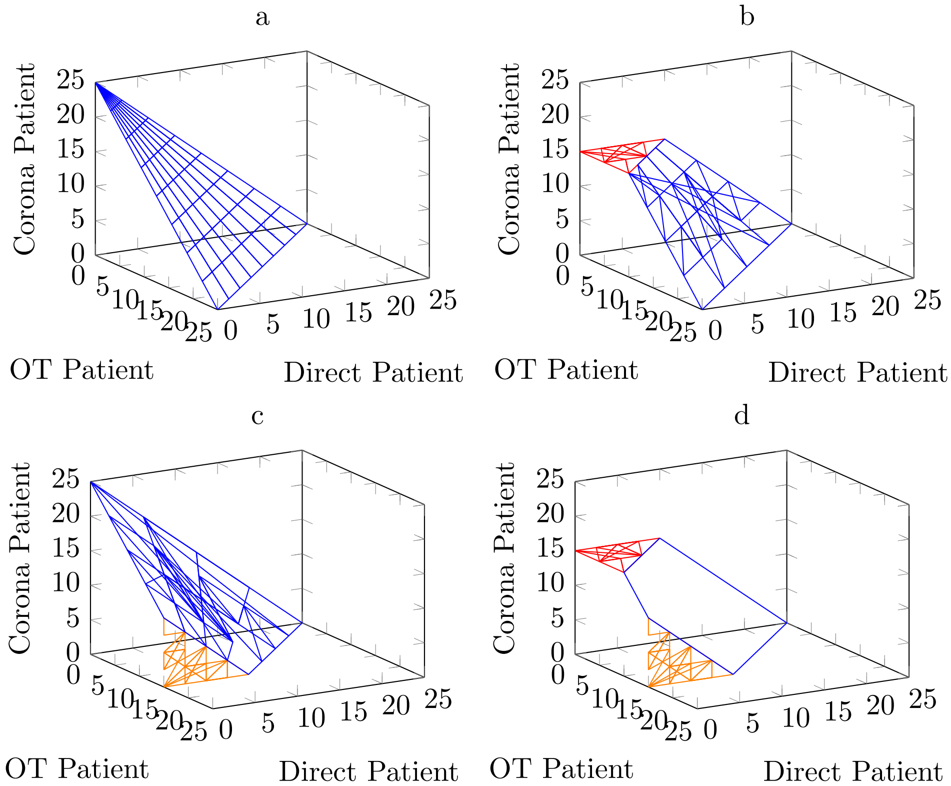

Figure 3: 3a Total constraint of M ICU-beds; 3b Additional limitation of COVID patients; 3c Limitation on OT patients; 3d Limitations on COVID and OT patients

3 RESULTS

In this section two systems will be studied, as system of interest in line with the description in section 2.1, with the ICU incorporating COVID patients. The first one (model 1) can be regarded as (next to) realistic as described in section 2.1, the second (model 2) is of more theoretical, yet also practical (computational) interest, as it leads to an identical closed form expression. For self-containedness and verifiability a compact proof is included for both.

3.1 Product form: model 1

We are interested in the steady state probability distribution $\boldsymbol{\pi}(n; m_1, m_2, m_3)$ at the set of admissible states: $S = \{(n; m_1, m_2, m_3) | n \geq 0, m_1 \geq 0, m_2 \geq 0, m_3 \geq 0, (m_1, m_2, m_3) \in \mathbf{C}\}$.

For shorthand notation, let

- $\mathbf{m} = (m_1, m_2, m_3)$,
- e_t: the unit vector for component t, and
- $f(n) = \min[n, s]$: the number of active servers at the OT.

Theorem 3.1 *(Product form) With c a normalizing constant at S and all $(n; \mathbf{m}) \in S$; (i.e. $\mathbf{m} \in \mathbf{C}$):*

$$\pi(n; \mathbf{m}) = cF(n) \left(\frac{\eta}{\nu}\right)^n \left[\prod_{t=1}^{3} \frac{1}{m_t!} \left(\frac{\lambda_t}{\mu_t}\right)^{m_t}\right] \tag{3}$$

$$\textit{where} \quad \mathbf{F}(n) = \left[\prod_{k=1}^{n} f(k)\right]^{-1} = \begin{cases} 1/n! & for \quad n \leq s \\ 1/[s!s^{n-s}] & for \quad n > s \end{cases} \tag{4}$$

Proof. To this end, we need to prove the GBE, $\boldsymbol{\pi} = \boldsymbol{\pi} Q$, where Q is the infinitesimal generator or transition rate matrix with $\boldsymbol{\pi}$ as row vector. More detailed, these are given below by equation (5). Here the terms on the left (as out rate from a state) and on the right hand side (r.h.s.) (as inrate into a state) are already pre-ordered such that these can be shown to be balanced in a more specified (as per patient type and station) manner, as by (5.i) and (5.i)', $i = 1, ..., 7$.

$$\begin{array}{l} (5.1) \\ (5.2) \\ (5.3) \\ (5.4) \\ (5.5) \\ (5.6) \\ (5.7) \end{array} \left\{ \begin{array}{l} \pi(n; \mathbf{m}) f(n) \nu 1_{(n>0)} 1_{(\mathbf{m}+e_1 \in \mathbf{C})} + \\ \pi(n; \mathbf{m}) m_1 \mu_1 1_{(m_1>0)} + \\ \pi(n; \mathbf{m}) m_2 \mu_2 1_{(m_2>0)} + \\ \pi(n; \mathbf{m}) m_3 \mu_3 1_{(m_3>0)} + \\ \pi(n; \mathbf{m}) \eta 1_{(\mathbf{m}+e_1 \in \mathbf{C})} + \\ \pi(n; \mathbf{m}) \lambda_2 1_{(\mathbf{m}+e_2 \in \mathbf{C})} + \\ \pi(n; \mathbf{m}) \lambda_3 1_{(\mathbf{m}+e_3 \in \mathbf{C})} \end{array} \right\} = \left\{ \begin{array}{l} \pi(n-1; \mathbf{m}) \eta 1_{(n>0)} 1_{(\mathbf{m}+e_1 \in \mathbf{C})} + \\ \pi(n+1; \mathbf{m}-e_1) f(n+1) \nu 1_{(m_1>0)} + \\ \pi(n; \mathbf{m}-e_2) \lambda_2 1_{(m_2>0)} + \\ \pi(n; \mathbf{m}-e_3) \lambda_3 1_{(m_3>0)} + \\ \pi(n; \mathbf{m}+e_1)(m_1+1) \mu_1 1_{(\mathbf{m}+e_1 \in \mathbf{C})} + \\ \pi(n; \mathbf{m}+e_2)(m_2+1) \mu_2 1_{(\mathbf{m}+e_2 \in \mathbf{C})} + \\ \pi(n; \mathbf{m}+e_3)(m_3+1) \mu_3 1_{(\mathbf{m}+e_3 \in \mathbf{C})} \end{array} \right\} \begin{array}{l} (5.1)' \\ (5.2)' \\ (5.3)' \\ (5.4)' \\ (5.5)' \\ (5.6)' \\ (5.7)' \end{array} \tag{5}$$

Indeed, first note that the indicators on the l.h.s. and r.h.s. are identical in each of the terms (5.i) and (5.i)', $i = 1, ..., 7$. Hence, if equal to 0 both sides are equal to 0. If not, we can substitute expression (3) and easily verify $(5.i) = (5.i)'$ for each $i = 1, ..., 7$.
For example by substitution (3) for $i = 1$:

$$\pi(n; \mathbf{m}) f(n) \nu = \pi(n-1; \mathbf{m}) \frac{1}{f(n)} \frac{\eta}{\nu} f(n) \nu = \pi(n-1; \mathbf{m}) \eta \tag{6}$$

□

3.2 Product form: model 2

As an alternative, less realistic but theoretically interesting process description: instead of rejecting patient arrivals at the OT if no ICU bed for an OT patient is available, the OT patient can always enter the OT, or possibly its waiting list. However, when the ICU is congested for a patient type, an ICU bed request is simply rejected and assumed to be lost, or said more directly, the patient is assumed to skip over the ICU.

Despite its different (unrealistic) description and corresponding transition rate structure, the following result still applies, as of interest by itself and usage later on:

Theorem 3.2 *(Equivalence) The steady state distribution for model 1 (say π_1) and 2 (say π_2) are identical i.e.; $\boldsymbol{\pi}_1 = \boldsymbol{\pi}_2 = \boldsymbol{\pi}$, as given by (3) and (4).*

Proof. Again, it suffices to verify the GBE which under the model 2 description for any $(n, \mathbf{m})$ with $\mathbf{m} \in \mathbf{C}$ is now given by:

$$
\begin{array}{c}
(7.1)\\ (7.2)\\ (7.3)\\ (7.4)\\ (7.5)\\ (7.5)\\ (7.6)\\ (7.7)
\end{array}
\left\{
\begin{array}{l}
\pi(n;\mathbf{m})f(n)\nu 1_{(n>0)}+\\
\pi(n;\mathbf{m})m_1\mu_1 1_{(m_1>0)}+\\
\pi(n;\mathbf{m})m_2\mu_2 1_{(m_2>0)}+\\
\pi(n;\mathbf{m})m_3\mu_3 1_{(m_3>0)}+\\
\pi(n;\mathbf{m})\eta\\
+\\
\pi(n;\mathbf{m})\lambda_2 1_{(\mathbf{m}+e_2\in\mathbf{C})}+\\
\pi(n;\mathbf{m})\lambda_3 1_{(\mathbf{m}+e_2\in\mathbf{C})}
\end{array}
\right\}
=
\left\{
\begin{array}{l}
\pi(n-1;\mathbf{m})\eta 1_{(n>0)}+\\
\pi(n+1;\mathbf{m}-e_1)f(n+1)\nu 1_{(m_1>0)}+\\
\pi(n;\mathbf{m}-e_2)\lambda_2 1_{(m_2>0)}+\\
\pi(n;\mathbf{m}-e_3)\lambda_3 1_{(m_3>0)}+\\
\pi(n;\mathbf{m}+e_1)(m_1+1)\mu_1 1_{(\mathbf{m}+e_1\in\mathbf{C})}+\\
\pi(n+1;\mathbf{m})f(n+1)\nu 1_{(\mathbf{m}+e_1\notin\mathbf{C})}+\\
\pi(n;\mathbf{m}+e_2)(m_2+1)\mu_2 1_{(\mathbf{m}+e_2\in\mathbf{C})}+\\
\pi(n;\mathbf{m}+e_3)(m_3+1)\mu_3 1_{(\mathbf{m}+e_3\in\mathbf{C})}
\end{array}
\right\}
\begin{array}{c}
(7.1)'\\ (7.2)'\\ (7.3)'\\ (7.4)'\\ (7.5)'\\ (7.5)''\\ (7.6)'\\ (7.7)'
\end{array}
\quad (7)
$$

The proof steps can be given in a similar way as those for Theorem 3.1 by substituting (3), except that one has to be conscious of the splitting on the r.h.s. in equality (7.5) = (7.5)' + (7.5)".

$$
\pi(n;\mathbf{m})\eta = \left\{ \begin{array}{lll} \pi(n;\mathbf{m}+e_1)(m_1+1)\mu_1 & for & \mathbf{m}+e_1 \in \mathbf{C} \\ \pi(n+1;\mathbf{m})f(n+1)\nu & for & \mathbf{m}+e_1 \notin \mathbf{C} \end{array} \right. \quad (8)
$$

□

Remarks

1. Theorem 3.1 can be seen as novel as it allows for a coordinate convex contention at one particular station rather than for just the total network, e.g. as in [7]. In that case, the routing can essentially be seen as a reversible routing with the exterior of the system. Reversible routing networks are well-known (as most elegantly displayed in [6]) to allow for a finite capacity product form network. In contrast, a serial structure as studied in the current paper has a nonreversible routing.

2. Theorem 3.1 can also be extended to include patients at the OT who will not visit the ICU. However, as it would complicate the notation and not contribute to the ICU congestion probability, as of prime interest, these are not regarded.

3. Clearly, real-life operations cannot be interrupted. In [9], therefore a product form based lower and upper bound was already shown for the ICU congestion probability while also including a recovery room. However as this paper focuses on the effect of COVID while a recovery time is essentially smaller than an IC duration the current paper is more restrictive in excluding this recovery. But it is extending in allowing COVID-patients as well as a more general patient interaction at the ICU.

4. With a finite constraint on the total number of OT patients at the OT, say $n \leq N$, a product form expression as reflected by (3) can still be obtained for both model 1 and 2. However, Theorem 3.2 will no longer be valid precisely as the state spaces will slightly differ.

5. Within earlier literature considerable attention has been paid to sojourn times and their distributional forms, such as lognormal, at the ICU. In this light, the next Theorem 3.3 can be seen of particular interest as it simply relies upon means. It enhances the practical applicability to study the COVID effect at the ICU.

Theorem 3.3 *(Insensitivity) Expression (3) and (9) in Corollary 3.4 also apply for arbitrary non-negative non-exponential ICU sojourn (or bed occupation) times with means τ_i for patient type i, i = 1, 2, 3.*

Proof. Again, a proof can be based in two ways i) by literature on insensitivity (e.g. [3], chapters 1 or 9) in combination with the particular balances shown for model 1 or 2 at the IC. ii) Or in a self-contained manner by using phase-type distributions. The technical details of the latter, however, are far too lengthy for the current setting, and left out. □

3.3 Practical ICU congestion probabilities

From Theorem 3.1 or 3.2 the patient dependent congestion probabilities for nó ICU bed to be available, denoted by $\mathbf{B}^t$ for patient type t, in particular OT and COVID patients, can now be presented and computed in analytic form.

Corollary 3.4 *(Patient loss expression) With c a normalizing constant at* $\mathbf{C}$*:*

$$\mathbf{B}^t = \sum_{\mathbf{m}} \pi(\mathbf{m}) 1_{(\mathbf{m}+e_t \notin \mathbf{C})} \quad with \quad \pi(\mathbf{m}) = c \prod_i \frac{1}{m_i!} \left(\frac{\lambda_i}{\mu_i}\right)^{m_i}, \quad t = 1, 2, 3 \tag{9}$$

Proof. First note that by summing (3) over all n and $\mathbf{m}$ we can decompose $\pi(n; \mathbf{m}) = \pi(n)\pi(\mathbf{m})$ with $\pi(n)$ as standard $M|M|s$ - queue. For $t = 2, 3$ and the Poissonian assumption of their arrival rates, the proof is now direct by PASTA (Poisson Arrivals See Time Averages).
For $t = 1$ (OT-patients) and by relying upon the fact that for model 2 the first station (OT) can just be regarded as a quasi-reversible queue (i.e. Poisson arrivals lead to Poissonian departures), as by [6], the same argument could be used.

Alternatively, as a self-contained and straightforward proof by Theorem 3.2, the proof for $t = 1$ can also be worked out by model 2 by $\mathbf{B}^1$ = [mean number of completions at the OT per time unit, while $\mathbf{m} + e_1 \notin \mathbf{C}$]/[mean number of completions at the OT per unit time]. □

4 NUMERICAL

In this section, the effect of COVID on the congestion probability of the ICU is shown. In Table 1, the arrival rates and the mean sojourn times are given. The arrival rate of OT and Direct patients originate from Dutch nationwide data 2018 and therefore do not incorporate the scaled-down number of surgeries due to an ICU bed shortage caused by COVID.

Arrival Rates	λ_1	λ_2	λ_3	λ
	2.68 [8]	1.85 [8]	1.67 [1]	6.2
Mean ICU Sojourn Times	τ_1	τ_2	τ_3	τ
	3.26 [8]	3.75 [8]	10.8 [5]	5.44

Table 1: Arrival rates and mean sojourn times in days

Figure 4 displays the $\mathbf{B}^t$ (9) for a varying number of available ICU beds (horizontal axis). More concrete, it shows that the difference in congestion probability for a period without COVID and a period with COVID is substantial (e.g. in case of 25 ICU beds, the congestion probability without COVID is close to 8%, while with COVID its close to 31%).

This may let a hospital limit the number of beds that can be reserved for COVID patients (e.g. to 10). This will then lead to a lower congestion probability for OT and Direct patients (e.g. 20% for 15 beds), while the congestion probability for COVID patients will rise to almost be 50%. In case that these 10 beds are occupied, a new COVID patient (or a substituted one) would need to be transferred to another hospital, while if the other 15 beds are occupied an OT patients surgery is likely to be postponed.

5 CONCLUSION

In this study we refined a so-called product form solution of an OT-ICU system, to include the interaction and effect of COVID and non-COVID patients at an ICU. The model may support hospitals (or some government) to determine to calculate an acceptable congestion probability for the different patient types, and what effect might be expected on the other patient

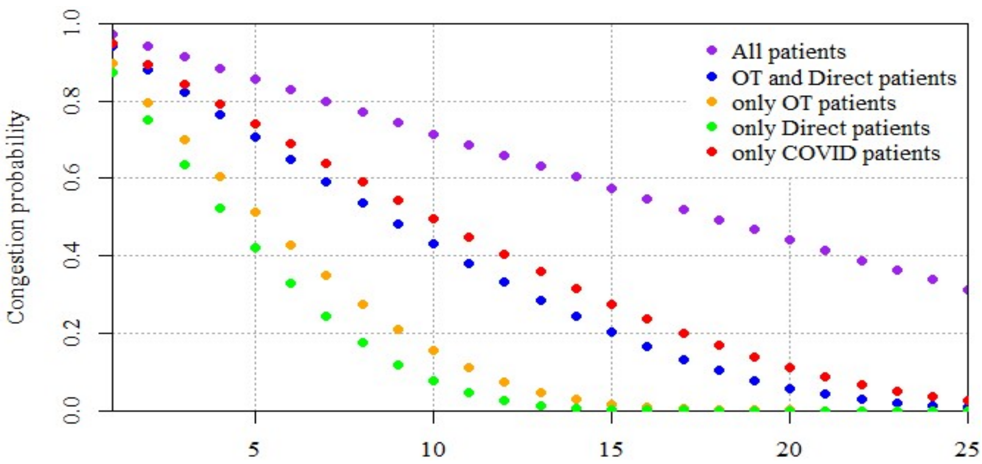

Figure 4: Congestion probabilities

types. Also for future non-COVID situations the system can be most useful as its generalization allows for more dedicated patient groups, such as distinguishing cardiac and neurological patients, who might have very different arrival rates and sojourn times. Particularly, it also provides congestion probabilities of merging or compartmentalizing these departments. Another direction of interest for extension, either with or without COVID, is to include a next Medium or Step Down Unit.

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SEGMENTING CENTENNIALS BASED ON THEIR CONSUMER BEHAVIOUR DURING COVID-19 PANDEMICS: THE CASE OF CONFECTIONERY INDUSTRY

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Abstract: The COVID-19 pandemics brought significant changes to everyday lives and disrupted the former life-style. One of the habits that was mostly affected by the lockdown and mandatory social distance was shopping. Consumers had to improvise and change not only their shopping habits, but their consumption habits, attitude towards shopping, and even opinion towards the company in question based on its activities in battling the global pandemics. This study aims to segment young consumers, the Centennials, based on their attitudes towards the corporate social responsibility (CSR) of the company and their consumer behaviour during COVID-19. Afterwards the differences in options of the retained segments are explored. As the study was done on an example of a confectionery company, we hope that the results could provide valuable insight on consumer behaviour change in a specific industry.

Keywords: Market segmentation, Consumer behaviour, Confectionery industry, Biclustering,

1 INTRODUCTION

The COVID-19 pandemic has had an impact on people’s everyday habits and activities. Shopping habits have been also changed due to lockdown measures and social distancing. These measures have pushed consumers to make their purchases online. There is a tendency for certain consumer behaviour that developed during the pandemic to continue in the post-pandemic period [1]. Corporate social responsibility (CSR) has gained a lot of importance in recent years, especially during the current pandemic. Almost all companies with a market-leading position pay special attention to the scope of CSR and show social responsibility through increased philanthropy [2]. During the pandemics, companies have contributed to the fight against the epidemics in the form of financial aid, food donations, providing disinfectants, masks for health institutions.

In such stressful conditions, it is believed that consumers pay more attention to the socially responsible activities of companies, which might lead to an increase in their trust in the CSR and consideration of purchase of the company’s products and services [3]. Taking into account that the COVID-19 pandemic has generated many changes in consumer habits and attitudes, companies need to understand how consumers perceive their CSR activities and how do they consume their products and services to adjust as quickly as possible and maintain customer loyalty.

This paper aims to segment younger consumers, those from the generation Z called Centennials, based on their consumer behaviour during the pandemic and opinions on CSR activities. Afterwards, differences between the segments were explored to better understand each group's perception and to devise business strategies for each group. The case of a specific company from the confectionery industry was observed. Studies showed there are differences in consumption and preferences for a particular type of food between younger and older consumers [4]. The older generations were more inclined to stockpile food at the beginning of the pandemic, while the Millennials and Centennials believe that the necessary food supplies will eternally be available [5].

The confectionery industry is a part of the food industry and it is based on the production of sweet snacks (e.g. candies, chocolates, cookies). Like many others, this industry was also affected by the pandemic. In 2020, the global confectionery market size decreased by $ 8 billion compared to 2019, although forecasts before the impact of COVID-19 had indicated market growth [6]. The pandemic affected consumer behavior and their eating habits, so organic products became more popular among consumers [7]. This new trend has affected confectionery too. Hence, more importance is given to attributes such as organic ingredients and the origin of cocoa [8].

The paper is divided into the following sections: the next section provides an overview of the literature on the importance of consumer segmentation in the COVID-19 era in different industries. Section 3 describes the identified segments in our research as well as the differences between groups and attitudes towards word of mouth (WOM) and loyalty. The last section provides the discussion and conclusion.

2 LITERATURE REVIEW

Below is an overview of the several papers that indicate consumer habits change during and after the pandemic and that clustering algorithms can be used to detect these changes.

Neuburger and Egger in their study in [9], examined changes in the perception of travel risk during the pandemic by observing two periods: at the beginning of the pandemic and at the culmination of the pandemic. They also segmented travellers according to the following characteristics: perceived risk of COVID-19, perceived risk of travel during a pandemic, and traveller behaviour. Three groups were identified in each period. In period 1, the largest number of travellers were classified as “Reserved”, followed by “Relaxed” and “Nervous”. Groups “Nervous” and “Reserved” exist in period 2, while the cluster of “Relaxed” is not identified here. Instead, the “Anxious” cluster was named as the most numerous.

Kamenidou, Stavrianea and Liava in [10] grouped Greek citizens based on their self-reported prevention behaviour and adherence to recommended precautions to prevent the spread of the COVID-19 virus. The authors divided the citizens into 5 segments: “Meticulous Proactive Citizens”, “Self-isolated citizens”, “Cautious citizens”, "Occasionally cautious citizens" and “Unconcerned Citizens”. Following the identified segments, adequate marketing communication strategies with each group were proposed to raise the awareness of the group.
A study by Romeo-Arroyo et al. [11], presents the groups of consumers depending on their eating habits and eating style during the lockdown period in Spain. The authors were first guided by the earlier segmentation conducted by Cebolla et al. [12]. Accordingly, they divided consumers into the following clusters: "Emotional eaters", "External eaters", and "Restraint eaters". The results of the research provide a basis for the development of different communication strategies with each cluster to encourage healthier eating styles.
Following the good results of the previous studies, we also opted for segmentation in order to better understand the change in consumer behaviour during the COVID-19 pandemic.

3 RESEARCH RESULTS

3.1 Conducted survey

The survey was conducted online from March 16 to April 2 using the Google forms and distributed on Facebook accounts of authors. Besides demographic information, the survey aimed to examine students' attitudes towards Stark products, as well as their habits in consuming these products at the time of the pandemic. Stark is a food company located in Belgrade, Serbia, and operates as a part of Atlantic Group as a business unit based on the production of salty and sweet snacks, primarily extruded snacks, chocolate, and biscuits. The Stark company is seen as the oldest, largest, most popular and the traditional confectionery company in Serbia. All questions were measured on a seven-point Likert scale and are presented in the sections that follow. After collection of the answers, SPSS 25 was used to perform statistical analysis while the biclustering was done in R package "biclust" [13].

3.2 Sample characteristics

The goal population in our study were Centennials, a demographic cohort of those born after 1997. As the survey link was open to everyone, after closing the survey, the respondents who could not be classified as Centennials were eliminated from further analysis. From 542 initial respondents, we observed 457 of them. In our sample, we had 95 (20.8%) males and 362 (79.2%) females. Gender disproportion can be noted in our sample. However, we did not treat the issue as bias, as it was shown that females are more prone to participating in online surveys [14]. The average age of the respondents was 21.90, with a standard deviation of 1.339. Most of the respondents come from Belgrade (58.6%), followed by those from Central region (11.8%) and Western region (11.4%). When it comes to the level of personal monthly income, most of the respondents indicated that they have a monthly income above 100,000 RSD (40.3%), followed by those with an income between 70,000 and 100,000 RSD (24.5%).

3.3 Segmentation results

The respondents were segmented based on the following seven questions: The company's CSR during the pandemic had a positive effect on my attitude towards the company and its products, I believe that by purchasing the CSR active company's products, I am participating in the fight against the pandemic, Knowing that the company was CSR active during the pandemic will influence me to buy its products even more, I pay attention to the CSR behaviour of companies during a pandemic and prefer to buy the products of those companies that are CSR active, At the beginning of the COVID-19 pandemic, I bought larger quantities of groceries, including Stark's products, During the lockdown, I consumed more Stark products, I would miss Stark's products and feel the need for them if I didn't have the opportunity to buy them during the COVID-19 pandemic. As all questions were answered on a seven-point Likert scale, we employed the BCQuestord biclustering algorithm [15]. The BCQuestord algorithm has six parameters, we varied the parameters until we obtained a meaningful segmentation. The similar approach was done in previous segmentation studies [16], [17]. One of the metrics of biclustering quality we used was the sample size. Namely, segments which encompass less than 5% of the sample should be discarded [18]. In our case, that would be 22.85≈23 respondents.

The descriptive statistics of the respondents within each of the four retained segments is given in Table 1. We successfully segmented 85.64% of the sample, with only 67 respondents left unclustered. We did not want to retain more segments in order to have less segments with more respondents within them. We retained the structure where each segment covers more than 5% of the sample.

Table 1: Statistics of obtained consumer segments

	Size	*Proportion of the sample*	*Female proportion (%)*	*Average age*	*Household income – above 100,000 RSD (%)*
Addicted	166	36.63%	80.7%	22.01	39.8%
Conscious	84	18.38%	92.9%	22.11	33.3%
Informed	58	12.69%	65.5%	21.51	39.7%
Ignorant	82	17.94%	78.0%	21.84	43.9%

To additionally present the obtained segments, we provide the Barchart Plot on the seven statements in each of the obtained segments (Figure 1). The Barchart Plot provides insights on which items were used to create each bicluster and the mean values. What can be immediately noted is that all questions have been used to create the four segments.

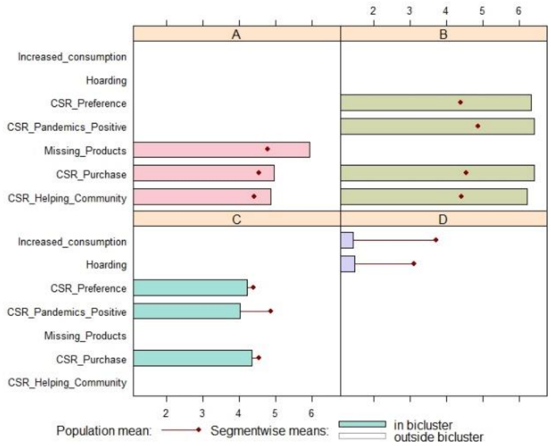

Figure 1: Barchart plot on the seven items within segments

The largest and the first segment is named *Addicted*, as this is the only segment which was defined using the statement regarding the issue of missing Stark products if they were not available during pandemics. Besides being big fans of Stark products, these respondents take into account the CSR activities of the company. Most of the sample are females and the respondents come from households with high income.

The second segment, *Conscious*, encompasses those highly aware and interested in knowing the CSR activities of the company during the pandemic. The level of agreement with the four statements is high and above the sample mean, indicating these respondents truly care about the society and community. Most of the sample are females (92.9%).

The segment *Informed* is the segment with the highest proportion of male respondents, 34.5%. The respondents in this segment, as their name suggests, are informed about the CSR activities of a company, but that fact is not so detrimental for their decisions on consumption. Namely, their mean level of agreement on all three statements is below the sample mean.

The final segment is called *Ignorant*, as these respondents did not pay any attention on the CSR activities of the companies during the pandemic and had no change in consumer behaviour of Strak products having low increased consumption and low hoarding activities. Most of the segment are females (78.0%). Interestingly, this is the segment in which are the respondents with the highest percent of high household income.

We additionally wanted to explore the external validity of the segments and see whether there are significant differences in the socio-demographic variables. First, there is statistically significant gender ratio between the segments (Chi square=16.973, $p<0.01$). The same accounts for the average age of the respondents ($F=2.671$, $p<0.05$). However, there is no statistically significant difference between segments regarding the household income.

3.4 Segment comparison

In these paragraphs we explored the differences between respondents' attitudes towards WOM and loyalty towards Stark products among the four retained segments.

To assess the WOM we observed the following four questions: I often recommend Stark products to friends, I often recommend new Stark products to friends, If a friend would come from abroad, I would recommend him to try Stark products, and If I am satisfied with a Stark product, I will share my experience on social media. The Kruskal-Wallis (KW) test indicated that there are statistically significant differences. The values of the statistics were respectfully: $H_1=37.952$, $H_2=70.027$, $H_3=38.011$, and $H_4=36.241$ with $p<0.001$. Regarding the willingness to recommend "old" and "new" Stark products, the respondents from the first two segments are more open to the idea with mean agreement up to 5.14 (*Conscious,* Recommendation of Stark products). All respondents are willing to recommend Stark products to friends from abroad, whereas the *Addicted* and *Conscious* lead the way. All respondents are in a way resentful of posting images of Stark products on social media, but for the *Addicted* it is a big no as their mean agreement is 1.68.

To assess loyalty, we observed the next four questions: I see myself as a loyal consumer of Stark products, I will continue consuming Stark products, I would rather choose Stark product than its competitor, and If the price of Stark products would increase, I would continue purchasing them. The KW test indicated statistically significant differences. The values of the statistics were respectfully: $H_1=78.221$, $H_2=30.502$, $H_3=51.016$, and $H_4=26.864241$ with $p<0.001$. The *Addicted* and the *Conscious* both see themselves as loyal consumers and will continue to consume Stark products. On the other hand, *Ignorants* and *Informed* do not observe themselves as loyal, but plan to continue consuming Stark products. The *Addicted* and the *Conscious* are trustworthy to Stark products even if they could buy the competitors' products. All respondents are in a way displeased with the idea of Stark products' price going up, but *Conscious* respondents are prepared to pay more.

4 CONCLUSION

According to the authors' knowledge, the market size of the chocolate category in Serbia showed a fall in volume and value. It is assumed that this outcome was influenced by the shortening of the working hours of the supermarkets during the lockdown. Interestingly, the segment of cooking chocolate showed a significant growth in volume and value market share during the lockdown. The reason for this may be that people turned to making sweets at home because they had more time to cook. These insights clearly show that the confectionery market has faced visible changes due to COVID-19 pandemics.

Our study showed that there are statistically significant differences between groups of Centennials regarding their attitude towards CSR activities of companies during the pandemics and their consumer behaviour. A large proportion of the sample does pay attention to CSR activities of companies during pandemics and they take this information into account during purchase decision making. The segment which attracts attention is the segment of medium size, the *Ignorant.* Those are the respondents who did not care on CSR activities of companies and did not change consumption habits. Is seems like that for these individuals the pandemic did not even happen or that they simply ignored it. It should also be noted that two segments stand out for their high loyalty and WOM of Stark products, which should be encouraging for the company as it indicates they have very loyal consumers of young age.

Future directions of the study could be defined. One encompasses the application of structural equation modelling (SEM) analysis to explore the relationship between different aspects of shopping. The next encompasses exploration of differences between segments on other issues such as Consumer loyalty, Perceived quality, and Purchase intention.

We hope that the presented study could initiate further research on the topic of consumer segmentation to discover new consumer attitudes and habits.

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THE RESPONSE OF MARKET VOLATILITY TO THE COVID-19 PANDEMIC

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Abstract: The paper investigates market volatility on the example of Sarajevo Stock Exchange at the time of coronavirus disease 2019 (COVID-19) outbreak. Sarajevo10 index was chosen and analysed as a representative of this stock market for the period 1 April 2019 - 10 March 2021. Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model was used to analyse the abovementioned index. The results showed that, for the observed period, the return of the chosen index satisfied ARMA(0,0)-GARCH(1,1) process. A significant rise in the volatility of the Sarajevo10 index return was noticed at the beginning of COVID-19 outbreak. Furthermore, the results show a significant volatility of this index return both prior to COVID-19 pandemic outbreak and during the pandemic.

Keywords: volatility, GARCH model, Bosnian index, COVID-19.

1 INTRODUCTION

Financial markets are defined by random fluctuations over time. This is particularly important because stock values and other financial instruments depend on the risk. Therefore, risk assessment can be observed as one of the main activities of financial markets. When investors want to invest in a risky asset, they compare the expected return of the asset with the risk they have to take. It is not possible to estimate the risk without measuring a time-varying conditional variance (volatility) of the asset return [6].

The volatility of a market variable measures the insecurity of the value of the variable in the future. Risk managers have to monitor and control the volatility of market variables in order to assess possible losses [8].

According to [7], stock volatility comprises of three components: event-driven volatility, price-driven volatility, and error-driven volatility [7]. Event-driven volatility is caused by rational and unbiased reactions of the market values of stocks to the real, economic events. In efficient markets, this is the only volatility component. If this were the only component, the stock volatility would be only a fraction of what it really is. In inefficient markets, the prices overreact to one type of information, and underreact to another type of information [7].

Volatility plays a crucial role in assessing and managing risk in different financial activities. For one-dimensional return series, volatility is frequently represented by conditional variances or conditional standard deviations. A great number of statistical models have been created for modelling one-dimensional conditional variance processes [14]. In recent years, Autoregressive Conditional Heteroscedastic (ARCH) model and Generalized ARCH (GARCH) model that was defined in [4] have been very successful in explaining time-varying variances of economic data [13].

On 31 December 2019, World Health Organization (WHO) received information that the cases of a pneumonia of unfamiliar origin had appeared in the city of Wuhan in China [15]. As the number of COVID19 cases outside China increased rapidly, on 11 March 2020, the Director-General of WHO declared that the outbreak of the disease could be described as a pandemic. By the middle of March 2020, the European region had become the epicentre of the pandemic, and reported over 40% of the confirmed cases of the disease all around the world [15].

The aim of this paper is to analyse the volatility of the Bosnian capital market at the time of the COVID-19 pandemic outbreak. Sarajevo10 index was chosen to represent the Bosnian market for the period 1 April 2019 – 10 March 2021. The volatility was measured by using the GARCH model and the results showed that the return of the Sarajevo10 index satisfies ARMA(0,0)-GARCH(1,1) process. A sudden rise in the return volatility of this index was noted at the beginning of the COVID-19 outbreak. A significant return volatility of this index was also noted. i.e. an extreme volatility of Bosnian market was noted during the COVID-19 pandemic.

The paper comprises the introduction and the following sections: Section 2 is dedicated to literature review, and Section 3 presents the used data and the applied methodology. Section 4 provides the results of the empirical analysis, and the concluding remarks with policy implication can be found in the final section.

2 LITERATURE REVIEW

The influence of the COVID-19 crisis on the market indices of the US stock exchange was analysed in [11], for the period April 2019 – April 2020. The author used Dow Jones and S&P500 indices and the results were based on GARCH(1,1) model. It shows that the change in the number of COVID-19 cases and deaths in the USA and other six countries (China, Italy, Spain, Great Britain, Iran, and France) that were hit by the COVID-19 crisis have no influence on the market return of the USA, except for the number of the reported cases in China [11].

The COVID-19 influence on the stock exchange in Nigeria was examined in [1] for the period March 2015 – April 2020. The authors used the Quadratic GARCH (QGARCH) and Exponential GARCH (EGARCH) models with, so called, dummy variable. The results show that a significant loss of stock return and a big volatility of the stock return happened at the beginning of the COVID-19 outbreak. Therefore, the results reveal that COVID-19 has a negative influence on the stock return in Nigeria [1].

The influence that COVID-19 pandemic had on the relationship between the market return and inflation in Nigeria for the period 27 February 2020 – 30 April 2020 was investigated in [9], by using a version of GARCH(1,1) model, namely GJR-GARCH. It is evident from the results that COVID-19 increases volatility and disturbs the balance between the inflation and market return in the Nigerian market. Furthermore, the authors confirm the existence of the leverage effect, which indicates that the negative shock was enhanced by the increasing number of COVID-19 cases, which increased volatility and disturbed the balance between the inflation and stock exchange return [9].

The relation between the Japanese yen and the stock return during the pandemic of COVID-19 for the period January 2010 – August 2020 was examined in [10]. The authors used GARCH-M(1,1) model to test the effects of the exchange rate on the stock prices. They found out that the influence of the exchange rate on stock prices increased during the COVID-19 pandemic [10].

The influence of the COVID-19 crisis on the expected returns and conditional volatility of the Chinese market return were analysed in [3] for the period 22 January 2020 – 30 April 2020. The authors applied GARCHX volatility model. The results show that COVID-19 had a significantly negative effect on the stock returns and their volatility [3].

The dynamic response of the stock returns to the unexpected changes caused by the pandemic on the markets of Canada and the USA was investigated in [16] for the period January 2020 – July 2020. The author used GARCH-in-Mean (GARCH-M) model. It showed the asymmetry in stock returns in Canada which resulted from the negative influence of the pandemic. As for the US stock market, the author found that the insecurity had a lower degree of negative influence on the returns. Moreover, the stock returns in the USA are quite symmetric in relation to the increased or decreased number of the COVID-19 cases [16].

3 METHODOLOGY

The Bosnian Sarajevo10 index was chosen for the analysis. Daily data were used, and the source of data was the website: https://www.investing.com/indices/. The observed period was 1 April 2019 – 10 March 2021.

Sarajevo10 is the main index of the Sarajevo stock exchange. It shows movements of prices of the first ten issuers on this stock exchange ranked according to the market capitalization and trading frequency. It is a price index weighted with the full market capitalization with 20% limitation [12].

The following equation was used to calculate he return for the Bosnian index:

$$R_t=(\log(P_t)-\log(P_{t-1}))\text{x}100, \tag{1}$$

where P_t presents the closing price of the stock exchange index in the trading day t, and P_{t-1} is the closing price of the stock exchange index in the trading day $t-1$.

GARCH model (thoroughly described in [4]) was used to analyse Sarajevo10 index return volatility. GARCH(p,q) model is presented by the following equation:

$$\sigma_t^2 = c + \sum_{i=1}^{q} a_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} b_j \sigma_{t-j}^2 \tag{2}$$

where a_i, b_j and c are the parameters. Actual conditional variance is parametrised and depends on q legs of squared errors and p legs of conditional variances [5].

The condition for the second-order stationarity is given in the following relation:

$$\sum_{i=1}^{q} a_i + \sum_{i=1}^{p} b_i < 1 \tag{3}$$

An important method used to estimate the above parameters is the maximum likelihood method [2].

4 EMPIRICAL RESULTS

Different types of ARMA model were tested prior to GARCH modelling of the Bosnian index volatility. Schwarz information criterion was used for selecting the ARMA model. So, an extensive research was conducted in order to determine which ARMA process satisfies the return of the Bosnian index. The values of Akaike and Schwartz information criteria were used each time when the return index equation was estimated. The models with minimal values of these two criteria were chosen. Akaike criterion shows that the return satisfies ARMA(2,2) model, while Schwartz criterion shows that the return satisfies ARMA(0,0) model. Therefore, the simpler form of the model (i.e. ARMA(0,0) model) was chosen, which is a white noise process.

Prior to the ARMA-GARCH modelling, Augmented Dickey–Fuller test (ADF) was used to examine the unit roots, i.e. the stationarity of the series of index values and index returns.

Table 1: Test of stationarity

	ADF test		
	Index Sarajevo10		
	Intercept	*Trend & Intercept*	*None*
Log value	-1.534	-1.564	-0.257
	(0.516)	(0.806)	(0.593)
Log return	-24.565	-24.552	-24.586
	(0.000)	(0.000)	(0.000)

Note: p – value (given in the parentheses).

Table 1 shows that the logarithmic value of Sarajevo10 index is non-stationary, while the return is a stationary value in all cases. After examining the unit roots of returns, ARMA-GARCH modelling was applied to get a time-varying return volatility of the analysed index.

Table 2: Volatility modelling

	GARCH modelling		
	Variance Equation		
	Coefficient	*Std. Error*	*Prob.*
C	0.099	0.020	0.000
ARCH(-1)	0.108	0.025	0.000
GARCH(-1)	0.750	0.046	0.000

The result shows that the return of Sarajevo10 index satisfies the ARMA(0,0)-GARCH(1,1) process. On the basis of the results presented in Table 2, the estimated variance equation for the return of Sarajevo10 index is represented by the following formula:

$$\widehat{\sigma}_t^2 = \mathbf{0.099} + \mathbf{0.108}\boldsymbol{\varepsilon}_{t-1}^2 + \mathbf{0.750}\boldsymbol{\sigma}_{t-1}^2. \tag{4}$$

The obtained variance was used to calculate the volatility of return (as a square root of the variance) for the chosen index.

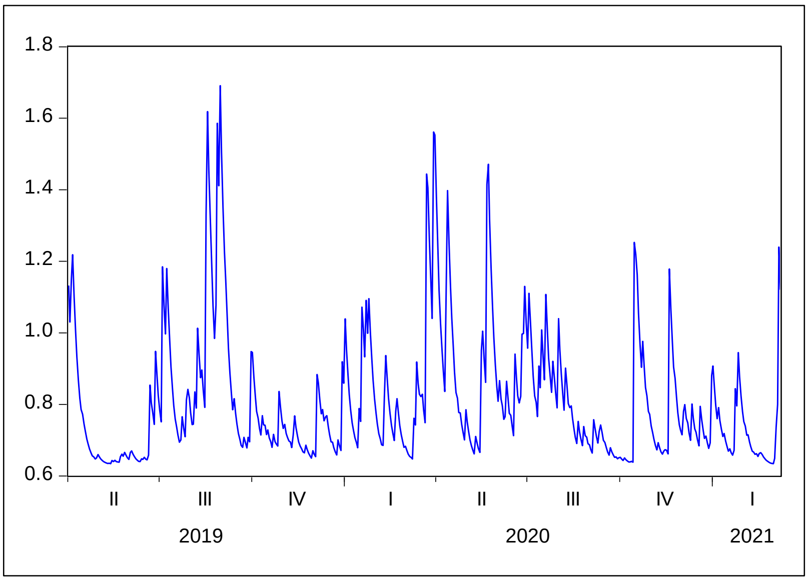

Figure 1: Daily return volatility of Sarajevo10 index.

The return volatility of Sarajevo10 index is presented in Figure 1 and it shows a significant instability of Sarajevo10 index return volatility during the COVID-19 pandemic. However, this market had been extremely volatile even before the outbreak of the pandemic. So, it is possible to conclude that the Bosnian market was prone to the effects of the COVID-19 crisis. The results are in accordance with the research in [3] related to the Chinese market and to [1] related to the Nigerian capital market.

Table 3 represents a diagnostics checking of the estimated GARCH model.

Table 3: Diagnostics checking

Ljung-Box statistics		***ARCH-LM(5) test***		***ARCH-LM(10) test***	
Q(36)	*Q^2(36)*	*F-stat.*	*Obs*R^2*	*F-stat.*	*Obs*R^2*
33.442 (0.591)	35.277 (0.503)	0.592 (0.706)	2.978 (0.703)	0.429 (0.933)	4.344 (0.931)

Note: p – value (given in the parentheses).

From Table 3, it is easy to conclude that according to the value of Ljung-Box statistics there is no autocorrelation in the residuals and residual squares of this model. Furthermore, according to the value of ARCH-LM test, there is no heteroscedasticity, i.e. ARCH effect in the residuals of the model. Therefore, it is possible to say that GARCH model for the return of Sarajevo10 index is adequately estimated.

5 CONCLUSION AND POLICY IMPLICATION

Each of the investors in financial markets (especially in the times of crises) has a task to assess the risk and the expected return that they get by investing in a risky asset. Therefore, it is very important to measure the time-varying conditional variance (i.e. volatility) of asset return as a measure of the risk of an asset.

The purpose of this paper is to investigate the volatility of the Bosnian capital market at the COVID-10 crisis outbreak. Sarajevo10 index was set as a benchmark for the Bosnian capital market. The data were observed on the daily basis for the period April 2019 – March 2021. GARCH model was used to examine the return volatility of the Sarajevo10 index. It is evident that the return of this index satisfies the ARMA(0,0)-GARCH(1,1) process. The result shows that the Bosnian capital market had been very volatile even before the outbreak of the COVID-19 pandemic, and the pandemic additionally increased its volatility. As in [3] it can be concluded that the diseases such as COVID-19 can have a serious effect on market returns and their volatility.

The research in this paper considers only the short-term impact of the crisis. The knowledge of the short-term behaviour of the financial market can help investors and regulators to anticipate risk in similar circumstances in the future. The government and market regulators can also take steps to boost investor confidence. The COVID-19 crisis can also be seen as an opportunity for investors and market speculators to make a profit, although COVID-19 is the cause of market inefficiency. Consequently, such crises can lead to the higher level of wealth inequalities.

The future research could be expanded to other Balkan countries using the same of slightly modified methodology.

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MEASURING EFFICIENCY OF HEALTH CARE SYSTEM OF OECD MEMBER COUNTRIES DURING PANDEMIC COVID-19

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Abstract: In this paper the health care efficiency of 32 OECD (Organisation for Economic Co-operation and Development) member countries dealing with COVID-19 virus is analyzed. The efficiency of health care systems is measured in June 2021 and compared to the results from June 2020, taking into account the number of tested and the number of the recovered patients. The aim is to test whether the systems have adapted and managed to increase efficiency in the fight against corona virus. DEA (Data Envelopment Analysis) method is one of the most used methods in health care system in general and it is used in this paper for efficiency analysis. This method represents nonparametric technique for relative efficiency measurement with heterogeneous inputs which produce or provide heterogeneous outputs. Beside the relative efficiency index, as a basic indicator, DEA is also providing preview of reference DMUs (Decision Making Units), which is important for efficiency improvement of inefficient DMUs. Also, this method is showing target values of inputs and outputs in order to determine the quantity of how much an inefficient unit needs to reduce (increase) its inputs (outputs) in order to become efficient. Comparing the efficiency analysis results from the two years, it is shown that the average efficiency level for 32 OECD countries increases.

Keywords: Efficiency, Health care system, COVID-19, OECD, DEA

1 INTRODUCTION

Improving the health of the population depends on a fair and efficient health care system. One of the main goals of most countries is to improve their health care system in terms of quality of service and efficiency on one side and better resource usage on another side. Therefore, it is crucial to accurately assess the health system efficiency to determine key performance indicators to improve. The importance of an efficient health care system is best shown in big crises, such as the COVID-19 pandemic. By the end of May 2021, almost 171.5 million cases of corona virus infection and over 3.7 million deaths had been confirmed worldwide (Worldometer, 2021). The number of infections and deaths, considering pandemic and the speed of spreading, greatly depends on the country's preparedness and quality of health system. Therefore, this paper aims to measure the efficiency of the health care system considering COVID-19 within 32 OECD member countries.

Breitenbach et al. (2020) use DEA to analyse the 31 most infected countries during the first 100 days since the outbreak of the COVID-19 for the efficiency in containing the spread of the virus with interesting results that among the worst performers were some of the richest countries in the world. To measure the operational efficiency of isolation hospitals in Egypt (Kamel & Mousa, 2021) combine three interrelated methodologies including DEA, sensitivity analysis and Tobit regression. Author (Castanedo Pereira, 2021) also combines DEA and Panel Tobit Analysis to measure efficiency of 19 OECD countries and then explores the determinants that affect hospitals' performance.

Most studies in the literature focus on the relative efficiency of the public health sector of OECD member and European Union (EU) countries. A study conducted by Evans et al. (2001), which covers 191 countries, is based on the health care expenses for the year 1997. Authors consider that efficiency is positively related to the level of health care expenditure per capita. A DEA model that can be applied by public sector management to assess the effectiveness of the health system of developing countries is presented by Alexander et al. (2003). The study compares the health care systems of 51 countries, which are divided into two groups based on GDP. The results showed that health expenditures per capita were positively related to efficiency. Asandului et al. (2014), in their paper, are estimating the efficiency of public health care systems in Europe. The authors used statistical data for 30 European countries for the year 2010. Collected results have shown that few developed, and few developing countries are efficient. In their study, Storto and Goncharuk (2017) used DEA to calculate the efficiency index of health care systems with various combinations of health quality indicators. The sample included 32 European countries for data from 2011 and 2014. The study showed that efficiency comparison and effectiveness of health care helps to identify the right leaders. Still, most importantly, it enables finding the most problematic countries that need health care sector reform.

Dincă et al. (2020) identified efficient health care systems on a sample of 17 members of the EU. According to health care financing schemes, the selected countries belong to two main groups, Beveridge and Bismarck and application of the DEA has shown that countries that use the Beveridge type of financing are on average more efficient than countries that use the Bismarck type. Radojicic et al. (2019) also analyzed the efficiency of 38 OECD member countries by using a two-stage approach based on the general assurance region DEA model. The results show that the Bismarck financing type is more efficient then the others. Cetin and Bahce (2016) conducted a study that estimates the efficiency of 34 OECD member countries with the use of the DEA model. As inputs, they used the number of doctors, number of beds and health expenditures per capita, and health-adjusted life expectancy and child mortality rates as outputs. Efficiency analysis of the most affected countries with the newly formed corona virus (COVID-19) in terms of controlling the spread of infection and treatment of the virus is conducted by Shirouyehzad et al. (2020). In the first step, efficiency values are calculated considering the country's performance in controlling the disease. In the second step, they are compared based on the effect in the medical treatment of patients that could lead to a decrease in the number of deaths and an increase in the number of cured cases.

This paper aims to analyze and compare the efficiency of the health care system of OECD member countries and their ability to cope with the corona virus based on data from June 2020 and 2021. Firstly, we will introduce DEA methodology in the second section. After that, the efficiency analysis with discussions will be presented in the third section, followed by the conclusion and reference list in the last two sections.

2 DATA ENVELOPMENT ANALYSIS

DEA (Charnes, Cooper, & Rhodes, 1978) was introduced for measuring relative efficiency of non-profit organizations called decision making units (DMUs), whose performance depends on multiple inputs and multiple outputs. The DEA application areas are later expanded to the wide range of areas and models are modified to adopt different assumptions. One of first modification was made by Banker, Charnes and Cooper (1984) with introducing variable return to scale and making BCC DEA model. Let us suppose that we have n DMUs in the observing using m inputs to produce s outputs. The values of inputs x_{ij}, (i=1,...,m) and outputs y_{rj} (r=1,...,s) for each DMUj (j=1,...,n). The envelopment form of output-oriented BCC DEA model, trying to increase outputs with current level of inputs is as follows (1-4).

$$(\max) Z_k \tag{1}$$

s.t.

$$\sum_{j=1}^{n} \lambda_j x_{ij} \le x_{ik}, \quad i = 1,...,m \tag{2}$$

$$Z_k y_{rk} - \sum_{j=1}^{n} \lambda_j y_{rj} \leq 0, \quad r = 1,...,s \tag{3}$$

$$\sum_{j=1}^{n} \lambda_j = 1, \; \lambda_j \geq 0, \; j = 1,...,n \tag{4}$$

where variable Z_k is intensity factor indicates the level to which it is necessary to proportionally increase outputs of DMU$_k$ to become efficient. Dual variables, λ_j, $j = 1,...,n$ show the importance that is assigned to DMU$_j$ ($j = 1,...,n$), in defining the input-output mix of a hypothetical composite unit (efficiency reference set). If DMU$_k$ is evaluated as a relatively efficient unit, Z_k is equal to 1. For inefficient DMUk, Z_k is below 1 (100%), and there are DMUs in the efficiency reference set that produce as much or more outputs and use fewer inputs offering a path to improve the efficiency of the inefficient DMUk.

3 EFFICIENCY OF THE HEALTH CARE SYSTEMS: RESULTS AND DISCUSSION

In this paper, we have analyzed and compared the efficiency of the health care system of 32 out of the 37 member countries of the OECD in fighting against COVID-19 based of indicator's values from June 2020 and June 2021. Some countries are excluded from the analysis due to the missing data. Assuming that the increase/decrease of the inputs does not result in a proportional increase/decrease of the outputs, the BCC DEA model is applied. The output oriented model is most often used when evaluating the efficiency of health systems and that is the reason for choosing this model. It is important to note that the indicator "number of deaths" actually represents the output from the system, but that in this analysis it represents the input, because it is an undesirable output. Selected outputs and inputs that are used in analysis are described in Table 1.

Table 1: Input and output indicators

Input/Output	***Description***
(I1) Number of infected	Total number of patients infected with corona virus(per million inhabitants).
(I2) Number of deaths	Total number of deaths from corona virus (per million inhabitants).
(I3) Cost of health care	Costs of health care products and services, but excludes investment costs (measured per capita and expressed in dollars)
(O1) Number of recovered patients	Total number of recovered patients from corona virus (per million inhabitants).
(O2) Number of tested	Total number of tested performed against corona virus (per million inhabitants).

The health care costs data are captured from the OECD database (OECD, 2021), and data for other indicators are taken from the Worldometer database (retrieved on 06.06.2020 and 17.06.2021) (Worldometer.info, 2021). Descriptive statistics is shown in Table 2.

Table 2: Descriptive statistics of data for the years 2020 and 2021

	(I1) Number of infected		***(I2) Number of deaths***		***(I3) Cost of health care***		***(O1) Number of recovered patients***		***(O2) Number of tested***	
Year	***2020***	***2021***	***2020***	***2021***	***2020***	***2021***	***2020***	***2021***	***2020***	***2021***
Max	6449	155289	827	3108	10586.1	10586	6214	152092	182444	11109208
Min	135	543	4	5	1138	1138	118	533	2431	56117
Average	2204.56	63573	132.25	1221	3926.89	3927	1640.47	60148	56894.8	1568961
SD	1964.65	38337	182.941	840	1957.11	1957	1595.77	37436	38266.2	2055822

Beside those, another one input indicator was included in the initial experiments: the duration of epidemic in days. Correlation analysis indicates the duration has negative influence on the number of recovered and the tested people but it does not have significance in the efficiency evaluation. Hence, we decided to exclude it from the further analysis.

Table 3: DMU's efficiency indexes and rank

	June 2020		***June 2021***		***rank***		***June 2020***		***June 2021***		***rank***
Country	***Eff.***	***Rank***	***Eff.***	***Rank***	***diff.***	***Country***	***Eff.***	***Rank***	***Eff.***	***Rank***	***diff.***
Australia	1	1	1	1	0 ⇔	***Italy***	0.714	26	0.956	25	1 ⇑
Austria	0.942	17	0.99	12	5 ⇑	***Japan***	1	1	0.962	23	-22 ⇓
Belgium	0.443	31	0.94	27	4 ⇑	***Latvia***	1	1	0.989	14	-13 ⇓
Canada	0.562	29	0.98	15	14 ⇑	***Lithuania***	1	1	0.971	19	-18 ⇓
Chile	1	1	0.96	22	-21 ⇓	***Luxembourg***	1	1	1	1	0 ⇔
Czech Rep.	0.740	24	1	1	23 ⇑	***Mexico***	1	1	1	1	0 ⇔
Denmark	0.932	18	1	1	17 ⇑	***New Zealand***	1	1	1	1	0 ⇔
Estonia	0.951	15	1	1	14 ⇑	***Norway***	0.963	14	0.694	31	-17 ⇓
Finland	0.840	23	0.49	32	-9 ⇓	***Poland***	0.578	28	0.934	28	0 ⇔
France	0.464	30	0.97	18	12 ⇑	***Portugal***	0.723	25	0.956	24	1 ⇑
Germany	0.918	20	0.97	16	4 ⇑	***S. Korea***	1	1	0.992	13	-12 ⇓
Greece	0.999	13	0.96	21	-8 ⇓	***Slovakia***	1	1	1	1	0 ⇔
Hungary	0.699	27	0.92	29	-2 ⇓	***Slovenia***	0.946	16	0.973	17	-1 ⇓
Iceland	1	1	1	1	0 ⇔	***Switzerland***	0.930	19	0.969	20	-1 ⇓
Ireland	0.908	21	0.94	26	-5 ⇓	***Turkey***	1	1	1	1	0 ⇔
Israel	0.877	22	1	1	21 ⇑	***USA***	0.389	32	0.844	30	2 ⇑

The index of health care system efficiency for each country obtained by DEA model enable ranking of inefficient countries. The efficiency indices, together with ranks, rank difference and descriptive statistics for both periods, June 2020 and June 2021, are given in Table 3. From the total of 32 health care systems, 12 are relatively efficient in 2020 (37.5%) and 11 are relatively efficient in 2021 (34.4%). Even though the number of efficient health care systems is slightly decreased, the average efficiency scores are increased from 0.859 in 2020 to 0.949 in 2021. The same case is with minimal efficiency which has risen from 0.389 in 2020 (USA) to 0.493 in 2021 (Finland). One can conclude that the health care systems of OECD countries are better able to cope with the COVID-19 crisis in 2021, probably due to one year of experience and vaccination campaign. Efficient systems in June 2020 were in Australia, Chile, Iceland, Japan, South Korea, Latvia, Lithuania, Luxembourg, Mexico, New Zealand, Slovakia and Turkey. The average efficiency index is 0.859, while the lowest efficiency index belongs to the USA, which is only 0.389. In 2021, six health care systems preserved their relative efficiency (Australia, Iceland, Luxembourg, Mexico, New Zealand, Slovakia and Turkey), joint by a group of four newly efficient countries (the Czech Republic with ranking growth by 21, Denmark by 17, Estonia by 14 and Israel by 21 positions).

Interestingly, the Czech Republic, as the country with the maximum number of infected (155258) and health-care costs of 3058 per capita as important inputs and 97.94% of recovered patients, is an incomparable and therefore efficient country in June 2021. Denmark became efficient in the fight against COVID-19 due to the below-average number of infected and deaths on the input side and a high per cent of recovered patients (97.14%), and a huge number of tests performed against coronavirus (more than 11 per capita). Estonia and Israel exhibit very similar figures: above the average number of infected and tested per million inhabitants, but the below-average number of deaths and health-care costs. One can conclude that they are successful in covid patients treatment with 96.83% of recovered patients in Estonia and almost 100% (99.2%) in Israel. Furthermore, according to vaccination data (COVID-19 Data Explorer - Our World in Data) Israel is one of the most prosperous countries with 59.48% fully vaccinated people.

On the other hand, the rankings of Chile and Japan health care systems fell by 21 and 22 positions respectively, despite a slight drop in efficiency of less than 5%. It means that systems in other countries performed quite well. One bad example is Norway which relative efficiency index fell from 0.963 to 0.694 (drop in rank by 17 positions) due to the second-lowest patient recovery rate of 68.90%. Finland, exhibited the lowest recovery rate of 48.86%, with bottom rank in June 2021. However, those countries had far below the average number of infected (16968 in Finland and 23653 in Norway), probably due to good protection politics and good performance in contagion control.

If we examine the influence of the number of inhabitants on the efficiency of health care system, it can be seen that there is no big difference while comparing the largest and the smallest countries (Figure 1). The efficiency of all health care systems (except Latvian) remains the same or rises in 2021, which is in line with the overall increasing.

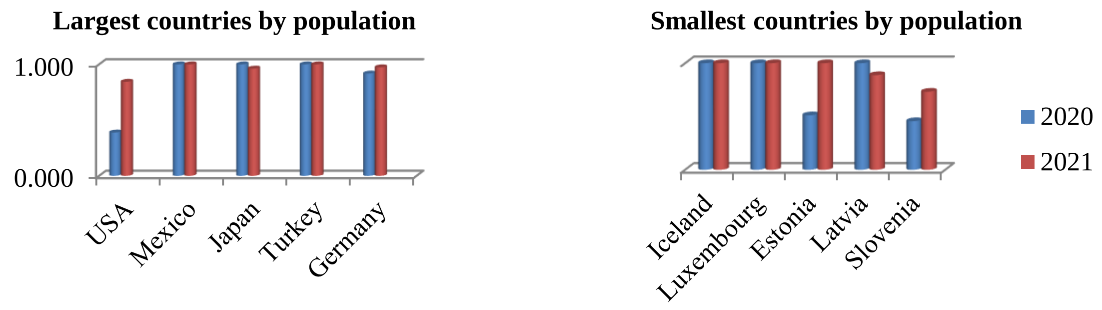

Figure 1: Countries population impact

The Figure 2 regards the cost impact on health care relative efficiency, showing increase in almost all observed countries (Figure 2). Only the efficiency of the Norwegian health care system has declined, as shown earlier, although Norway is among the countries with the highest costs per capita.

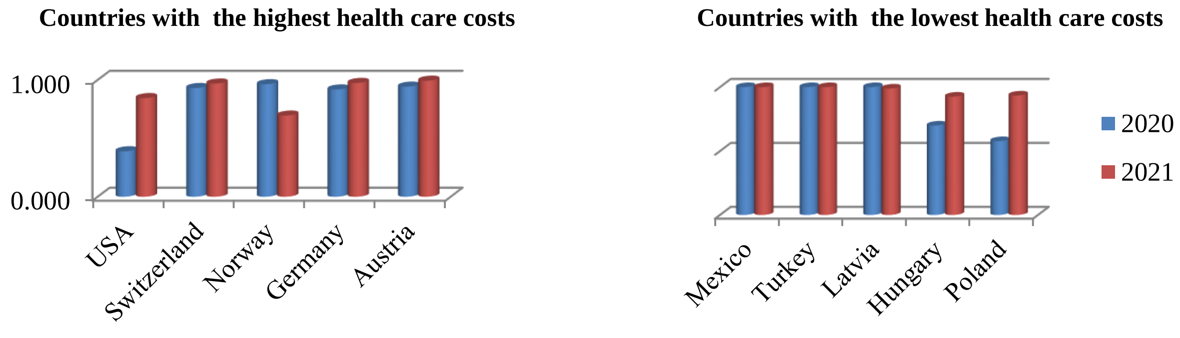

Figure 2: Health system expenditures

4 CONCLUSION

Performance measurement is very important for profit or non-profit organization, in order to determine whether an organization is effectively using its resources to achieve a predefined goal using performance analysis.

Performance measurement, i.e. the assessment of the relative efficiency of the health systems of the OECD countries during the COVID-19 pandemic using the DEA method is shown in this paper. The aim was to compare the efficiency of health systems in relation to the data from June 2020 and 2021. It was shown that there was an expected increase in average efficiency during this period in the fight against covid virus. The systems with the highest growth, such as the Czech Republic, Denmark, Estonia and Israel are countries with a high patient's recovery rate, and a high vaccination rate. On the contrary, countries where the recovery rate and number of infected are low (Finland and Norway) are also ranked low. The low number of infected could mean that the prevention in these countries is at a high level and that government measures gave good results (Haug et al., 2020).

This paper has several limitations. The analysis can be performed for different time periods, so that the changes of countries' efficiency over time can be seen. The choice of indicators certainly affects the results, therefore different groups of indicators can lead to different results and analyzes. Some other parameters that are not directly related to the coronavirus can be introduced into the analysis, such as the number of doctors, the number of beds or the population over 65 years of age.

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ASSESSING THE IMPACT OF COVID-19 LOCKDOWN ON AIR POLLUTANT EMISSIONS IN CITIES: THE CASE OF EUROPE'S CLEANEST AND MOST POLLUTED COUNTRIES

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Abstract: In this paper, we compare emissions of major air polluters from 20 March to 20 April 2020 to the same period in 2019. Our study area covers major cities in Europe's cleanest and most polluted countries. Results show that there is a statistically significant decrease in maximum daily values of NO_2 emissions in almost all cities. The concentrations of other pollutants indicate that the closure measures cannot be related to statistically significant reductions. A noticing finding is that a statistically significant reduction in pollutants (except for SO_2) is more frequent in cleaner cities.

Keywords: air quality, cross-city comparison, COVID -19, Europe, lockdown, major polluters

1 INTRODUCTION

The harmful effects of anthropogenic emissions on air quality and public health arouse even more attention during the COVID-19 pandemic due to the possible interaction with respiratory problems caused by the coronavirus. On the other hand, anti-epidemic measures that followed suggest the possible environmental benefits during these measures were put in force. Although the influence of lockdown on air quality improvement is temporary, the recorded pollutant emission levels provide a basis for many lessons to learn for the future. These are primarily related to the effects of movement restrictions - whether and how effective they are, how much their effectiveness depends on their duration, and finally, which pollutants could be most affected.

Previous studies report valuable data on emission changes during the lockdown period. What can be argued is the decrease of major traffic-related pollutant - NO_2 emissions, with various reduction rates going up to 60% [1, 3-7, 11]. Initial estimates show that concentrations of PM2.5 and PM10 were lower at most of the sites compared to the same calendar periods from previous years and/or to the pre- and post-lockdown period [1-4, 7]. The recorded decrease was generally less notable than with nitrogen-dioxide emissions. Compared to the above-quoted polluters, SO_2, O_3, and CO concentrations show a rather inconsistent picture. Studies report either no significant change or even an increase in some pollutants [3, 5, 8, 10, 12]. When it comes to European countries, although we can talk about certain similarities in emission changes [4], the trends are far from conclusive. Apart from meteorological conditions, which needed to be included to adjust emission estimates, the contribution of major energy consumption sources like industry, transportation, etc., is very much country-specific. This is particularly pronounced between countries that have invested more in clean technologies and those whose economic development has limited such opportunities.

This paper aims to contribute to numerous studies on the impact of lockdown on air quality parameters. Our study area covers major cities in Europe's cleanest and most polluted countries. We have focused on the urban environment, where activities were more affected by pandemic control measures. The first research question of this study is whether and in which cities there is a statistically significant reduction in emissions of major polluters? The second question of interest is whether there is a difference in the recorded decrease between cleaner and more polluted countries? We also hypothesise that the emission levels correspond to the scope of shutting down during the course of the observed period.

2 DATA AND METHOD

In response to our research questions, we compare emissions of major air polluters from 20 March to 20 April 2020 to the same period in 2019 in the cleanest and most polluted European countries. Starting from the IQAir report [9], our analysis included the five most polluted and the five cleanest European countries and their larger cities[1] (see Table 1). Daily concentrations of major air pollutants - SO_2, O_3, CO, $PM_{2.5}$ and PM_{10} for these cities expressed in AQI units were taken out from the World Air Quality Index project data platform [15]. This data source also provides min, max, median and standard deviation for each pollutant.

After the World Health Organisation declared a global pandemic on 11 March 2020, epidemiological measures have been announced in most European countries. The period from 20 March to 20 April 2020 was selected because, at that time, in most of the observed countries, the measures were largely in practice. As regards the implemented lockdown policy during the studied period, according to data provided by Reuters COVID-19 Global Tracker database [13], we have estimated that three groups of countries can be distinguished: 1) those that have implemented tight measures, 2) moderate level measures, 3) countries that have mostly relied on recommendations. In reference to our sample, the first group of countries includes Turkey, Estonia, Serbia and Bosnia and Herzegovina. The second one consists of North Macedonia, Norway and Bulgaria, while Finland, Iceland and Sweden belong to the third group.

Paired comparison of the air pollutants' AQI values for the lockdown period and the same period the year before has been carried out using the Wilcoxon test (*wilcox.test* function in R). The confidence intervals for the tests were considered as 95% (*) and 99% (**). Tests are conducted only for the pollutants with 20 or more complete paired data points for the observed city. Details of the Wilcoxon test can be found in [14].

3 RESULTS

Table 1 presents the results of the statistical analysis. As read from it, there is a statistically significant decrease of maximum daily values of NO_2 emissions in all cities (except in Novi Sad) regardless of the levels of lockdown policy. The same does not apply for mean daily emission values, where, for example, the two largest cities in Turkey (Ankara and Istanbul), a first-group country, do not show a statistically significant reduction of NO_2 pollution. The data for concentrations of other pollutants indicate that the closure measures cannot be related to statistically significant reductions. For example, when it comes to $PM_{2.5}$ in Serbia, where schools and almost all economic sectors have fallen under closure measures, no decrease has been recorded. This applies to both maximum and median values. If we observe results closely, even some statistically significant increases in pollutants' values can be identified. These increases are more often seen in most polluted cities.

[1] Due to missing data, Greece was excluded from the analysis so we took the next ranked country - Turkey

Table 1: Descriptive statistics of air pollutants during lockdown (20 March - 20 April 2020) and the same period in 2019

Country	City	Pollutant	Mean(Max (2019 period))	Mean(Max (2020 period))	Difference (2020-2019)	p-value	Mean(Median (2019 period))	Mean(Median (2020 period))	Difference (2020-2019)	p-value
Bosnia and Herzegovina	Sarajevo	NO_2	32.69	11.86	-20.83 (-63.72%)	0.000**	9.32	3.18	-6.14 (-65.93%)	0.000**
		O_3	65.48	43.78	-21.70 (-33.14%)	0.000**	31.76	32.32	0.56 (1.78%)	0.589
		PM_{10}	106.50	63.21	-43.29 (-40.64%)	0.008**	30.43	30.89	0.46 (1.53%)	0.191
		$PM_{2.5}$	144.32	113.32	-31.00 (-21.48%)	0.001**	84.64	68.05	-16.59 (-19.6%)	0.011*
	Tuzla	NO_2	29.55	22.58	-6.97 (-23.59%)	0.044*	11.31	6.67	-4.64 (-41.01%)	0.000**
		O_3	30.46	39.84	9.38 (30.78%)	0.039*	9.18	15.91	6.73 (73.33%)	0.000**
		$PM_{2.5}$	170.59	213.63	43.04 (25.23%)	0.012*	83.04	86.56	3.52 (4.24%)	0.829
		SO_2	80.88	85.16	4.29 (5.30%)	0.213	22.39	20.64	-1.75 (-7.83%)	0.636
	Zenica	CO	11.86	17.89	6.02 (50.75%)	0.042*	3.01	4.36	1.34 (44.55%)	0.000**
		NO_2	20.49	38.96	18.48 (90.20%)	0.000**	5.66	11.26	5.6 (98.99%)	0.000**
		O_3	52.09	71.39	19.29 (37.04%)	0.000**	23.13	29.15	6.03 (26.07%)	0.007**
		PM_{10}	106.79	149.07	42.29 (39.60%)	0.876	39.14	43.89	4.75 (12.14%)	0.339
		$PM_{2.5}$	118.75	143.04	24.29 (20.45%)	0.146	61.21	86.04	24.82 (40.55%)	0.017*
		SO_2	94.93	83.25	-11.68 (-12.30%)	0.425	31.46	29.60	-1.86 (-5.93%)	0.638
Republic of North Macedonia	Skopje	NO_2	34.36	26.43	-7.93 (-23.08%)	0.003**	4.80	4.31	-0.49 (-10.28%)	0.054
		O_3	35.55	39.99	4.44 (12.48%)	0.074	18.39	16.23	-2.16 (-11.74%)	0.202
		PM_{10}	77.23	79.74	2.52 (3.26%)	0.614	33.35	29.26	-4.1 (-12.28%)	0.290
		$PM_{2.5}$	127.26	127.16	-0.10 (-0.08%)	0.717	82.55	68.81	-13.74 (-16.65%)	0.020*
		SO_2	6.45	4.37	-2.08 (-32.23%)	0.010**	1.63	1.29	-0.33 (-20.44%)	0.068
Bulgaria	Sofia	NO_2	32.10	14.64	-17.46 (-54.39%)	0.000**	8.94	3.78	-5.16 (-57.72%)	0.000**
		O_3	39.64	21.72	-17.91 (-45.19%)	0.000**	23.33	12.83	-10.5 (-44.99%)	0.000**
Serbia	Belgrade	CO	14.49	14.02	-0.47 (-3.25%)	0.281	7.66	5.95	-1.72 (-22.4%)	0.000**
		NO_2	46.11	21.03	-25.07 (-54.38%)	0.000**	14.07	5.75	-8.33 (-59.16%)	0.000**
		O_3	39.69	47.46	7.77 (19.57%)	0.012*	19.44	27.06	7.62 (39.19%)	0.000**
		PM_{10}	66.94	109.06	42.13 (62.94%)	0.003**	30.74	35.26	4.52 (14.69%)	0.814
		$PM_{2.5}$	132.87	150.45	17.58 (13.23%)	0.112	73.26	73.74	0.48 (0.66%)	0.471
		SO_2	23.82	31.00	7.18 (30.15%)	0.090	4.06	4.80	0.74 (18.19%)	0.040*
	Niš	NO_2	21.77	11.69	-10.08 (-46.30%)	0.000**	11.73	3.89	-7.84 (-66.85%)	0.000**
		PM_{10}	51.13	64.00	12.87 (25.17%)	0.017*	26.71	33.94	7.23 (27.05%)	0.161
		$PM_{2.5}$	129.26	140.42	11.16 (8.63%)	0.173	74.61	88.03	13.42 (17.99%)	0.153
		SO_2	15.91	19.50	3.59 (22.56%)	0.153	6.87	8.56	1.7 (24.71%)	0.001**
	Novi Sad	CO	5.58	11.99	6.41 (114.86%)	0.000**	3.13	6.01	2.88 (91.86%)	0.000**
		NO_2	19.18	19.05	-0.13 (-0.67%)	0.721	6.07	5.17	-0.9 (-14.82%)	0.060
		O_3	37.06	42.58	5.52 (14.91%)	0.064	21.56	30.24	8.68 (40.26%)	0.000**
		PM_{10}	60.84	90.32	29.48 (48.46%)	0.021*	30.52	39.74	9.23 (30.23%)	0.556
		$PM_{2.5}$	122.84	130.77	7.94 (6.46%)	0.769	73.94	71.32	-2.61 (-3.53%)	0.150
		SO_2	16.29	14.89	-1.40 (-8.58%)	0.704	4.71	4.63	-0.08 (-1.71%)	0.754
Turkey	Ankara	CO	21.28	16.58	-4.71 (-22.11%)	0.029*	6.87	4.95	-1.93 (-28.02%)	0.000**
		NO_2	52.15	41.68	-10.46 (-20.07%)	0.007**	14.09	14.72	0.63 (4.49%)	0.727
		O_3	21.41	32.36	10.95 (51.15%)	0.001**	4.76	10.00	5.25 (110.24%)	0.000**
		PM_{10}	75.58	67.74	-7.84 (-10.37%)	0.019*	24.77	34.65	9.87 (39.84%)	0.002**
		$PM_{2.5}$	86.39	106.29	19.90 (23.04%)	0.019*	34.42	56.68	22.26 (64.67%)	0.000**

Country		Pollutant	Mean(Max(2019 period))	Mean(Max(2020 period))	Difference (2020-2019)	p-value	Mean(Median (2019 period))	Mean(Median(2020 period))	Difference (2020-2019)	p-value
Turkey		SO_2	23.84	11.23	-12.61 (-52.89%)	0.015*	2.75	2.66	-0.09 (-3.28%)	0.673
	Istanbul	CO	40.54	68.18	27.64 (68.17%)	0.000**	19.20	19.52	0.32 (1.66%)	0.144
		NO_2	62.46	114.67	52.20 (83.57%)	0.001**	17.59	16.11	-1.48 (-8.44%)	0.563
		O_3	38.73	42.07	3.34 (8.63%)	0.077	25.19	15.37	-9.82 (-38.97%)	0.001**
		PM_{10}	87.39	220.52	133.13 (152.34%)	0.550	34.52	34.42	-0.1 (-0.28%)	0.837
		$PM_{2.5}$	122.81	94.81	-28.00 (-22.80%)	0.019*	62.71	65.52	2.81 (4.48%)	0.530
		SO_2	18.04	33.88	15.84 (87.82%)	0.000**	3.46	6.72	3.26 (94.13%)	0.000**
	İzmir	CO	5.18	4.67	-0.50 (-9.72%)	0.360	2.13	2.71	0.58 (27.47%)	0.000**
		NO_2	29.32	3.60	-25.72 (-87.72%)	0.000**	8.07	2.34	-5.74 (-71.03%)	0.000**
		PM_{10}	319.77	51.23	-268.55 (-83.98%)	0.000**	24.71	28.32	3.61 (14.62%)	0.114
		SO_2	17.45	7.93	-9.52 (-54.57%)	0.000**	4.20	5.06	0.86 (20.41%)	0.000**
Norway	Bergen	NO_2	32.21	22.67	-9.54 (-29.61%)	0.002**	13.87	4.66	-9.21 (-66.39%)	0.000**
		PM_{10}	32.91	39.75	6.84 (20.80%)	0.345	14.75	10.91	-3.84 (-26.06%)	0.015*
		$PM_{2.5}$	47.66	55.78	8.13 (17.05%)	0.061	31.19	24.94	-6.25 (-20.04%)	0.070
	Oslo	NO_2	42.14	31.48	-10.66 (-25.30%)	0.001**	11.35	7.09	-4.25 (-37.48%)	0.000**
		PM_{10}	144.75	128.06	-16.69 (-11.53%)	0.933	21.81	19.69	-2.13 (-9.74%)	0.410
		$PM_{2.5}$	118.84	94.22	-24.63 (-20.72%)	0.432	29.81	29.28	-0.53 (-1.78%)	0.243
	Stavanger	NO_2	30.86	17.96	-12.90 (-41.80%)	0.000**	6.66	4.58	-2.07 (-31.13%)	0.008**
		PM_{10}	33.16	28.06	-5.09 (-15.36%)	0.123	15.16	11.75	-3.41 (-22.47%)	0.018*
		$PM_{2.5}$	61.84	64.25	2.41 (3.89%)	0.743	37.28	33.72	-3.56 (-9.56%)	0.210
Sweden	Göteborg	NO_2	32.96	25.41	-7.55 (-22.91%)	0.013*	10.83	7.92	-2.91 (-26.84%)	0.004**
		O_3	39.76	30.93	-8.84 (-22.23%)	0.000**	29.66	24.83	-4.84 (-16.31%)	0.000**
		PM_{10}	55.94	60.22	4.28 (7.65%)	0.268	24.25	20.38	-3.88 (-15.98%)	0.073
		$PM_{2.5}$	49.50	48.94	-0.56 (-1.14%)	0.829	32.63	26.19	-6.44 (-19.73%)	0.039*
	Malmö	NO_2	18.53	25.47	6.94 (37.45%)	0.041*	7.00	5.48	-1.53 (-21.78%)	0.001**
		O_3	37.68	35.95	-1.72 (-4.58%)	0.158	29.20	28.05	-1.15 (-3.94%)	0.282
		PM_{10}	36.38	26.97	-9.41 (-25.86%)	0.003**	20.06	14.56	-5.5 (-27.41%)	0.033*
		$PM_{2.5}$	63.03	60.94	-2.09 (-3.32%)	0.940	42.56	38.84	-3.72 (-8.74%)	0.456
	Stockholm	NO_2	40.94	20.93	-20.01 (-48.87%)	0.000**	13.46	7.60	-5.86 (-43.51%)	0.000**
		O_3	38.56	38.25	-0.31 (-0.81%)	0.654	33.70	31.01	-2.69 (-7.98%)	0.019*
		PM_{10}	90.84	70.09	-20.75 (-22.84%)	0.007**	37.06	19.63	-17.44 (-47.05%)	0.000**
		$PM_{2.5}$	58.47	41.81	-16.66 (-28.49%)	0.000**	34.81	22.16	-12.66 (-36.36%)	0.001**
Estonia	Tallinn	NO_2	24.76	11.08	-13.68 (-55.24%)	0.000**	6.75	3.06	-3.68 (-54.59%)	0.000**
		O_3	38.94	34.86	-4.08 (-10.47%)	0.004**	28.63	29.10	0.47 (1.65%)	0.742
		PM_{10}	65.00	36.65	-28.35 (-43.62%)	0.001**	14.19	11.35	-2.84 (-20%)	0.211
		$PM_{2.5}$	33.82	25.82	-8.00 (-23.65%)	0.050	22.39	14.25	-8.14 (-36.36%)	0.030*
		SO_2	15.44	0.64	-14.80 (-95.84%)	0.000**	0.34	0.25	-0.08 (-25%)	0.101
Iceland	Reykjavík	NO_2	13.67	12.93	-0.74 (-5.44%)	0.715	1.53	1.66	0.13 (8.48%)	0.222
		PM_{10}	85.33	66.63	-18.70 (-21.91%)	0.102	9.93	7.57	-2.37 (-23.83%)	0.206
		SO_2	7.58	14.36	6.78 (89.45%)	0.158	0.73	1.44	0.71 (96.36%)	0.003**
Finland	Helsinki	NO_2	37.72	21.53	-16.19 (-42.91%)	0.000**	9.19	3.73	-5.46 (-59.42%)	0.000**
		O_3	37.01	33.43	-3.59 (-9.69%)	0.012*	27.58	27.78	0.2 (0.74%)	0.674
		PM_{10}	112.50	61.09	-51.41 (-45.69%)	0.003**	25.31	12.78	-12.53 (-49.51%)	0.000**
		$PM_{2.5}$	69.63	53.78	-15.84 (-22.76%)	0.014*	29.84	21.44	-8.41 (-28.17%)	0.010*

		Pollutant	Mean(Max(2019 period))	Mean(Max(2020 period))	Difference (2020-2019)	p-value	Mean(Median (2019 period))	Mean(Median(2020 period))	Difference (2020-2019)	p-value
		SO_2	1.53	1.49	-0.04 (-2.61%)	0.910	0.38	0.32	-0.06 (-15.93%)	0.150
	Tampere	NO_2	24.69	14.47	-10.23 (-41.41%)	0.000**	5.53	3.11	-2.42 (-43.75%)	0.000**
		PM_{10}	64.19	48.69	-15.50 (-24.15%)	0.042*	20.03	13.59	-6.44 (-32.14%)	0.024*
		$PM_{2.5}$	64.66	49.28	-15.38 (-23.78%)	0.047*	25.81	17.63	-8.19 (-31.72%)	0.026*
	Turku	NO_2	18.84	9.25	-9.59 (-50.91%)	0.000**	4.21	1.62	-2.59 (-61.47%)	0.000**
		PM_{10}	67.09	43.06	-24.03 (-35.82%)	0.050*	15.53	8.81	-6.72 (-43.26%)	0.002**
		$PM_{2.5}$	44.00	35.81	-8.19 (-18.61%)	0.082	23.09	17.38	-5.72 (-24.76%)	0.016*
		SO_2	1.08	0.84	-0.24 (-22.01%)	0.183	0.32	0.43	0.11 (33.77%)	0.119

* - indicates 95% confidence level; ** - indicates 99% confidence level
The most polluted countries: Bosnia and Herzegovina, Republic of North Macedonia, Bulgaria, Serbia and Turkey; The cleanest countries: Norway, Sweden, Estonia, Iceland and Finland.

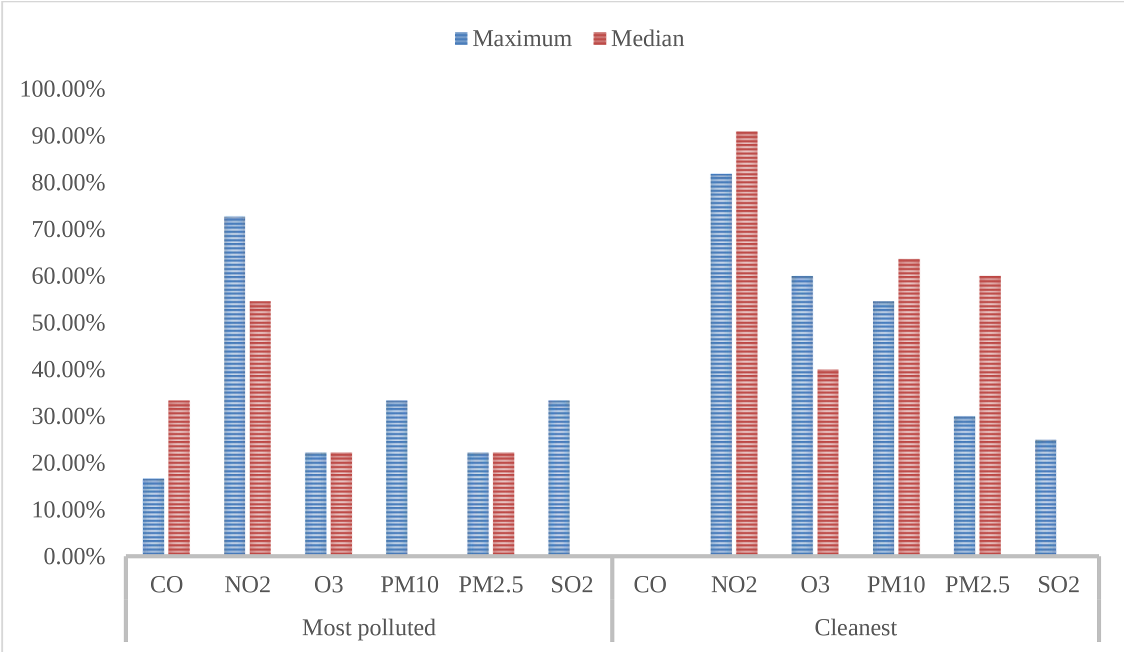

Figure 1: Ratio of statistically significant decrease of major pollutants

Figure 1 represents the share of cities (in total number of cities in a given category) with a statistically significant decrease in the observed pollutant. A noticing finding is that a statistically significant reduction in pollutants (except for SO_2) is more frequent in cleaner cities during the observed period. Unfortunately, due to the missing data, it could not be possible to find out whether there is a statistically significant decrease in the value of CO among cities from the cleanest countries.

4 CONCLUSION

This paper evaluates the impact of COVID-19 lockdown on air pollutant emissions in Europe's cleanest and most polluted countries and their cities. The findings within cities and cross-city comparisons can be helpful for future in-depth analysis of polluter generators as well as for the assessment of aggressive emission reduction policies.

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DOES THE COVID-19 DISCRIMINATE BY GENDER? CROATIAN AND SLOVENIAN CASE

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Abstract: The paper aim is to investigate whether males or females are more likely to get infected by the COVID-19 disease. Due to the fact that the COVID-19 disease is a new disease about which a lot of things are not well known yet, in the analysis daily data from the one-year period from March 1, 2020 to February 28, 2021 are used. The comparison of total confirmed COVID-19 cases according to gender is conducted for Croatia and Slovenia. In addition, the comparison is conducted by taking into account age groups as well.

Keywords: comparison, COVID-19, Croatia, Slovenia, statistics, total confirmed cases.

1 INTRODUCTION

The World is fighting against the COVID-19 disease since the end of 2019. The worldwide pandemic started in the city of Wuhan, in the Chinese province of Hubei. The causative agent of the COVID-19 disease is the SARS-CoV-2 virus due to which the coronavirus disease, or shortened COVID-19, is a highly contagious disease (Hiscott et al., 2020). Some symptoms of COVID-19 are: high fever, cold, cough, shortness of breath, difficulty breathing, diarrhea, fatigue, myalgia (muscle pain), hemoptysis (coughing up blood from the respiratory tract), headache, loss of sense of smell and taste, rash, chest pain, loss of speech, inability to move (Pal et al., 2020, Janik et al., 2021, World Health Organization, 2021a). The symptoms are ranging from harmless to very difficult that could lead to lethal outcome. Also, the consequences of the COVID-19 disease for a person's health can be long-lasting (del Rio, Collins, Malani, 2020).

There are a lot of things which are not known about the COVID-19 disease. Therefore, countries have implemented different measures in order to protect population general health but their economies as well (Tadić, 2020). The great hope in the fight against the COVID-19 disease was found in the vaccine development. The first vaccines against the COVID-19 appeared at the end of 2020 (World Health Organization, 2021b). Unfortunately, the vaccines are not available to all people worldwide at the moment. According to some estimates, about 70% of the population needs to be vaccinated if the COVID-19 disease pandemic wanted to be stopped (Janik et al., 2021). In addition, there are some open questions related to the COVID-19 vaccines (Forni, Mantovani, 2021).

Except against the COVID-19 disease, the World is fighting against different ways of discrimination. Unfortunately, new ways of discrimination are introduced by countries with their measures against the COVID-19 disease pandemic but which in the same time discriminate some individuals and business entities putting them in different positions than others (Equal Rights Trust, 2020). The aim of the paper is to investigate whether the COVID-19 disease discriminates against people according to gender. To be more precise, in the paper it will be observed whether males or females are more likely to get infected by the COVID-19 disease. The total confirmed COVID-19 cases will be observed by gender, age group and in Croatia and in Slovenia.

Overall three research hypotheses have been developed. The first research hypothesis is that more females than males tend to be infected by the SARS-CoV-2 virus and have COVID-19 disease. The second research hypothesis is that the share of females in total confirmed COVID-

19 cases is at the same level across all age groups. The third research hypothesis is that proportions of females in the total cases in Croatia and in Slovenia observed by age groups are statistically at the same level.

The paper is organised as follows. After the brief introduction, in the second chapter data sources are discussed and used methodology approaches are explained. In the third chapter the analysis is conducted whereas in the final, fourth, chapter conclusions are provided.

2 DATA AND METHODOLOGY

The main variable under the study is the number of total confirmed COVID-19 cases. In order to collect data for Croatia and Slovenia two different data sources are used (GitHub, 2021, Koronavirus.hr, 2021). Both databases provided information not only about the number of total confirmed COVID-19 cases, but information about gender and age of infected people as well. For the purpose of analysis daily data from the one-year period from March 1, 2020 to February 28, 2021 will be used. The starting point for analysis is set to be March 1, 2020 because the first confirmed COVID-19 cases started to appear in both observed countries at the very end of February 2021.

Due to paper length restrictions, the analysis focus will be given to descriptive statistics methods application. However, in order to compare proportions of females in the total number of COVID-19 cases in Croatia and in Slovenia by age groups on February 28, 2021, statistical tests of comparing the proportions of two populations will be applied. In the statistical test the null hypothesis will be that there is no statistical difference of proportions of females in the total number of COVID-19 cases in Croatia and in Slovenia observed by certain age groups.

3 ANALYSIS AND RESULTS

In Figure 1 the numbers of total confirmed COVID-19 cases in Croatia and in Slovenia in the period from March 1, 2020 to February 28, 2021 are shown.

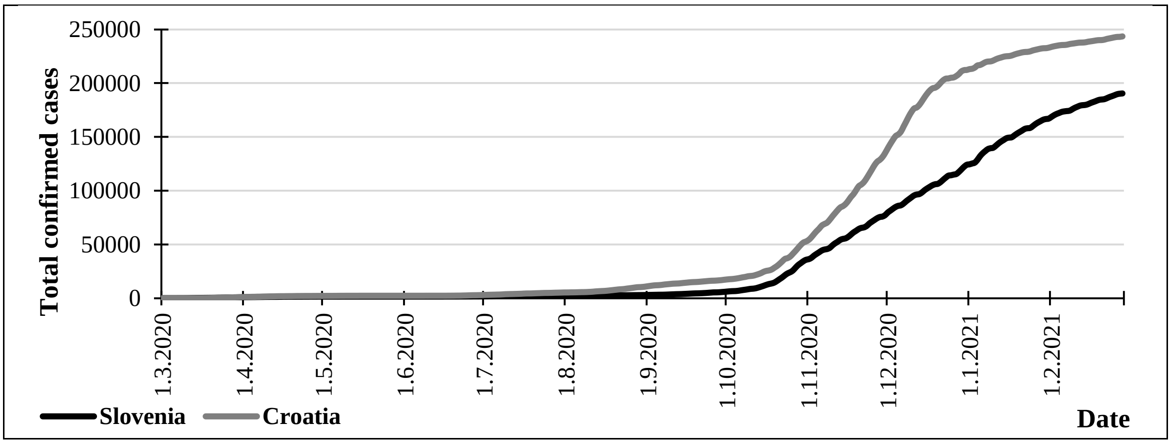

Figure 1: Total confirmed COVID-19 cases in Croatia and in Slovenia, in period from March 1, 2020 to February 28, 2021

According to Figure 1 the number of total confirmed COVID-19 cases in Croatia is, if the period with really low values is neglected, always higher than in Slovenia. That was expected due to the fact that Croatia has more than twice more population than Slovenia. Accordingly, if the end of the observed period is observed, it can be concluded that Slovenia, in relative sense to the overall population size, is more infected by the COVID-19 disease than Croatia. In addition, the number of total confirmed COVID-19 cases in Croatia and in Slovenia started to increase significantly from the middle of October 2020. Despite the fact that Croatia had steeper increase of total confirmed COVID-19 cases since the middle of October 2020 than Slovenia, the daily increase of new confirmed COVID-19 cases was drastically lowered by the middle of December 2020. On the other side, Slovenia seems to have had a constant absolute increase of total confirmed COVID-19 cases since the middle of October 2020.

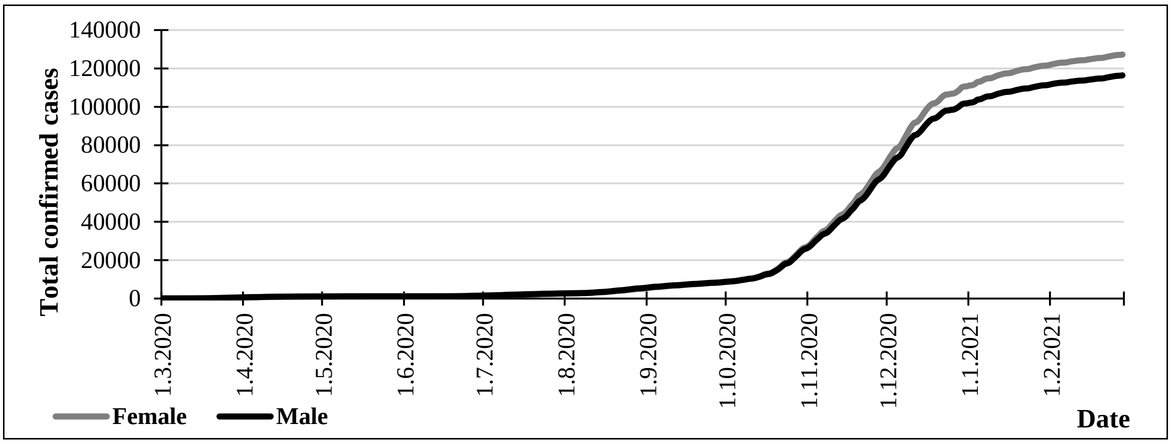

Figure 2: Total confirmed COVID-19 cases in Croatia by gender, in period from March 1, 2020 to February 28, 2021

In Figure 2 the number of total confirmed COVID-19 cases in Croatia by gender in the period from March 1, 2020 to February 28, 2021 is shown. Until the middle of October 2020 the number of total confirmed COVID-19 cases at males and females was at about the same level. However, the difference becomes more expressed after the beginning of December when the number of total confirmed COVID-19 cases among females started to obviously be higher than among males.

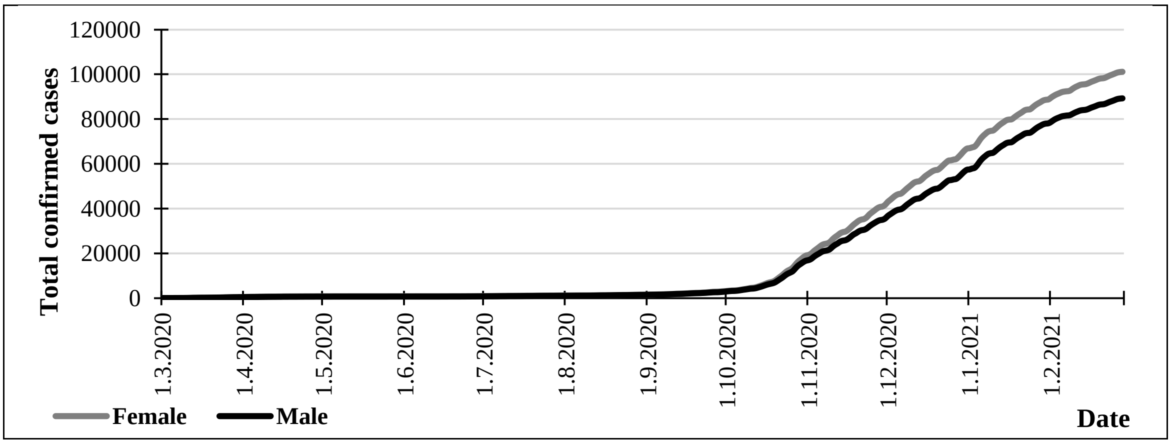

Figure 3: Total confirmed COVID-19 cases in Slovenia by gender, in period from March 1, 2020 to February 28, 2021

Figure 3 shows the number of total confirmed COVID-19 cases in Slovenia by gender in the period from March 1, 2020 to February 28, 2021. The difference between the number of total confirmed COVID-19 cases at males and females started to become obvious earlier than in Croatia at the beginning of November 2020. However, as in Croatia, in Slovenia the number of total confirmed COVID-19 cases in females is considerably higher than in males at the end of the observed period.

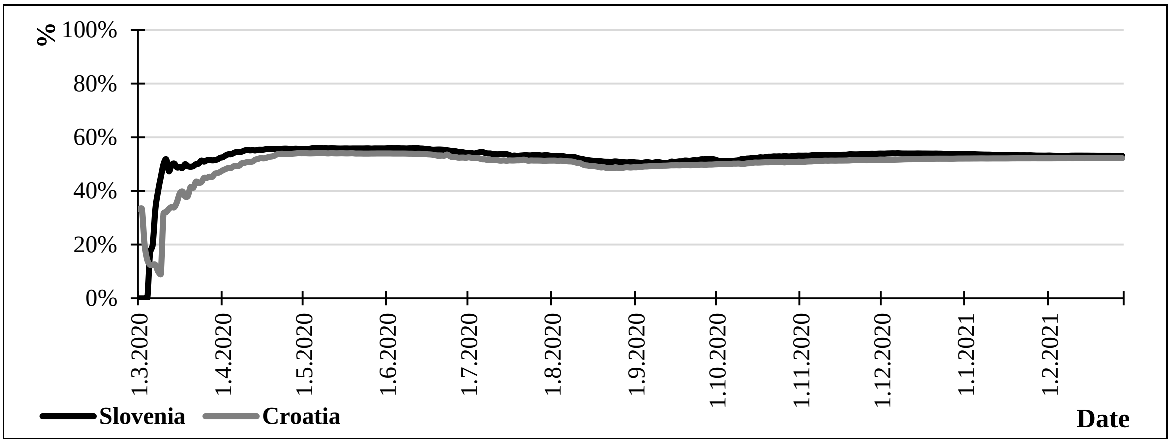

Figure 4: Share of females in total confirmed COVID-19 cases in Croatia and in Slovenia, in period from March 1, 2020 to February 28, 2021

In Figure 4 are shown shares of females in total confirmed COVID-19 cases in Croatia and in Slovenia. Fluctuations of female shares are quite expressed in the beginning of the observed period due to low total number of confirmed COVID-19 cases. The share or females in total confirmed COVID-19 cases seems to be stabilized after the end of April 2020. The share or females in total confirmed COVID-19 cases tend to be above 50% in both countries. Still, the share or females in total confirmed COVID-19 cases in Slovenia seems to be slightly higher than in Croatian since the end of April 2020.

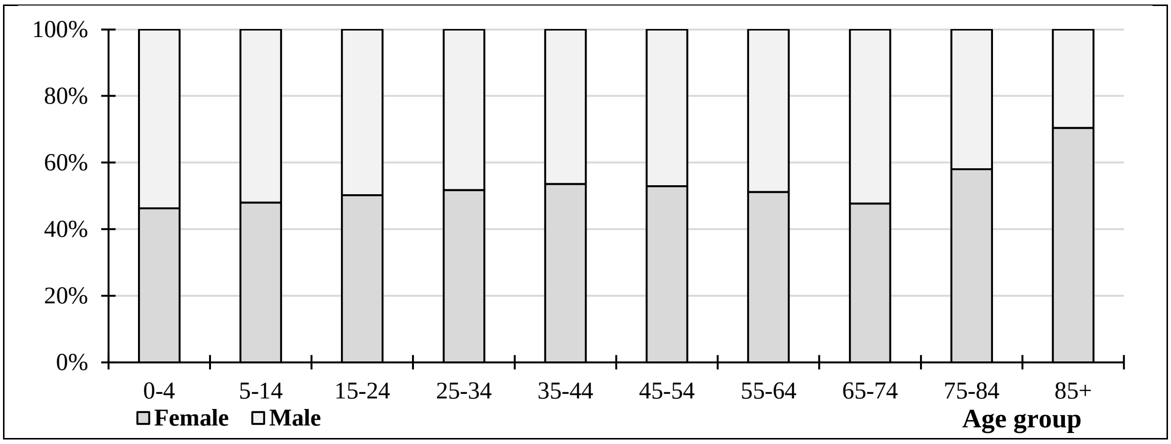

Figure 5: Gender structure according to age groups, total confirmed COVID-19 cases in Croatia, on February 28, 2021

Figure 5 is showing the gender structure according to age groups of total confirmed COVID-19 cases in Croatia on February 28, 2021. According to Figure 5 it can be concluded that only at three age groups the share of females is lower than the share of males. The lowest share of females in total confirmed COVID-19 cases was at age group 0-4 and it was equal to 46.31%. So, there is about a 7 percentage point difference between female and male shares at that age group which is not so high a difference. However, more expressed differences are present in at last two age groups. Namely, the share of females of total confirmed COVID-19 cases at age group 75-84 is 58.02% and at age group 85+ is 70.46%. Still those numbers were expected due to the fact that women are living longer than men and therefore there are more females than males at those age groups in the general population.

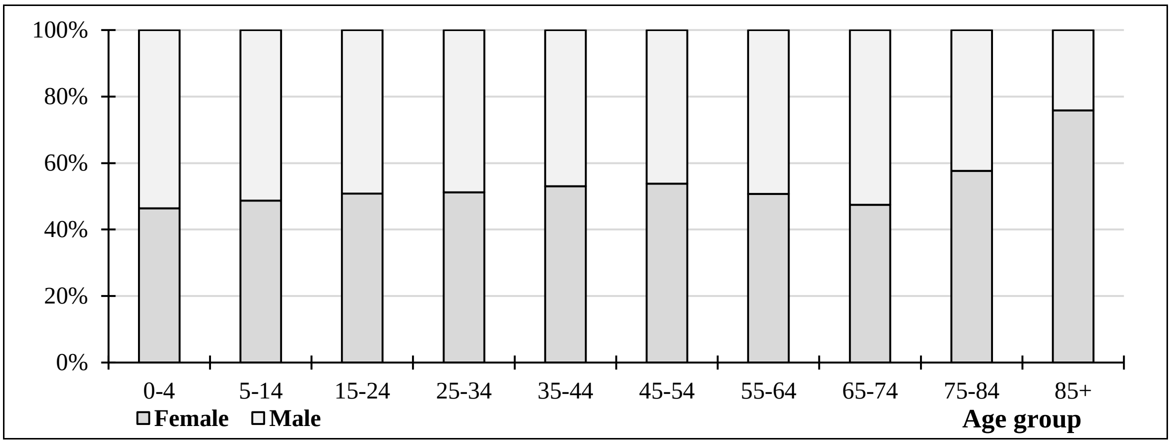

Figure 6: Gender structure according to age groups, total confirmed COVID-19 cases in Slovenia, on February 28, 2021

Figure 6 is presenting the gender structure according to age groups of total confirmed COVID-19 cases in Slovenia on February 28, 2021. The shares are quite similar to those at Croatia. The lowest female share in total confirmed COVID-19 cases is 46.42% at age group 0-4. On the other side, the highest female share in total confirmed COVID-19 cases is 75.81% at age group 85+ which is about 5 percentage points more than in Croatia at the same age group.

Table 1: Test results of comparison proportions of females in the total cases in Croatia and in Slovenia, by age groups, on February 28, 2021

Age group	***Number of cases, Croatia***	***Proportion of females in the total cases, Croatia***	***Number of cases, Slovenia***	***Proportion of females in the total cases, Slovenia***	***Standard error***	***P-value***
0-4	2,142	0.4631	1,342	0.4642	0.0237	0.2406
5-14	11,461	0.4796	4,310	0.4872	0.0124	0.1348
15-24	26,661	0.5025	16,518	0.5081	0.0070	0.1069
25-34	38,340	0.5174	30,860	0.5121	0.0055	0.4180
35-44	44,989	0.5357	37,426	0.5305	0.0051	0.4227
45-54	42,256	0.5292	37,419	0.5380	0.0052	0.0223
55-64	36,857	0.5114	27,117	0.5069	0.0057	0.3917
65-74	21,976	0.4767	15,008	0.4743	0.0073	0.3120
75-84	12,735	0.5802	11,591	0.5768	0.0098	0.3178
85+	60,25	0.7046	87,31	0.7581	0.0144	4.87E-05
Overall	243,442	0.5223	190,322	0.5311	0.0022	1.86E-05

In Table 1 the results of conducted statistical tests in which the proportions of females in total confirmed COVID-19 cases in Croatia and in Slovenia overall and at each age group separately are compared. At almost all age groups at significance level 5% the difference between the proportion of females in the total COVID-19 cases is not statistically significantly different. However, at two age groups the difference turned out to be statistically significant at significance level 5%. Whereas the difference at age group 45-54 is not so large, the difference in proportion of females in the total cases between Croatia and Slovenia is quite large at age group 85+. If the proportions of females in total confirmed COVID-19 cases in Croatia and in Slovenia on overall level are observed, it can be concluded that at significance level 5% there is a statistically significant difference in proportion of females total confirmed COVID-19 cases in Croatia and in Slovenia.

4 CONCLUSIONS

In the paper the number of total confirmed COVID-19 cases according to the gender and the age groups in Croatia and in Slovenia have been observed and compared. The results have shown that more females than males tend to be infected by the SARS-CoV-2 virus and, consequently, therefore they have COVID-19 disease. That conclusion is valid for both countries, Croatia and Slovenia, at overall levels and at almost all age groups. Also, it can be concluded that proportions of females in the total cases in Croatia and in Slovenia observed by age groups are statistically at the same level, again, at almost all age groups.

The age group which is considerably different from the other groups is the age group which includes the oldest people. At this age group the share of females of total confirmed COVID-19 cases is more than 40 percentage points higher than is the share of males in Croatia and in Slovenia. However, that may be happening due to the fact that there are more females than males at those age groups (75-84 and 85+). So, that is also the main limitation of the research. In the future research shares of males and females in the population should be taken into account to get more improved results. Also, in the future research the shares of males and females in total deaths due to confirmed COVID-19 disease should be inspected as well.

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Special Session 9:

Logistics and Sustainability

CONSUMER'S WILLINGNESS TO ENGAGE IN THE CIRCULAR ECONOMY: THE HIGHER EDUCATION OUTLOOKS

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Abstract: As a forefront approach of sustainability, Circular Economy (CE) has been considered one of the most powerful principles of modern society. It due to resource consumption continues to rise, governments and companies have started looking at the circular model, as a hedge against resource scarcity and as an engine for innovation and growth. This paper aims to bring together CE and consumer's perspective, to perceive the impact of buyer's choice on CE initiatives. A survey was conducted having in mind the engagement of the consumer with the circular economy concepts. The results pointed out the awareness and willingness of consumers for the transition of the linear to the circular production model, providing a value add by consumers for reducing environmental impacts and enhancing sustainability through CE initiatives such as reuse repairability.

Keywords: Logistics, Circular Economy, Reuse, Repairability, Consumers

1 INTRODUCTION

Over the last decades, sustainability has been considered one of the most powerful principles of modern society. This principle has been contributing to society increase the value of sustainable technologies, processes and products that, either have zero impact on our ecosystem or function within the limits of its carrying capacity. Also, society is increasingly sensitive to issues related to sustainable values [1].

From the industrial perspective, this sector faces significant economic and environmental challenges towards a sustainable process. Challenges such as the lack of non-renewable resources have culminated in a prompting call for disseminating initiatives aiming to develop sustainable business models in the industrial sector [2].

Circular Economy (CE) has emerged as an alternative to achieve sustainability, for both industries and governments. According to Ellen MacArthur Foundation [2], CE can be defined as a restorative industrial system. Replacing the concept of the end's life and shifts towards a business model which consider waste elimination from the design to a disposal of a product or service in all stages of production.

Also, Morseletto [5] defends that as an economic model, CE can be seen as an efficient approach to use resources through waste minimization towards a closing loop of products, contributing to environmental protection and delivering social benefits. In doing so, CE aims to reduce the negative impacts of the linear economy through building long-term resilience business and economic opportunity, to provide environmental and social benefits.

As a sustainable approach, initiatives related to CE has been increasingly in developing and developed economies. It has been supporting different sectors of economies such as industrial, tourism and services to emphasize the importance of waste reduction, from the design to disposal in all stages of their production, and contributing to both sustainability and close the loop of the supply chain.

Despite the increasing attention of researchers and practitioners in the CE field, few studies have investigated the possibility of CE be integrated with other approaches, which can also contribute to achieving sustainability. As such, the engagement of companies, governments, and consumers into initiatives towards CE, can be a key element to closing the loop in the traditional linear economy model.

Logistics activities can be seen as a decisive element for the supply chain, since its directly associated with two main aspects, namely consumption of resources by costumers, and the possibility to serve as a bridge to manage the waste generated by costumers in the product's end-of-life. In the supply chain, each stage could obtain raw materials to end-of-life, when well-managed, these products can contribute to the overall circularity as well as sustainability [3-4]. In this perspective, this research aims to understand the impact of consumers choices on CE initiatives.

2 METHODOLOGY

This section presents an overview of the main steps adopted in this research to achieve the objective proposed. The work was designed to assess CE in terms of consumers' value, considering logistics activities as a major player to CE. The work was developed as follows:

1) The research began with an initial screening of studies in the topic CE, with its challenges and benefits, were carried out;
2) Based on step 1, a questionnaire was developed to understand consumers' willingness to embrace CE practices. The questionnaire was inspired by the previous report published by European Commission (see: Implementing Framework Contract – _CHAFEA/2015/CP/01/LE) [7]. The survey is composed of three parts: the first one is related to general information about the inquiry to describe the sample taken; the second part has questions associated with CE behaviours and environmental attitudes; the last one is concerned with the durability and reparability of the products;
3) The questionnaire was then applied. The sample consists of 123 inquiries, with are enrolled in Higher Education Institutions. The was chosen by convenience, due to time and budget constraints.
4) A statistical analysis was developed resorting to IBM SPSS version 27;
5) Based on the achieved results from the questionnaire, the linkage between Logistics and CE was established, focus on aspects such as reparability, availability to spare part and repair.

The undertaken and summarized steps presented in this section were used as a strategy to capture consumer's behaviour towards moving on an alternative to the traditional linear economy; then to draw suggestions regarding the role of logistics activities in this shift.

3 RESULTS AND ANALYSIS

This section presents the main findings achieved in this research. Regarding the sample, it is related to both genders (67% female and 33% male, approximately), where 75% of the inquiries are under 25 years, and 45% of them attend training in the logistics field.

3.1 The connection between CE and environmental attitudes

In this research, a four-point Likert Scale (1- Strongly disagree, 2- Tend to disagree, 3- Tend to agree, 4- Strongly agree) was used to assess the general CE-related behaviors. Figure 1 shows the level of agreement for each sentence described in Table 1. Overall, inquiries agree with the CE statements, particularly those relating to long-term possession (CE1) or repair/recycle (CE2 and CE3) of the item. The results showed that more than 50% of participates do not buy the latest fashion clothes or electronic goods and gadgets (CE5 and CE6). When compared with the EU report, the students adopt similar behaviors as the rest of European consumers, increasing the purchase of second-hand items. In order to refine the analysis, the Mann-Whitney U test was developed to understand if gender and training in logistics could influence the answer given (Table 1).

Table 1: Statistics analysis for Agreement Level on Circular Economy behaviours

	Descriptive Statistics				Mann-Whitney U test (significance level 0.05)	
	Min	Max	Mean	St. Dev.	By gender (sig.)	By logistics training (sig.)
CE1 - I always keep things I own for a long time	1	4	3.24	0.682	0.004	0.847
CE2 - I always recycle my unwanted possessions	1	4	2.82	0.758	0.019	0.218
CE3 - I always repair my possessions if they break	1	4	2.71	0.674	0.288	0.476
CE4 - I buy second hand products	1	4	2.29	0.908	0.402	<0.001
CE5 - I always buy the latest fashion for clothes	1	4	2.15	0.736	0.479	0.481
CE6 - I always buy new the newest electronic goods and gadgets	1	4	2.55	0.960	0.632	0.568

The results showed that there is a difference of opinions according to gender in items CE1 and CE2. After carefully analyzing the answers, it was possible to confirm that there is a higher level of dispersion of agreement level for men answers, while the female inquiries tend to choose the positive agreement levels of the items. Regarding the logistics training as a factor of differentiation, there is no significant difference between groups, except the item CE4, where the individuals who had no training in logistics tend to disagree with the sentence, while the others tend to agree.

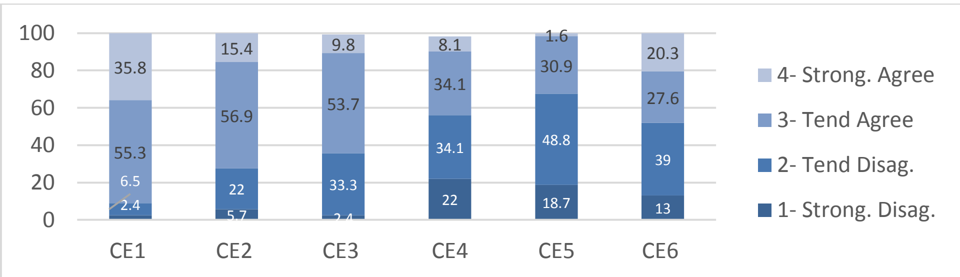

Figure 1: Agreement Level (%) on Circular Economy behaviours

Furthermore, Figure 2 and Table 2 summarizes the results related to environmental attitudes. The analysis showed that the inquiries tend to agree with all sentences, particularly the consciousness of being environmentally friendly and they tend to show this attitude in front of other people (EA1 and EA2). In this direction, the results showed that this behavior was considered as the lower score of item EA6.

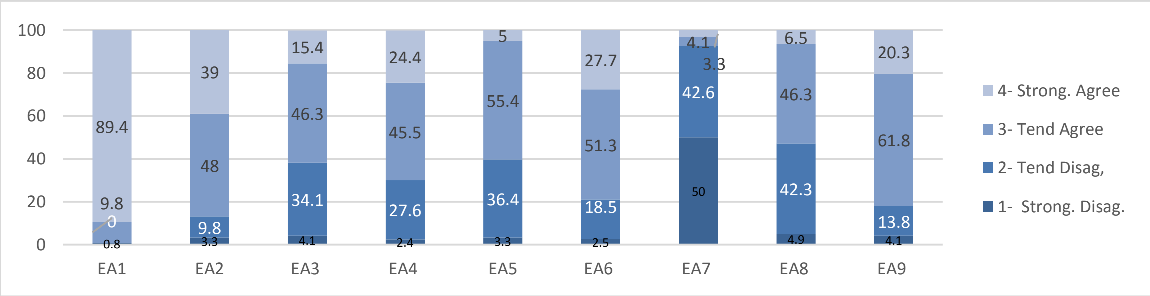

Figure 2: Agreement Level (%) on environmental attitudes

Despite this environmental attitude, the third sentence that drawn more positive responses was EA6. It could be positive when it is adopted to buy products that could be considered eco-friendly. On the other, it could have a negative impact if the idea is to discard an old model or not to try the fix a good product. Using the nonparametric test Mann-Whitney, it is shown that there are differences of opinions when it is compared according to gender factor in items EA1, EA2, and EA6. Following the previous dimension, women tend to give more positive answers. There is no difference in agreement levels when the environmental attitudes are evaluated when education qualifications are considered.

Table 2: Agreement Level on environmental attitudes

	Descriptive Statistics				Mann-Whitney U test (significance level 0.05)	
	Min	Max	Mean	St. Dev.	By gender (sig.)	By logistics training (sig.)
EA1- It is important to be environmentally friendly	1	4	3.88	0.396	0.022	0.616
EA2 - I want my friends to know that I care for the environment	1	4	3.23	0.755	0.006	0.980
EA3 - When I buy things, I know the expected lifespan of the product	1	4	2.73	0.769	0.051	0.777
EA4 - I am aware of repair services for the products I own	1	4	2.92	0.785	0.100	0.760
EA5 - Second hand products are usually good quality	1	4	2.62	0.636	0.561	0.265
EA6 - I much prefer possessions that are brand new	1	4	3.04	0.752	0.012	0.503
EA7 - I want my friends to know I own the latest trends or fashion	1	4	1.61	0.722	0.990	0.503
EA8 - I trust claims made by companies about their products	1	4	2.54	0.692	0.065	0.089
EA9 - If something is good enough I don’t need it to be perfect	1	4	2.98	0.713	0.540	0.900

3.2 Durability and reparability of products

In this section, the results are discussed in light of three associated concepts, namely CE durability and reparability of the products. When there is an increasing the reuse and repair of products, it contributes to some aspects such as reduce waste and providing consumers financial gains. The results also put in evidence that consumers could also benefit from better environmental information and improved enforcement of guarantees.
The results presented in Figure 3 show that more than 50% of the sample agree or strongly agree with the sentences. The searching for durability and reparability information is high when they buy products. Yet, respondents often felt these features difficult to find.

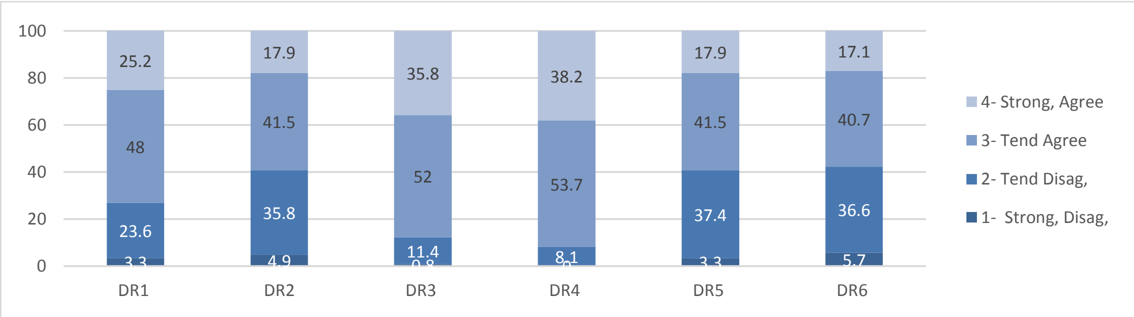

Figure 3: Agreement level about durability and reparability information

Table 3 shows that the inquiries tend to agree with the statements. Regarding the Mann-Whitney tests, female respondents strongly agreed with sentence DR3, when compared with male individuals (DR3). Besides, the respondents that are not from the logistics area, do not feel the need to have additional information about the reparability of the product, when compared with the ones that are from the logistics area (DR4).

Table 3: Agreement level about durability and reparability information

	Descriptive Statistics				Mann-Whitney U test (significance level 0.05)	
	Min	Max	Mean	St. Dev.	By gender (sig.)	By logistics training (sig.)
DR1 - I always search for information on how long a product will last	1	4	2.95	0.788	0.565	0.595
DR2 - I always search for information on how easy it is to repair a product	1	4	2.72	0.813	0.093	0.676
DR3 - I would like to receive better information on how long a product will last	1	4	3.23	0.675	0.026	0.059
DR4 - I would like to receive better information on how easy it is to repair a product	2	4	3.30	0.613	0.130	0.032
DR5 - It is difficult to find information on how long a product will last	1	4	2.74	0.788	0.694	0.080
DR6 - It is difficult to find information on how easy it is to repair a product	1	4	2.69	0.821	0.575	0.098

Finally, the respondents were asked to rate their experience related to the repair service of a product. Table 4, demonstrates that for the case of the ones that already have used a repair service, the experience was positive. These results are in line with the ones achieved by the EU report, which shows the awareness of these consumers.

Table 4: Satisfaction with professional repair services

	1 Very poor	2 Fairly Poor	3 Fairly good	4 Very good	Min	Max	Mean	St. Dev.
RS1 – Convenience	3.9	8.8	69.6	17.6	1	4	3.01	0.652
RS2 – Speed of repair	6.7	27.6	51.4	14.3	1	4	2.73	0.788
RS3 – Consumer friendliness	1.9	7.8	53.4	36.9	1	4	3.25	0.682
RS4 – Quality of the repair	3.9	4.9	59.2	32.0	1	4	3.19	0.701

As summarized in Table 4, the time of repair of the product was the lowest-ranked level of satisfaction, while the consumer-friendliness was the highest.

4 CONCLUSIONS

The transition of Linear to Circular Economy has prompted industries and consumers the shift the production and consumption approaches. This research has sought out some aspects related to CE and its contribution from the consumer's side. Based on the results achieved, it was possible to conclude that aspects such as reuse and better design can contribute to the transition to a circular economy can significantly reduce the material bill and the expense of disposal. However, as consumers have the power to choose every time, they make a purchase, the success to pass from a linear to a circular economy may require a shift of consumers in this paradigm.

There is a window of opportunities for companies to implement circular flows and initiatives. At this moment, this research shined that from the young consumers' point of view, there is already an environmental awareness. The fact that only students of higher Education have answered the survey is a limitation to this work. But, at least, it can be considered a first path towards the transition from the consumer perspective. For future work, the authors are going to extend the sample a wider audience to check if this opinion remains the same or have reasonable difference between the age and educational qualification.

However, the buying level of second-hand products is still lower. The mind-set change to repair a product instead of buying a new one could be improved. At this moment, the information about the reparability and durability of a product was considered as a barrier to consumers. Nevertheless, when they decided to use repair service the general level of satisfaction is high.

This research is part of an ongoing project, and the preliminary results are summarizing in this research. Also, as the next step, the authors are going to analyse the trade-off between the expenditure by companies when providing better repair service, or to contribute to discard the old products taking a specific product as a sample (TV/Smartphone).

Acknowledgement

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URGENT ORDERS IMPACT ON MATERIALS MANAGEMENT IN PORTUGUESE CONSTRUCTION SECTOR - CASE STUDY

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Abstract: The urgent orders could have an impact on construction company performance since affects the organization of the work in the materials warehouse and enhance stress of workers. In this work, the effect of material urgent orders in a Portuguese construction company was analysed. This project consisted of an exploratory study carried out in two phases, the analysis of data and direct observation of the process. The results show that, in this company, there are no-cost impacts on the operations related to logistics, but with urgent requests, the rate of meeting deadlines is lower.

Keywords: Urgent Orders, Materials Management, Construction Sector, Case study.

1 INTRODUCTION

The management of the construction supply chain has a deep effect on success and project expectations in terms of cost, time, and quality, providing a collaborative relationship between suppliers and contractors. The control of the logistics activities is very important since the complexity of the construction supply process will need resources, such as materials, equipment, labour and other services, that need to be available at the right time, in the right amounts and with the desired quality and price.

A good performance on the management of materials and information flows are very important for construction companies since contributes to significant benefits and allow the adding of value for customers. Supply Chain Management (SCM) can be a very useful approach for construction companies since the construction activity is a process characterized by high levels of fragmentation and where the effective integration, coordination, and management of the chain, from suppliers to final clients, is a necessary condition to obtain good results [5].

In the construction sector, a good SCM aims to avoid any risks related to the performance of the company, reducing costs and time, and increasing quality. One important aspect in this supply chain is associated with material flow management, which needs to guarantee the deliveries on time avoiding the delays that could imply urgent orders which could be traduced in increased costs associated with urgent transportation or deliveries after the lead time.

A supply chain is a set of companies that, together, performs the functions of procurement of materials, the transformation of these materials into intermediate and finished goods, and the distribution of these to the consumers. To manage a supply chain positively, it is necessary to reduce lead times and inventory levels, since they contribute to increasing the global cost of the supply chain and reducing customer service. Furthermore, any delays related to a discrepancy between supply and demand may cause an excess of inventories and stock-outs that must be avoided [5]. The procurement process is very important to companies since contributes to improving the performance in product quality, cost, cycle time, and responsiveness [1]. Any construction project uses labour, material, tools, equipment and cash. Material management is the system for planning and controlling to ensure that the right quality and quantity of materials and equipment are specified on time. Materials should be obtained at a reasonable cost and be available for use when needed [6].

In construction projects, changes are very common and possible to occur at any phase of the project. Most changes, if not managed properly will have a considerable impact on the performance of the company as they interrupt work and affect its planned sequence, impacting productivity and accordingly causing schedule delays and cost overrun [3]. Another consequence of project changes is the possibility of urgent orders that could promote an increase in transportation cost, schedule delay and could promote re-work in the materials warehouse. Given this business context, construction companies have increasingly invested in the optimization of their resources, seeking to reduce the duration and costs of projects. What distinguishes supply chains in the construction industry from other industries is the fact that they are temporary, since the location of the works differs from project to project [2]. This factor makes it difficult to standardize the material delivery process, which requires constant reformulation. Building customer loyalty is a way of guaranteeing the company's future, which includes the adoption of effective and efficient logistics.

To analyse the impact that urgent orders may have on the satisfaction of customer orders, the typology of orders placed, the supply chain at the level of processes, the impact that these orders have on the logistics and construction costs, and the best way to fill the situations that lead to urgent orders, should be analysed in order to improve the quality of the services provided.

In this perspective, this research aims to understand the impact of urgent orders in the overall performance of a civil construction company. All the steps considered the specificity of the request, the context in which it is made, the objectives and the urgency of it. Analysing these data, we could assess the impact that the urgent order had on the company's productivity, the response given to the customer and the degree of satisfaction on both sides, because if it is important to satisfy the customer's request, it is equally important to realize the company goals and personal fulfilment of its employees.

In this work, the urgent orders impact on the logistic department in a Portuguese construction company was analysed through a case study, The studied indicators are time, cost and quality related to the materials management process.

The paper is organized as follow: section 2 describes the methods applied, in section 3 the results obtained are discussed and on section 4 the main conclusions are presented.

2 METHODS

To understand the variations that exist concerning the evolution of the civil construction market sector in Portugal, INE was used, more specifically the variable "Number of licensed buildings" in Portugal. This study was carried out from 2010 to 2018 and shows the variation compared to the previous year [4]. Based on Fig. 1, it is noticeable that as of 2015, the market is booming, thus counteracting the crisis it has experienced.

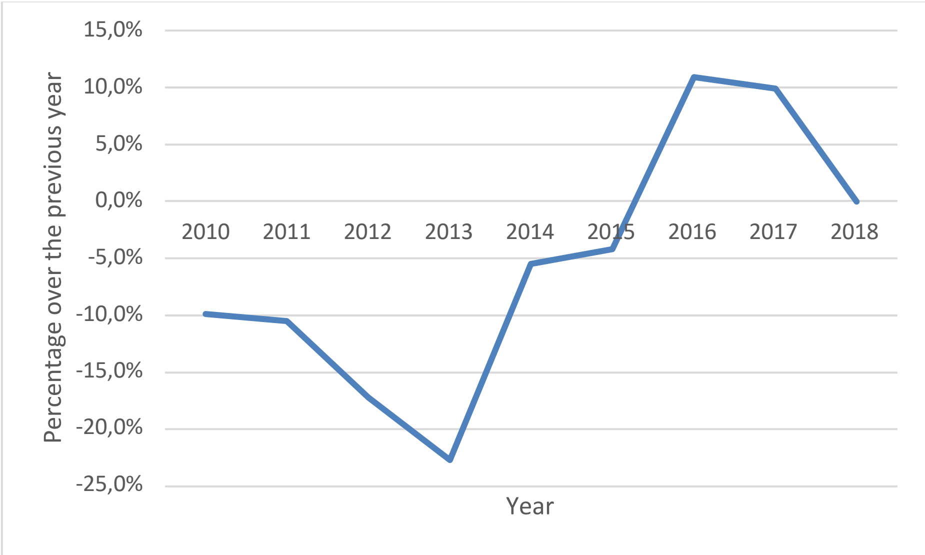

Figure 1: Variation of licence buildings in Portugal

Considering the entire history of the civil construction market in Portugal, the limitations and obstacles occurring in this sector are notorious, evidence of these limitations is the lack of studies and the technological backwardness, which is still experienced today in civil construction, despite that the efforts of the construction companies to overcome this situation are increasingly visible. Urgent orders are an example of possible obstacles that the construction sector faces, being a problem that may affect the normal functioning of the works, compromising delivery times and changing the budgets established at the beginning of each project. In this sector, the customer intends to have the product on time, with excellent quality and at the lowest possible cost. In turn, the company aims to serve its customers well.

As a way of studying the impact of urgent requests on the management of a warehouse of materials, it was important to start by defining its time window, as well as defining what an urgent request is. The time window was defined that the study time corresponds to 4 years of the company's activity, that is, from the beginning of the year 2015 to the end of the year 2018. As an urgent request, a request was considered -what is done less than 3 days in advance.

This project consisted of an exploratory study carried out in two phases, the analysis of data and direct observation of the processes.

2.1 Data Analysis

To carry out this study, it was essential to create and develop a database. In this way and in order to better understand all the phases of its construction, it was divided into 3 phases, as can be seen in Fig. 2.

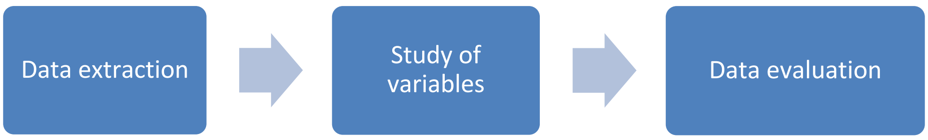

Figure 2: Database processing

Starting with data extraction, this was done using the SAP management software (dstgroup ERP) and occasionally the information from Excel.

After extracting the data, the study of the variables was carried out, that is, all the variables that were contained in SAP and Excel were analysed in detail so that it was possible to later analyse the data. In this last phase, the entire supply chain related to order processing was studied in detail, in other words, the entire process was studied from the moment the material order is placed until its dispatch.

All these processes were carried out to make the database more efficient and thus allowing the best drawing of conclusions. Examples of these same conclusions refer to the study of the typology of requests, the percentage of urgent requests made within the stipulated period, as well as the relationship between this variable and the urgent character, also considering the geographic location of the works and their typology.

In short, it is possible to conclude that through these successive studies the database went from 55,386 lines to 35,232 lines, the latter data being as accurate as possible.

2.2 Direct Observation of Processes

Once the analytical part was completed, and as a way of understanding the process inherent to material management, there was a need to carry out an on-site observation of the warehouse management processes. During this second part of the project, the main objectives were to assess the costs and quality of the service provided, since the rate of meeting deadlines was analysed in the previous point. For a better understanding of the work developed, the following diagram was created to summarise all the steps, Fig. 3.

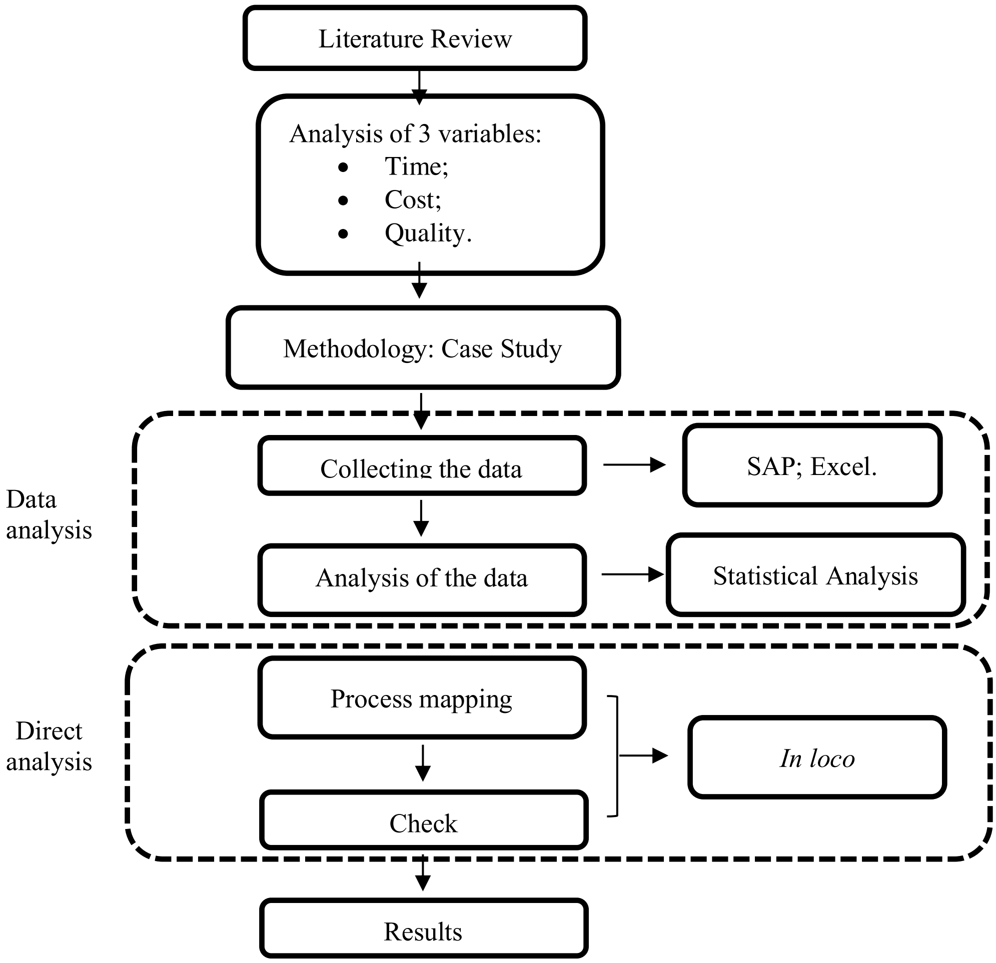

Figure 3: Research process

As for the cost variable, and since the material price is already closed, the only factor that could have an impact on cost would be rework. As rework, the need to redo certain activities was defined due to the occurrence of urgent orders. Regarding the quality variable, the study carried out would analyse how the occurrence of urgent orders could influence non-conformity in orders. The performance of these analyses was based on direct observation of all processes.

To better develop the three pillars of logistics (Time, Cost and Quality), these variables were reorganized to demonstrate a possible way of analysing them. We always focus on the problematic proposal to be studied (see Tab. 1).

Table 1: Variables studied

Time	Cost	Quality
Urgent demand	Product cost	Wrong product
Deadline met	Human resources	Insufficient
	Transport	
	Rework	

It is important to mention that at the beginning of this study urgent demands were thought to have an impact on the logistics department.

3 RESULTS AND DISCUSSION

As previously mentioned, the time window used for the elaboration of this analysis refers to the years 2015-2018. The material families with the most urgent requests were cement (51%), pipes (48%), bricks/blocks (45%), water mains (44%), glass (43%) and sun and wire mesh (41%).

In Tab. 2 it can be observed that the number of orders is increased, and the percentage of urgent orders has fluctuated along the period analysed.

Table 2: Evolution of material orders and urgent orders

Year	Number of material orders	Urgent material orders
2015	7340	34%
2016	8278	42%
2017	8937	34%
2018	10592	29%

For the materials, in the last four years, the probability it requested be urgent is 34% and the probability the deadlines met is 88%. The last probability, how was considered less than was supposed (95%), was a study in particular, in one of the analyses, it is clear in the year 2018, this probability was 92%, very close to the goal. Confronted with this situation, was trying to understand if this situation was punctual or if there is a reason which supports the idea that this will can be continuous, this way it was clear this happens because of the introduction of the request consignment at the material warehouse. The other analysis it was important for analysing the variable time, is the relationship between the type of request (urgent or normal) and the deadlines met, and it was possible to see that when a request is urgent it is less likely to be met than when the request is normal.

For the variable cost, the cost is contractually close, for this reason, the study focused on operations. For this study, all the operations a worker does when processing order was analysed to the extent that we understand when there is rework, being them: (1) Issuing the waybills; (2) When it is necessary to withdraw material that had been separated for another order before; (3)

Checking the order again when there is an urgent demand; (4) Truckloads; Redo the packaging; (5) Phone calls.

After the examination of possible operations, it was understood the only operation, which was a real operation, was the phone call, but in this operation, the cost is insignificant regarding the annual company's annual budget.

Concerning the last variable, quality, the study wasn't exhaustive because there was not enough data and during the time spent with this operation, there were no "problems" because of the occurrence of urgent demands. However, an analysis was carried out as a way to be able to assess the impact that quality could have on the present problem, being studied as follows: (1) Mistakes in the type of material sent; (2) Errors in counts. In the time allotted for this analysis, no non-conformities were resulting from "errors" related to quality.

4 CONCLUSIONS

Although there are no-cost impacts in the operations related to logistics, it is clear that, when it comes to an urgent request, the rate of meeting deadlines is lower, which may have an impact on the costs of the work, so suggests that this fact should be studied in more detail.

By analysing the data provided by the company under study, it was found that urgent orders do not have a great impact on the identified indicators (compliance with deadlines, cost and quality), however, despite the fact that the company has over the years always filled their difficulties and have responded to customer requests, the stress caused by the occurrence of urgent requests is frequent and of little benefit to workers. Although financially there is no direct impact on the company's performance, in human terms, the stress experienced by workers increases in these pressure situations. The main limitation of this project are related with the data treatment.

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SCHEDULING OF WASTE WOOD PROCESSING FACILITIES WITH OVERLAPPING JOBS

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Abstract: An important phase in most waste wood value chains is the processing of bulk waste from various sources, usually by means of shredding. This paper presents a method for scheduling the machines in such a waste wood processing facility, where incoming deliveries of different types of wood are processed by a series of treatment and transformation steps to produce shredded wood. A mathematical model is presented for the problem, that allows overlaps between consecutive steps to optimize resource flow through the system. The efficiency of the model is presented on randomly generated instances.

Keywords: scheduling, waste-wood processing, reverse wood value chain

1 INTRODUCTION AND MOTIVATION

The role of renewable materials and their reuse and recycling possibilities have become increasingly important with the growing significance of environmental awareness. One of the best examples for this is wood, a material that has a variety of primary uses, while also being a prime candidate for reuse and recycling. Optimization of the traditional product flows of wood is a well-researched area, with problems ranging from harvesting [14, 12] through facility-level decision-making (e.g. sawmilling [11], cutting pattern optimization [8]) to network-level modeling [13]. However, the utilization of waste wood and the reverse flows of this material are not widely studied. Waste wood can originate from a variety of sources, the two main groups being residual industrial wood (from the woodworking industry) and used wooden products (ranging from demolition waste to household items). However, similarly to other biomass residues, waste wood is mostly considered as a resource for energy production [15], and scientific studies usually concentrate on this aspect, while there might be more sustainable recycle possibilities [5].

As it was mentioned, the literature studying the optimization problems of waste wood is scarce. The two main research areas are the resource flow of waste wood for energy [6, 10] and the optimization problems of network design [2, 1, 16, 4]. While the previous studies concentrate mostly on network-level decisions, optimization problems in the nodes of waste wood logistics networks should also be studied. One important step is the processing of the collected waste, which is usually done by means of shredding, as most end-uses (e.g. energy or chipboard) require wood to be shredded to a certain size.

This paper presents the scheduling of a waste wood processing plant where the incoming wood deliveries are processed by a series of transformation steps in order to produce shredded wood. A mathematical model is formulated for the problem that allows overlapping of the automated processing steps in order to provide as continuous operation as possible. The efficiency of the proposed model is shown on instances that were randomly generated based on distributions from the literature. The presented model is a variation of our previously published work on scheduling waste wood processing facilities [3]. This previous study considered the uncertainty of the type and origin of the incoming deliveries (which is not tackled in the current paper), it did not allow any overlapping between the various processes of the facility.

2 PROBLEM DESCRIPTION

The goal of the proposed approach is to minimize the total weighted lateness of a waste wood processing plant that processes deliveries from collection centers and households. Each delivery is considered to be a job that has to go through 5 processing steps:

- inspection and sorting (`IS`)
- metal separation (`MS`)
- coating removal (`CR`)
- shredding (`SH`) and reshredding (`RS`)
- screening (`SC`)

Shredding is the main step, which is carried out by dedicated, high-throughput machines. The shredded wood needs screening, which selects large pieces for reshredding. Screening has its dedicated machines, while reshredding is executed by the same machines as the shredding step.

For metal separation, two options are available. It can either be done manually by a dedicated crew or in an automated fashion by a magnetic separator after shredding. If metal-separation is done manually, it has to precede coating removal, and succeed inspection, both carried out by their dedicated crew. Coating removal is only needed for a portion of the whole delivery.

The overall process of the plant is illustrated in Figure 1.

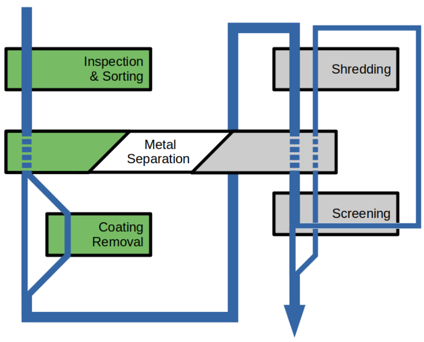

Figure 1: The possible flow of waste wood through the different transformation processes (green: manual steps, gray: machine steps).

The processing plant works in a semi-continuous fashion. Manual steps can be considered as batch subprocesses that cannot overlap or be interrupted. While the automated steps are also not interruptible, they can operate in a continuous way, so they may overlap with each other. Moreover, these steps may have an input storage/buffer that can hold shredded wood as long as needed, with sufficient capacity. Thus, fully batch operation is also available, if equipment availability would require it.

The re-entry of insufficiently shredded wood into the shredding machines forces the shredding step to envelop screening (and metal separation if done automatically) in time. Figure 2 illustrates the possible timings of these steps for both options with metal separation.

The dedicated crews for manual steps may not be split up between different jobs at the same time. However, several machines can be assigned to the same job simultaneously for the

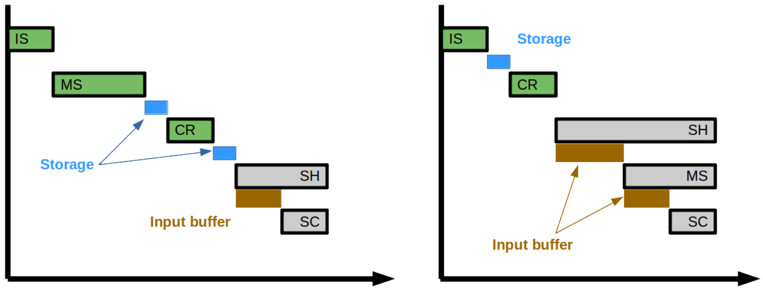

Figure 2: Possible timing of processing steps for both metal removal operations.

same step, if available. The percentage of wood / shredded wood that requires coating removal / reshredding can be estimated based on statistical data, based on the type of the delivery that can be either solid ($\mathtt{S}$) or derived ($\mathtt{D}$).

3 FORMAL PROBLEM DEFINITION AND THE PROPOSED MODEL

3.1 Problem data

The problem data is formally given as:

J is the finite set of jobs/deliveries.

$S = \{\mathtt{IS}, \mathtt{MS}, \mathtt{CR}, \mathtt{SH}, \mathtt{SC}\}$ is the set of steps.

$d_j^a \in \mathbb{Z}^{0,+}$ is the day of arrival for the delivery of job $j \in J$. $[day]$

$d_j^s \in \mathbb{Z}^{0,+}$ is the day of shipping for the product of job $j \in J$. $[day]$

$p_j \in \mathbb{R}^{0,+}$ is the priority of job $j \in J$. $[-]$

$m_j \in \mathbb{R}^{0,+}$ is the total mass of the delivery of job $j \in J$. $[t]$

$t_j \in \{\mathtt{S}, \mathtt{D}\}$ is the type of job $j \in J$. $[-]$

M is the finite set of machines, partitioned to $M^{\mathtt{IS}}$, $M^{\mathtt{MS}}$, $M^{\mathtt{CR}}$, $M^{\mathtt{SH}}$, and $M^{\mathtt{SC}}$.

$c_{mj} \in \mathbb{R}^{0,+}$ is the throughput capacity of a machine $m \in M$ for job $j \in J$. $[t/h]$

$s \in \mathbb{R}^{0,+}$ is the length of the shifts. $[h]$

$p_{\mathtt{S}}^{\mathtt{CR}}$, $p_{\mathtt{D}}^{\mathtt{RS}} \in [0, 1]$ are the percentages requiring coating removal and re-shredding for solid ($\mathtt{S}$) and derived ($\mathtt{D}$) deliveries. $[-]$

From the modeling point of view, dedicated crews behave exactly as machines, thus they are considered as such later on ($M^{\mathtt{IS}} = \{\mathtt{IS}\}$, $M^{\mathtt{CR}} = \{\mathtt{CR}\}$, and $\mathtt{MS} \in M^{\mathtt{MS}}$)

3.2 Variables

The proposed model relies on the following variables:

t_{js}^s, $t_{j,s}^c$ non-negative continuous variables for starting and completion of step $s \in S$ for job $j \in J$.

a_{jm} binary variable that indicates if machine $m \in M$ is assigned to job $j \in J$.

q_{jm} non-negative continuous variable for the quantity of wood processed by machine $m \in M$ from job $j \in J$.

$b_{jsj'}$ binary variable that indicates if processing of job $j \in J$ precedes that of $j' \in J$ for step $s \in S$. $(j \neq j')$

3.3 Constraints

Due to space limitations, only the key parts of the mathematical model are presented here. The constraints can broadly be categorized into three groups: logical/quantity constraints, recipe timing constraints and scheduling/sequencing constraints.

A key logical constraint forbids the assignment of any magnetic metal separator to a job if a crew already performed the task:

$$a_{jm} \leq 1 - a_{j\mathtt{MS}} \qquad \forall j \in J, m \in M \setminus \{\mathtt{MS}\} \tag{1}$$

The total quantities assigned to the machines from a job must add up to the total mass of that job for each step. Depending on the step and the type of the job, this total mass may be different from m_j. The equation is the most complex for metal separation, as the total quantity is larger by the reshredded volume if automatic separation is selected:

$$\sum_{m \in M^{\mathtt{MS}}} q_{jm} = m_j + m_j \cdot p^{\mathtt{RS}}_{t_j} \cdot (1 - a_{j\mathtt{MS}}) \qquad \forall j \in J \tag{2}$$

These quantity variables can be used to provide a lower bound on processing times:

$$t^c_{js} \geq t^s_{js} + q_{jm}/c_{mj} \qquad \forall j \in J, s \in S, m \in M^s \tag{3}$$

A group of recipe timing constraints set the starting and completion times for tasks of the same job. This constraint, for example, sets the timing appropriately between manual metal separation and coating removal:

$$t^s_{j\mathtt{CR}} \geq t^c_{j\mathtt{MS}} - \mathbf{M} \cdot (1 - a_{j\mathtt{MS}}) \tag{4}$$

where $\mathbf{M}$ is a sufficiently large number.

Sequencing of tasks assigned to the same unit are tackled with the following constraint:

$$t^s_{j's} \geq t^c_{js} - \mathbf{M} \cdot (3 - a_{jm} - a_{j'm} - b_{jmj'}) \qquad \forall j, j' \in J, j \neq j', s \in S, m \in M^s \tag{5}$$

3.4 Objective

To calculate the objective, an integer helper variable l_j is introduced, which indicates the lateness. This variable is set by the following constraint:

$$t^c_{j\mathtt{SH}} \leq (d^s_j + l_j) \cdot s \qquad \forall j \in J \tag{6}$$

Then, the objective is simply expressed as:

$$\sum_{j \in J} l_j \cdot p_j \rightarrow \min \tag{7}$$

4 NUMERICAL RESULTS

As acquiring real-life datasets with varied sizes and structures is not a trivial task, testing of the model was done with the same methodology presented in [3]. Input instances were randomly generated based on available distribution data. The arrival day of the deliveries was chosen randomly over a one-week horizon for every instance. The features of the waste wood deliveries were determined based on statistics in [7], their sizes were determined using the capacities of biomass transport trucks [9] and data on real machines was used to determine throughput.

Two different instance types were created: instances with small deliveries had a mass corresponding to the payload of a small truck (6 t–15 t) and the ones with large deliveries had a mass corresponding to the payload of an average-sized biomass transport truck (31 t–49 t). The number of deliveries was a multiple of five between 5 and 30 for each instance. This resulted in 12 instance sets (one for each each pair of delivery size and delivery number, e.g. '25 large deliveries'), with 20 different random instances in each set. The model was solved for all instances using the Gurobi 9.1 solver on a PC with an Intel Core i7-5820K 3.30 GHz CPU and 32 GB RAM. A running time limit of 1800 s was introduced to all test runs.

Instances with 30 or fewer small deliveries were all solved to optimality in less than 1 s. The model was also tested for instances with 35 and 40 small deliveries, but these did not yield optimal solutions in the given time limit.

Instances with large deliveries were solvable to optimality in the case of 15 or fewer deliveries. Only half of the 20-delivery instances yielded optimal solutions within the time limit, while the suboptimal results of the remaining 10 instances had an average gap of 44.33%. A significant number of the larger instances did not provide solutions within the time limit: only 9 and 13 instances were optimal in the case of the 25- and 30-delivery sets respectively. For the remaining instances, there were either no feasible solutions found within the time limit, or only ones with extremely large optimality gaps.

5 CONCLUSIONS

This paper presented the problem of machine scheduling in a waste wood processing plant where the incoming deliveries of wood are shredded. A mixed-integer linear programming model was presented for the problem that allows overlapping of the machine processing steps so the flow of material can be as continuous throughout the facility as possible. The efficiency of the model was shown on instances that were randomly generated based on real-life statistical data. Results showed that the model is capable of scheduling a large amount of jobs over the short-term period of one week, under a short solution time. Possible extensions of this work can include an exhaustive testing of larger planning periods of several weeks, as well as the development of metaheuristic algorithms for solving instances with even larger number of deliveries. The proposed model should also be tested for real-world datasets.

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ORDER VARIATION AND FLEXIBILITY RULES DASHBOARD

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Abstract: In the Logistics Planning and Fulfilment department of an auto components plant in the Automotive Industry, planners take too much time checking if orders variations are within the flexibility rules agreed with customer. This paper focuses on the development of a dashboard to optimize time and manual effort spent on tasks like data searching, collection and reporting, key in the management of customer orders. A comprehensible and easily interpreted dashboard was developed that covers over 70% of the projects within the plant, potentially saving over 1 300 hours per year in the department.

Keywords: Order variation calculation, flexibility rules, customer order management, dashboard development, data analytics, industrial logistics system

1 INTRODUCTION

Over the years, the manufacturing industry has witnessed a steady increase in complexity and requirements, with digital transformation revolutionizing the industrial environment to an unprecedented degree, establishing a variety of new business potentials and opportunities for industries all over the world. Industry 4.0 and logistics 4.0 concepts imply the integration of new technologies and organizations [3], with trends such as digitalization, Internet of Things (IoT), Internet of Services (IoS) and Cyber-Physical Systems (CPS) becoming progressively more significant [4]. The success of an industry essentially depends on how consistently and actively the digital transformation is shaped and how the use of new opportunities is made, making it possible for industries to improve quality, costs and delivery performance and thus increase customer satisfaction [1].

Through data analytics, extracting useful information from raw data allows for the discovery of patterns and relationships from rough data, thus improving process understanding, support decisions and reduce the time spent analysing data [5,10].

There are several ways to view and present data. Information processing can be strongly supported by Visual Analytical Tools that combine automated and interactive modelling [2]. Through dashboards, managers and planners can receive useful information that is customizable, easy to use and presented almost in real time, proving crucial "understanding the characteristics of dashboards that promote use and lead to individual and organizational performance gains" [8]. Additionally, can be as narrow or broad as needed, allowing organizations to create multiple dashboards to better organize their analytics.

Designing a dashboard must be different from other visualisation systems. For instances, the information must be accessible and easily comprehended by the users, avoiding any distracting functionalities. Displaying data is tabular form data is superior to graphs, allowing for greater detail and broader analysis. However, graphs reduce the information overload when compared to tables [11].

Contemporary information systems such as production and logistic dashboards provide vast amounts of information and, in those large volumes, frequently the user cannot find appropriate and important information on demand [6]. Combining different databases with different visual layouts that leads to unique visual interfaces enables gathering more information in a shorter time [7], revealing how important it is to focus on detecting and repairing data inconsistency problems. Data quality is an essential characteristic that determines the reliability of data for decision making in organizations. Specifically, guaranteeing high-quality dependable data is a competitive advantage for all industries [9].

This project focuses mainly on optimizing time and manual effort spent on tasks like data searching, collection, and reporting, essential to improve the analysis of customer orders within the Logistics Planning and Fulfilment department of Bosch Car Multimedia Portugal, S.A. in Braga.

2 PROBLEM

Tasks performed in the planning department include customer order management and production planning. The planners receive via electronic data interchange the customer order for a specified forecast period and compare if variation in orders of current release with last forecast period is within flexibility rules agreed with the customer. This analysis is crucial to determine whether the plant has the capacity to fulfil the order, or it needs to renegotiate order quantity or reallocate production for the next forecast period.

The main problem identified is that planners take too much time checking if orders variations are within the flexibility rules agreed with customer. As a consequence, planners just accept the order leading to capacity problems to fulfil the orders, as well as shortage of raw materials in orders with large increases in variations. On the other hand, there is a wasteful accumulation of stocks with large decreases in orders quantity.

3 PROJECT DEVELOPMENT & IMPLEMENTATION

To define what procedures should be structured to accomplish the automation objective, the most important aspect was to ascertain what type of tool would best support the planners in their analysis, what data should be taken into consideration and how that data should be displayed.

The purpose of the tool would be to compare current week's releases with snapshots of previous releases for a specific forecast period, clearly and visually indicating whether there is variation between the current release and the forecast release and whether this variation is permitted, restricted by the flexibility limits contractually defined with the customer. Furthermore, the tool should also be able to quantify the variation, as this information is necessary to report to the customer. The team of planners was already acquainted with the use of dashboards, using them daily to support planning activities, examine stocks levels, coordinate production backlogs and occupation of production lines. Therefore, it was decided to develop a new dashboard sheet for the management of customers' orders and integrate it into the team's existing dashboard. This dashboard would be powered by reports that could also be consulted if planners needed a more detailed analysis, and would report information regarding releases, forecasts, variations in quantities and flexibility rules associated with each customer.

The first step taken into the project development was to analyse the planners' daily activities and how the tasks were currently performed, then automate as possible these tasks. Three main actions were established:

- Automate order variation calculation;
- Analyze flexibility rules by customer from the orders variation report;
- Develop order variation dashboard.

The first two actions identified consisted of the creation of the reports that would serve as the database for the dashboard and the third action is the development of the dashboard itself.

3.1 Automation of order variation calculation

Each order release is characterized with a set of predetermined parameters. To automate the calculation of the variation of order releases, the first stage was to define which forecast period would be considered. The requirements for unit of time to be selected and the time horizons to be compared were defined:

- The variation in releases would be calculated on a weekly basis as there are no significant daily variations;
- To allow for records comparison, the report would comprise information of releases from the snapshot of the current week (SW_n) up to six weeks prior (SW_{n-6});
- Would only be considered variations in percentage in releases between the snapshot of current week's releases (SW_n) and the two previous weeks (SW_{n-2}), in a 60-week calendar horizon (CW_{n-8} to CW_{n+52}).

For each calendar week, the variations of the ordered quantities (Q) are calculated as follows:

$$\Delta Q_{SW_{n,n-x}} = Q_{SW_n} - Q_{SW_{n-x}}, for\ x = \{1, 2, 3, 4, 5, 6\} \quad (1)$$

$$\Delta_{SW_{n,n-1}}(\%) = \left(Q_{SW_n}/Q_{SW_{n-1}}\right) - 1 \quad (2)$$

$$\Delta_{SW_{n,n-2}}(\%) = \left(Q_{SW_n}/Q_{SW_{n-2}}\right) - 1 \quad (3)$$

After identifying the parameters characterizing each release and the fields needed for the calculation, the order variation report was created. (Table 1).

Table 1: Order variation calculation report

Calendar Week	Order Release Parameters	SW_{n-6}	…	SW_n	$\Delta Q_{SW_{n,n-1}}$	…	$\Delta Q_{SW_{n,n-6}}$	$\Delta_{SW_{n,n-1}}$	$\Delta_{SW_{n,n-2}}$
CW_{n-8}		PC	…	PC	PC	…	PC	%	%
…		…	…	…	…	…	…	…	…
CW_{n+52}		PC	…	PC	PC	…	PC	%	%

The report comprises information of orders variations quantity, in pieces (PC) and percentage (%) per customer material, ship-to, plant and total volume with data retrieved from various integrated systems.

3.2 Flexibility rules analysis

Following the completion of the orders variation report was the development of the flexibility rules report. Consisted of gathering the logistics analysis reports from the different customers, standardize the flexibility rules defined within the agreements and group customers and projects by standard. Four standard rules were identified (Figure 1): Increase/decrease percentage limit set per week; Maximum order quantity calculation tables; Project specific rules; Must comply to order quantity.

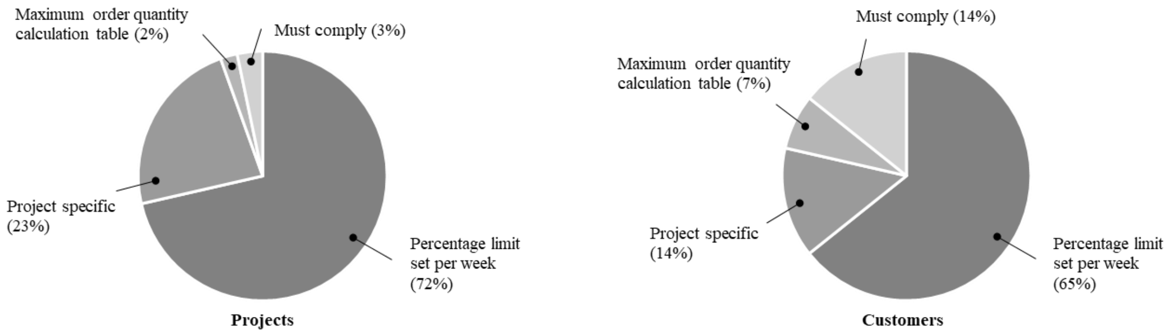

Figure 1: Project and Customer distribution by standard.

The development of the report and dashboard will mostly include the first and most significant standard, since there is no standard guideline for active projects with specific rules and customers with must comply rules are outside the scope of this analysis. For the clients with the calculation tables standard, an adapted calculator was developed, accessible through the dashboard. It returns, by entering specific parameters, what are the maximum daily, weekly, and monthly quantities allowed to order.

The first standard identified characterizes the limit as a percentage change defined in a predetermined time horizon, in weeks (Table 2). This standard is known in 9 customers and more than 60 projects of the plant.

Table 2: Flexibility rule standard - increase/decrease percentage limit per week

	x%		y%				z%		
CW	1	2	3	4	5	6	7	8	…
	-x%		-y%				-z%		

After identifying the fields characterizing the first flexibility rule standard, the flexibility rules report was created (Table 3).

Table 3: Flexibility rules report

Calendar Week	**Customer**	**Rule Description**	$\Delta_{SW_{n,n-2}}$ **Upper Limit**	$\Delta_{SW_{n,n-2}}$ **Lower Limit**	$\Delta_{SW_{n,n-1}}$ **Upper Limit**	$\Delta_{SW_{n,n-1}}$ **Lower Limit**
CW_{n-2}			%	%	-	-
CW_{n-1}			%	%	%	%
…			…	…	…	…
$CW_{...}$			-	-	%	%

The report comprises information of percentage limits (%) per customer group with data retrieved from the requirements matrix of customers.

3.3 Order variation dashboard development

Completed the reports that would serve as the database for the dashboard, the final action was design an easy and visual dashboard with graph comparison between order variation percentage and flexibility limits defined. Since planners have access to all the information detailed in the reports, it would be unnecessary to repeat data in the dashboard, displaying only the information that would be relevant in the comparison between order variation and flexibility rules in the dashboard.

The developed dashboard contains 2 charts that represent variations in orders between snapshot weeks for the different calendar weeks and compares these variations with the limits set by the rules. It also contains a table with the quantities ordered each week and another with variation quantities. The dashboard represented in Figure 2 contains fictitious data reporting order releases for a product from weeks 13.2021 to 21.2022. In the current week of the analysis, 22.2021, the releases in the week's snapshot, SW_{21}, are compared with the releases of the previous two weeks, SW_{19} and SW_{20}. This variation is represented by the values of the columns in both charts. Line values represent the maximum percentage variations allowed.

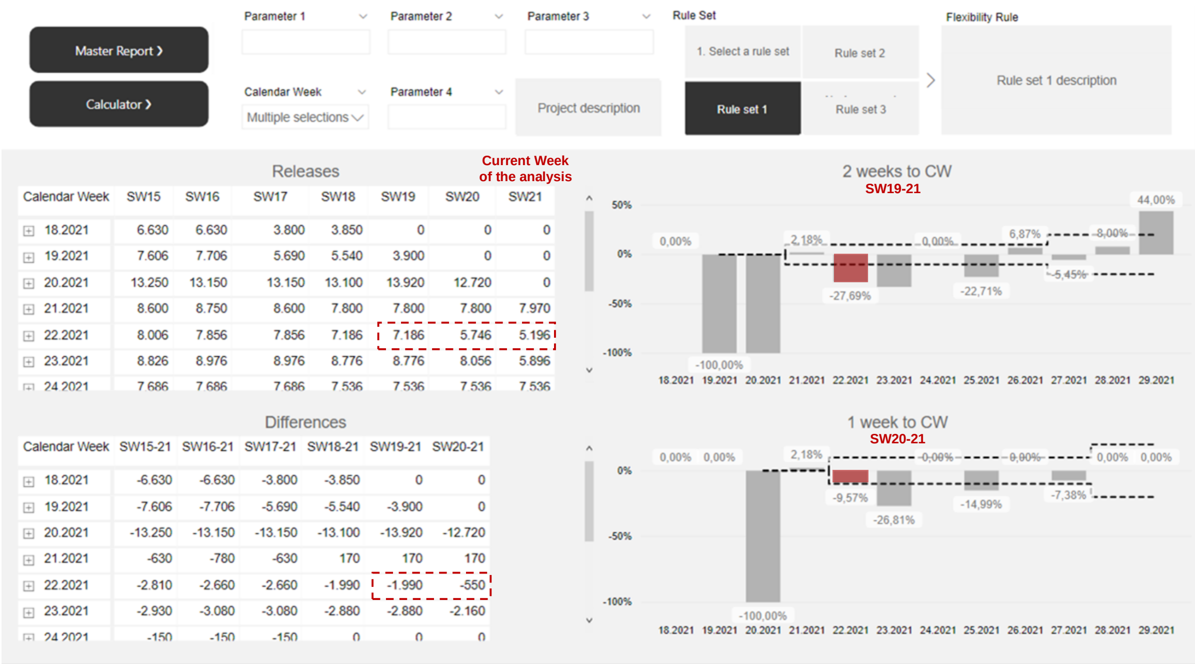

Figure 2: Order variation dashboard

In this example, when analysing calendar week 22.2021, it is observed that:

- In the snapshot for the week two weeks prior to the current week, SW_{19}, the ordered quantity for week 22.2021 was 7 186 PC, while in the current week's snapshot, SW_{21}, the ordered quantity is 5 196 PC. This decrease of 1 990 PC represents a variation of -27.69% in the ordered quantity that is outside the permitted limit of ±10% for that week.
- In the previous week's snapshot, SW_{20}, the order for week 22.2021 was 5 746 PC, and in the current week's snapshot, SW_{21}, 5 196 PC. This decrease of 550 PC represents a -9,57% variation that is within the permitted limit of ±10%.

This design made it possible to achieve the main objective of this dashboard, comprehensible and easily interpreted by planners. Ideally, the planner stops checking manually the comparison between orders variation and customer flexibility rules.

4 DISCUSSION

By this time, the customer order variation dashboard is available and tested by the planners, whose response on its accuracy and suitability provides further improvements for customer order management. The dashboard covers 72% of customers and 74% of projects within the plant, with over 18 000 customer orders being automatically evaluated per week. To cover the entire range of projects and customers, guidelines for projects with the specific rules standard or must comply standard could be aligned with one of the two standards covered by the dashboard. Automating this task allows for potential savings up to 1 337 hours per year in the department.

Each customer group has stipulated flexibility rules applied to all projects associated with that customer, although there are 4 projects associated with several customers with different rule sets. Selecting the flexibility rule and the project as two independent parameters presents the planner the ability to evaluate one project by different rules and allows for greater flexibility in the analysis and support in reviewing the flexibility rules with the customer. Another contribution made possible by this dashboard concerns the response to demand fluctuations. Having an automated record of variation in customer orders allows the planning department to better predict production plans, but also the purchasing department to align this variation in orders with the variation in raw material purchases. In the future, based on the data provided by the dashboard, flexibility rules adapted to the needs of the plant can be agreed with suppliers.

Enhancements can be developed in future work, such as the flexibility of reports and dashboard, as with a more detailed and real-time analysis of customer order launches. It was stated that the variation in releases would be calculated on a weekly basis as there were no significant daily variations. However, a variation to an already planned quantity would be registered once a week. Orders received the next days would only be considered the following week, substantial or not. A potential solution would be reducing the time between updates and to replace weekly snapshots with daily snapshots.

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THE ROLE OF INTERMODAL TRANSPORTATION ON REDUCING CO_2 EMISSIONS

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Abstract Intermodal transport is a driver for reducing CO_2 emissions and offers solutions with low CO_2 content and low costs. The objective of this article is to identify the combination of intermodal transport that emits the lowest CO_2 content into the atmosphere through the design and analysis of several possible scenarios, using a CO_2 calculator available online (DHL Carbon Calculator). Different scenarios of intermodality were created and the results were analysed in relation to the indicators of CO_2 reduction, cost and time of transport and distance.

Keywords: Sustainability, Intermodal Transport, CO_2 Emissions.

1 INTRODUCTION

Over the last years the possibility of industries operate in a global market, has been contributing to increase the transportation of goods by highways. The transportation is considered a key sector for several countries but is also considered as one of the main sources of CO_2 emission [1].

The increase of freight transport in the global market has increased concerns regarding the negative impacts on air quality and climate change. Since transport is mainly driven by the combustion of fossil fuels, which results in the emission of various greenhouse gases such as carbon dioxide (CO_2), nitrogen (NOx) and Sulfur oxide (SOx) [2].

According to data estimated by International Energy Agency [3], CO_2 emission in the transport sector represented about 24% in 2020, and it expects to continue growing in the coming years. The transport sector is constantly changing due to technological advances, it has been contributing to find solutions for freight transport more efficient in terms of time and costs. In doing so, the intermodality in transportation has gaining ground as a system for transporting goods over long distances, resorting different types of transport, such as, ports and includes coastal routes, waterways, railways, roads, and airways [4].

Traditional models of logistics management are concerned with minimizing transport costs, but due to the increase number of CO_2 emissions in the last decades, it is imperative the development of new models and technologies to support companies in minimizing and controlling it [5]. Considering the importance of intermodality in transports as a strategy to minimize CO_2 emissions, this research aims to analyse the contribution application of intermodality to reduce the emission generated by a furniture company, namely the IKEA company. Then, identify the combination of intermodal transport that produces the lowest CO_2

content into the atmosphere through the design and analysis of several possible scenarios, using a CO_2 calculator available online, at a commercial company.

2 METHODOLOGY

This research focuses two main sources of data, namely the DHL Carbon Calculation, which is a platform widely used by companies and researchers to quantity CO_2 emissions in the transportation, considering different scenarios and transport modal and data from IKEA company public reports.

The calculation of CO_2 emissions used in DHL's Carbon Calculater can be found online and free of charge on the DHL platform [6]. The methodology used in the platform is in line with the reports published by IPCC (See [7]), which focusing on the role of transportations on mitigating climate change. This works was also inspired in the work developed by Lagoudis and Shakri [8], in this research a framework to measure carbon emissions for inbound transportation was developed, taking into consideration cargo distribution between air and sea as variables. For the creation of the scenarios some aspects were considered, namely the cost of transport and the time required for transport, and then these values were used to estimate calculated using data provided by a forwarding company.

In this research, the CO_2 values on the "SCENARIOS" represent the CO_2 emission from the combustion of fossil fuels used to transport the configured shipment scenario. The emission calculations are based on the guidelines outlined in the Greenhouse Gas Protocol, the Corporate Accounting and Reporting Standard and the Corporate Value Chain Accounting and Reporting Standard.

The data were also prepared in accordance with the requirements of the European Emissions Trading System and the standards EN 16258 [9] and ISO 14064 [10]. For the creation of the scenarios, The Carbon Calculator was used considering the waypoints between a pair of origin and destination location, based on a network data set specific to the mode of transport, and links the waypoints to build a route. The sum of all connected waypoints shows the shortest distance travelled on that route. If a location is inserted that is not part of the mode-specific network data set, using a built-in algorithm, the Carbon Calculator adds a connection from that location to the nearest location that is part of the mode-specific network data of joint transport.

In order to get a picture of CO_2 emission generated by transports of products by IKEA company a set of scenarios was created. In doing so, this research has considered three routes Matosinhos (PT) - Valls (ES); Penamaior (PT) - Erfurt (DE); Tábua (PT) - Piacenza (IT). Through the help of DHL Carbon Calculater, we were able to determine the ideal scenario for each route.

3 IKEA CASE STUDY

The environment can affects the business of organizations in several ways, including the scarcity of resources, the socio-demographic context, and the presence of competitors. As a consequence, over the last decades companies have been pushed to develop projects in the planning and construction of strategies to minimize the cost of its impacts on the environment, the transport has been seen as longwinded part of these strategies, especially when defining routes to transport companies goods [11].

In this research the IKEA company was used a case study to illustrate the impact of transportation on climate footprint. Since intermodality in transports, can be considered as a driver towards reducing CO_2 emissions, and offering solutions that produces a low CO_2 content and low costs, we focused on suggesting a set of alternatives for transportation of the company's products in more sustainable way.

In the last report published by IKEA in 2020 for the previous year, the company points out that its biggest long-term goal is to reduce its climate footprint by the year 2030 compared to 2017, in which the footprint value was 1.2 million tons of CO_2. IKEA is a company with great concern regarding sustainability and environment impacts. For this research, the combination of different modal transport was considered aiming to propose the lowest CO_2 content emitted. As presented in Table 1, for the calculation of CO_2 emissions, three routes were identified from where transport will be dispatched to the destination:

Table 1: Proposed scenarios for the case study.

Scenarios	***Route***	
	Origin	Destination
S1	Matosinhos, PT	Valls, ES
S2	Penamaior, PT	Erfurt, DE
S3	Tábua, PT	Piacenza, IT

The locations for the departure of goods transport and reception, were chosen since, in these cities, IKEA has stores and distribution centres. For the development and calculation of scenarios, it is necessary to consider some assumptions directly related to the adopted cost values, and these values were identified by a freight forwarder with extensive experience in the market:

(1) Regarding road transport, the cost of traveling will be calculated according to the number of kilometers travelled. (2) Routes with less than or with 100Km were estimated by a cost of 100 €. In these cases, it was not possible to count the cost of traveling the route as it is not compensatory for freight forwarders, since there are fuel costs, maintenance costs, delays in loading and unloading which can lead to the fact that they are no longer able to do the next service. Thus, it is necessary to estimate a value that can cover all possible costs. For journeys over 100 km, the estimated cost will be 1 euro per kilometer. (3) For the sea mode, the values were estimated according to the destination. Therefore, the cost of sea freight to Spain will cost 950 €. For Germany, Sea freight cost 1250 € and finally, for Italy the cost 1150 €. It always adds to the value of the Sea freight, whatever the destination, the value of the tax-rate that is the rate that is always charged due to the pollution that is emitted by maritime transport. In this case the value used as an estimate was 25 € but this value is updated every month. (4) For the railway mode, it is necessary to consider the cost of rail freight, which also varies according to the destination and the handling cost, which is the cost that the terminal has in handling the loads, and a fixed value of 20 € per movement is estimated. The cost of rail freight to Spain is approximately 400 €, to Italy 500 € and to Germany 600 €.

Table 2 details the configuration for each combined scenario, considering the Starting point to destination point.

Table 2: Details of chosen routes.

Route	***Matosinhos (PT) – Valls (ES)***	***Penamaior (PT) – Erfurt (DE)***	***Tábua (PT) – Piacenza (IT)***
S1	*Road*	*Road*	*Road*
S2	*Road – Rail- Road*	*Road – Sea - Road*	*Road – Sea - Road*
S3	*Road – Sea - Road*	*Road – Rail- Road*	*Road – Rail- Road*
S4	*Road – Sea –Rail- Road*	*Road – Sea –Rail- Road*	*Road – Sea –Rail- Road*

For each route aiming to understand the difference between transport mode, a set of scenarios was suggested, as summarized in the Table 2, three cities in Portugal were taken as sample, and then three different countries were chosen, namely Germany, Spain, and Italy. These countries were chosen because IKEA has large distribution centres in these countries.

4 RESULTS AND DISCUSSION

The results presented in this section summarizes the novelty of this research, which lies in two main aspects, namely, to bring to the light the need for further discussion by companies on understanding their environmental impact of transportation and, the contributing of intermodality as a logistics strategy to reduce CO_2 emission. After defining the configuration of each route selected, the first analysis was carried out. Here is important to highlight that for all scenarios a total of 20 tons of products was considered in each route transportation. Since this research focused on quantifying emissions for different routes, the next sections will be discussed detailing the results achieved for each one of them.

4.1 Matosinhos (PT) - Valls (S)

For the case of Matosinhos (Portugal - PT) - Valls (Spain - S) route, the results from Table 3 shows that scenario 1 was considered as the one most effective in terms of the number of kilometers and in terms of transport time, on the other hand, scenario 2 is the most effective at level of costs and number of CO_2 emissions.

Table 3: Results for Scenario Matosinhos (PT) - Valls (S)- PT-S_S1 -S4

	Distance (Km)	*Cost (€)*	*Time (hour)*	*CO_2 Emission (KgCO2)*
PT-S_S1	1063	1063	13	944,05
PT-S_S2	1247,44	659,16	20	**502,23**
PT-S_S3	2434,52	1163,19	50	647,19
PT-S_S4	2549,33	1849,47	72	1408,13

For scenarios 3 and 4, the results showed that they were considered as not successful on the variables chosen for study because the distance, costs and emissions has a higher value. Scenario 3 combines the road and sea mode; this modality contributes the value of each variable to increase significantly. This increase is due to the fact that we use the sea mode and the location of the destination. The freight from Leixões Port – Portugal to Barcelona, has a cost of almost 1000€, and it takes about 48 hours, with a distance travel of approximately 2325.84Km. In terms of CO_2 emission, the results showed that the route emits about 550.69KgCO_2. When compared to scenario 1, PT-S_S3 would be more effective in terms of costs and CO_2 emissions, but in terms of time and kilometers it would no longer be, as it takes more time and travels more kilometers. Thus, PT-S_S2 was considered as the most effective intermodality proposal for the Matosinhos (PT) - Valls (ES) route, since the one that contains lower costs and a low CO_2 emission level.

4.2 Penamaior (PT) – Erfurt (DE)

Regarding the Penamaior (PT) - Erfurt (DE) 4 scenarios were also considered, for this case, the results showed that route PT-DE_S1 was considered as the most effective in terms of the number of kilometres and time. PT-DE_S1 was pointed out as positive in terms cost-effective. Finally, for the case of PT-DE_S4 the results put in evidence the effectiveness of the scenario in terms of CO_2 emissions. Despite not being effective in any of the variables, PT-DE_S4, presents a very attractive number of CO_2 emissions compared to scenario 3 and scenario 1. In this scenario, 3 modes of transport were considered, namely road, sea, and rail.

Table 4: Results for Scenario Penamaior (PT) - Erfurt (DE) Results

	Distance (Km)	*Cost (€)*	*Time (hour)*	*CO_2 Emission (KgCO2)*
PT-DE _S1	2394	2394	25	2125,65
PT-DE_S2	2744,30	1940,52	58	**1184,53**
PT-DE_S3	2770,14	1415,78	85	1685,15
PT-DE_S4	2826,01	2571,71	129	1311,35

The scenario with the longest route being done in maritime mode. which leads to a low number of CO_2 emissions compared to, for example, the road mode. In terms of costs, it is no longer so attractive because the combination of sea mode and the rail mode were considered, and even for the road mode that showed the higher value than the other scenarios that only combine 2 modes of transport. Regarding the number of kilometres, PT-DE_S4 is higher than the other scenarios since it is necessary to create a route that can include the 3 modes. For the time needed for the transport, it is normal that it will be necessary for around 7 days because PT-DE_S2 the modes chosen are slower transport and where there is a possibility of more delays or even accidents. So, the results showed that PT-DE_S2 was considered as the most successful scenario for the Penamaior (PT) - Erfurt (DE) route.

4.3 Tábua (PT) – Piacenza (IT)

For this route, Tábua (PT) - Piacenza (IT), the results from the platform showed that in terms of time and number of kilometres, PT-IT_S1 was positively evaluated. In terms of cost, the most effective scenario is PT-IT_S3, for the case of CO_2 emissions, PT-IT_S2 would be the best choice.

Table 5: Results for Tábua (PT) - Piacenza (IT)- PT-IT_S1 -S4

	Distance (Km)	*Cost (€)*	*Time (unit)*	*CO_2 Emission (KgCO2)*
PT-IT_S1	1915	1915	22	1700,35
PT-IT_S2	3187,69	1646,91	79	**1006,89**
PT-IT_S3	2201,12	801,53	54	1194,55
PT-IT_S4	3456,07	1964,27	77	1113,13

Regarding PT-IT_S4, which is the scenario that does not fit the effectiveness of any of the variables, results presented in Table 5 shows that this scenario is the longest in terms of the time it takes to transport from the beginning to the destination. Regarding CO_2 emissions, PT-IT_S4 ranks second place with a slight difference from scenario 3, a difference of 81.42Kg CO_2. This difference is due to the fact that, for this scenario, the marine mode has been combined with the railway in the part of the route with greater kilometres, in order to cause less emissions since the more kilometers the more emissions Finally, in terms of costs, this was the scenario with the highest cost, as freight to Italy by sea is high and the remaining costs are also high. For this route, the results showed that from Tábua (PT) - Piacenza (IT), the intermodality scenario that emits the lowest CO_2 content is PT-IT_S2.

5 CONCLUSIONS

In this research, results from the literature showed Intermodality transport have appeared as an option to support companies on delivering goods reducing their carbon footprint. This work used a case study to illustrate the role of Intermodality on reducing CO_2 and contributing to a sustainable transportation. In this way, three routes were selected, and IKEA company was used as a case study, the were considered as source to study four different scenarios.

The scenarios were analysed resorting to DHL Carbon Calculator platform, to calculate the kilometers and the CO_2 content emitted. From the application the results were able to determine the ideal scenario for each route. The evaluation of the remaining variables also allowed us to draw conclusions regarding the choice of the best scenario. For example, the cost of transport increase with the growth in the number of kilometres and also if we combine several types of transport modes. The evaluation of the remaining variables also allowed us to draw conclusions regarding the choice of the best scenario. For example, the cost of transport increase with the growth in the number of kilometres and also if we combine several types of transport modes. The results showed that in terms of emissions scenario 2 was considered the best option for route PT-S. For the case of route PT-DE scenario 2 is the one that has lower emissions and finally, for route PT-IT the best option is scenario 2.

Is important to highlight that the emissions are directed related to the load weight and number of mileages travelled. Yet, this research calls attention for importance of using the concept of intramodality as a particular and relevant strategy in supporting companies in the transition for a sustainable transport. Regardless the potential contribution of this research, some limitation needs to be highlighted, such as the difficulty for assessing availability and schedules if transports used as sample and the need for a detailed economic cost analysis for CO_2 emissions. Despite being a simple approach, the results achieved here could offer an important lesson for companies, logistics operators and local governments on developing strategies to support companies in this transition.

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A PDCA-BASED APPROACH TO IMPROVE THE LOGISTIC SUPPLY OF AN ASSEMBLY LINE IN THE AUTOMOBILE SECTOR: A CASE STUDY

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Abstract: This case study aims to determine the optimal cycle time of the milk-run supply process for an automotive industry assembly line, based on PDCA methodology. The problem was modelled with MS Excel and analytical tools as SIPOC, 5S and visual management were implemented. The developed simulator provided an optimal cycle time of 1h10min, by implementing a logistic train. Using SIPOC, it was possible to establish concise flows and define a supply pattern, which resulted in a reduction of 24% of movements. It was possible to release an area of 1.92m^2, by eliminating unnecessary stocks, and by fixing position in the trailers for 60% of the materials, which reduced transportation waste.

Keywords: Logistics, Milk-run, Continuous improvement, PDCA

1 INTRODUCTION

Developed between 1940 and 1950 decades, the Lean quickly became a strong and dominant reference of management in business environments [1]. Waste reduction is linked to the suppression of activities that do not add value to the product/service, including overproduction, overprocessing, transport, movements, waiting, defects, and stock. This methodology is supported by theoretical and empirical evidence from increasing the competitiveness of organizations [1, 2]. In a manufacturing environment, the internal logistics is essential to optimize the performance of assembly lines/systems [3] and to ensure efficient material flows [4]. This requires important decisions, due to the need in predicting: what, how much, by whom, where, when and how to move materials, considering the supply and demand [5].

There are different logistic solutions to ensure the internal supply of materials in factories. Milk-run process is a solution commonly used in production systems due to its successful results in providing waste reduction [5, 6]. Milk-runs can be used for internal supply, allowing an efficient distribution of different resources (raw-materials, consumables, semi-finished products, etc) in small batches, from distinct locations, with standard routes [6, 7]. Thus, milk-run systems contributes to reduce the seven types of waste, mainly transport waste, wasted waiting time, and wasted stock [6]. Besides the Milk-run processes, there are several methodologies and tools for reducing and eliminating waste, such as the PDCA methodology [8]. Developed by Edwards Deming in the 1950s, this quality tool is especially useful for promoting continuous improvement [9]. The method is defined by four steps - Plan, Do, Check and Action - and its implementation aims to improve the quality of processes and products [8]. Also, PDCA cycle is focused on the continuous learning and the knowledge creation [8]. The first step of this cycle is *Plan* stage. In this phase, the improvement opportunities are identified and the priorities are defined. Likewise, the goals are settled and the processes to achieve specific results are planed [8, 9]. In the *Do* phase, the action plan developed in the previously step is implemented, selecting and creating an information document [8]. The third step is the *Check,* where all the results are analysed, through a before-and-after comparison to verify if there were improvements and if the goals were achieved [8]. The last step of the PDCA cycle is the *Act* stage, where an action plan is created to improve and standardize the achieved results [8, 9]. There are many quality tools used as support to the PDCA cycle, as 5S, brainstorming, checklists, the flowchart and Six Sigma tools, that provide the supplier–input–process–output–customer (SIPOC) matrix and control charts [8, 10].

There are several applications of the Deming cycle in different sectors of industry. Recently Mantay de Paula & Feroni [11] applied the PDCA cycle and a Milk-run system in reverse logistics process for food industry. According to the authors, the PDCA methodology contributed to solve problems related to customers dissatisfaction with reverse logistics processes, facilitating the identification of the problem's root causes. The study describes the milk-run system efficiency as a solution in returning process of goods. The four stages of PDCA also allowed the control and the management of all returned tax invoices and their respective goods. As consequence, the reverse logistics process became faster, resulting in higher levels of customers satisfaction, increased product reuse rates and reduced reverse freight costs. In the automotive sector, for example, Nabiilah *et al.* [12] used the PDCA cycle to improve the quality of the electrodeposition painting process, in order to reduce operating cost and time. By applying the PDCA cycle, the authors evidenced the most frequent defects and the solutions that were implemented to improve work process quality. By reducing the amount of sanding process, the time spent on this activity was reduced, resulting in: a reduction of 33% in man-hours, a 37.5% reduction in labour and a 50% reduction in the consumption of sandpaper disc. These results represent cost savings of, approximately, 797€ in the sanding disc consumption of the and 7.18€ in the man-hour costs.

Bringing these concepts together, the objective of this paper is to explore the use of the PDCA cycle as a tool for Lean Thinking application, by demonstrating that simple and economical approaches can also be effective, and it can contribute to the improvement of a logistical process for internal supply. The paper is organized in five sections. After a brief introduction, section two describes the methodology and the case study framework. The Lean tools implementation was caried out considering the PDCA four steps application, which are presented in section three. The results validation and the main conclusions are presented in section four and five, respectivelly.

2 METHODOLOGY AND CASE STUDY DESCRIPTION

This study is of descriptive in nature, classified as a case study and developed through observation and data collection in loco [13]. The research conducted within the industrial context at automobile sector, specifically, in a company dedicated to the production of electromechanical components for vehicles.

The PDCA methodology was applied as a guide for the project implementation. The case study was carried out between October 2020 and April 2021, with focus on the analysis of the supply process of one of the assembly lines, designated from now on as line Y. By applying all the benefits of Lean, it was determined the optimal cycle time of the internal supply process, the milk-run supply process was standardized, and the materials and people movement flows were optimized.

The company has an in-plant milk-run system for internal supply, to deploy deliveries of different materials in small batches, from a central storage area to distinct production locations, with predetermined cycle times and standard routes. Based on the JIT (just-in-time) concept, only the materials that have been consumed are restocked. This enables higher vehicle loading rates, low inventory levels and more accurate delivery, maximizing the efficiency of continuous-flow manufacturing cells. Adapting this concept, the company uses this milk-run method to supply the assembly line and to the reverse logistic processes, carrying residual materials, as plastic boxes, and other packaging, as well as reusable materials that have an internal flow, as injected plastic parts trays. Despite the well-defined logistic train route and the use of the supply vehicle to carry out complementary activities of the production, a detailed analysis of the line Y supply process showed several improvement opportunities.

3 PDCA-BASED APPROACH IMPLEMENTATION

The tools were applied following the PDCA cycle steps. The strategy for its application was to effectively identify and measure environmental wastes in the materials flow of the assembly line to then formulate and undertake suitable methods to optimize the supply strategy.

3.1 Phase 1: Plan

This phase was carried out between October 2020 and November 2020. The initial stage of the assembly line supply was identified, and, after the identification of improvement opportunities, strategies were defined for the optimization of the milk-run process. To help the understanding of the process, a SIPOC (supplier, input, process, output, and customer) matrix was developed. As disclosed by Table 1, two main improvement opportunities are identified: (1) the methodology to supply the logistic train and the assembly line; and (2) the management of both residual and reusable materials.

Table 1: SIPOC matrix to identify improvement opportunities.

Suppliers	***Inputs***	***Process***	***Outputs***	***Customers***
Supermarket	Materials to transport	Supply the logistic train with material	Stocked logistic train	Logistic train
Logistic train	Availability of materials to the assembly line	Supply the assembly line	Stocked assembly line	Assembly line
Assembly line	Residual materials and reusable materials	Supply the logistic train with residual and reusable materials	Logistics train loaded of residual and reusable materials	Logistic train
Logistic train	Residual materials and reusable materials	Discard of residual materials and return of reusable materials	Discarded residual materials and returned reusables	Availability of residual material and reusable material

The cycle time was stratified (Figure 1), dividing the process into supply activities, reverse logistic activities, and the number of movements. To determine the optimal cycle time for the milk-run process, it was decided to develop a simulator in MS Excel, by collecting the data of the assembly line operation from RFID controller. Data collection was based on a sample of 30 observations, randomly performed, half in the morning shift and the remaining in the afternoon shift. It was also necessary to perform a motion study analysis based on the movement diagram of the assembly line to identify possible wastes at the supply process.

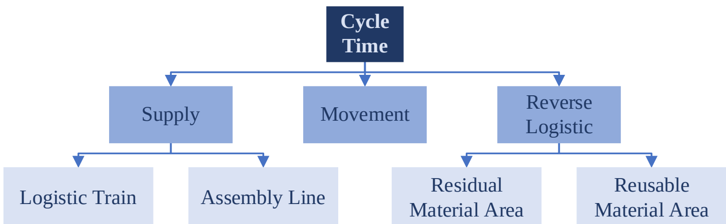

Figure 1: Stratification of cycle time in the milk-run supply process.

To organize the workspace and increase the quality of work processes, it was decided to apply visual management and to use the 5S methodology. This was applied on the assembly line and on the logistic train. To guarantee the standardization of the process, the logistic train operators were instructed to keep the improvements and the correct process.

3.2 Phase 2: Do

At this stage, that happened between November 2020 and January 2021, the information and data needed to determine the optimal cycle time of the milk-run supply were collected and the simulator in Microsoft Excel was developed. This simulator considered the assembly line settings, specifying the batches of materials to be transported by logistic train at each cycle. From the simulation program and with the defined cycle time, a new work pattern was determined according to the needs of the line, promoting the process normalization and the movement waste reduction.

The 5S methodology was applied both to the assembly line and to the logistic train, to optimize the workspace and to reach the company’s strategic goals. This process used tags for visual management in the supply tasks performed by different operators. On the assembly line, the excess material that contributed to wastes was removed. Visual management was also used to identify workstations that required two supplies per cycle, delimiting the maximum quantities of batches in the supply process, as well as defining extra positions for support material for the assembly line.

In the logistic trailers, the 5S was implemented to facilitate the visual management and to restock the vehicle, resulting in a more agile shift change, reducing wastes of overproduction, transport, movements, and stock. According to the simulation results, the most used materials in the production line and the necessary quantities per supply cycle were determined, fixing positions for those that are most frequently used. The allocation of materials in the milk-run trailers and the different fixed positions were validated with the operators to guarantee a maximum capacity of 80%, so the last trailer is always available for transporting residual and reusable materials. Finally, with the new specifications of the line supply process, the operators received specific training to learn the new procedures, the best practices, and the expected cycle time. The new procedures were properly documented to instigate the standardization.

3.3 Phase 3: Check

In this phase, that was carried out between February 2021 and April 2021, the milk-run supply process was analysed once again to confirm the cycle time and to evaluate the obtained results with the implementation of the improvements from the previous phase. To validate the implementations, a brief satisfaction survey was developed to understand how the changes were evaluated from the perspective of the operators as well as their impact in the productivity of the assembly line.

3.4 Phase 4: Action

In the last stage of the PDCA, that occurred at the ending of April 2021, after the validation of the improvements with the managers, an action plan was created to maintain the obtained results, regarding the continuous improvement of the supply process for the line Y and to bring operators and managers closer.

4 RESULTS ANALYSIS

The development of the project brought direct contributions to the company. First, the development of a simulation tool aiming to define the cycle time for milk-run supply processes allowed to determine the optimal cycle time of 1h10min for the process of supplying the assembly line Y. The creation of standardization for the assembly line supply process, along with the development of documentation for training operators have represented a reduction of 9%, in the average, of the cycle time practiced in milk-run. This result can be observed by comparing the control charts of Figure 2 and Figure 3 for the milk-run process before and after improvement tools implementation, respectively, those show the average cycle time, the average standard deviation and its upper and lower limits. The first control chart (Figure 2) was developed at the beginning of the project using historical data from the previous 9 months. It provided an insight about the instability of milk-run process. The second control chart

(Figure 3) was developed after the improvements implementation, corresponding to a 3 months period. Results showed that is possible to reduce the cycle time if the company keep the changes towards the optimal cycle time target.

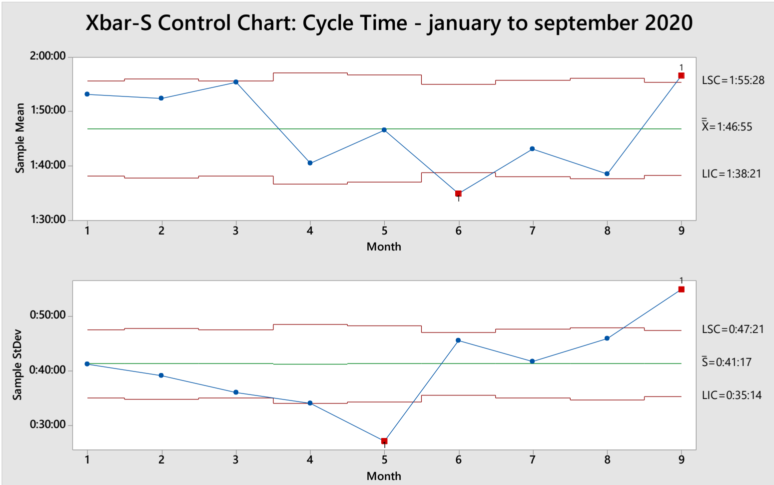

Figure 2: Control chart of the milk-run process before improvements.

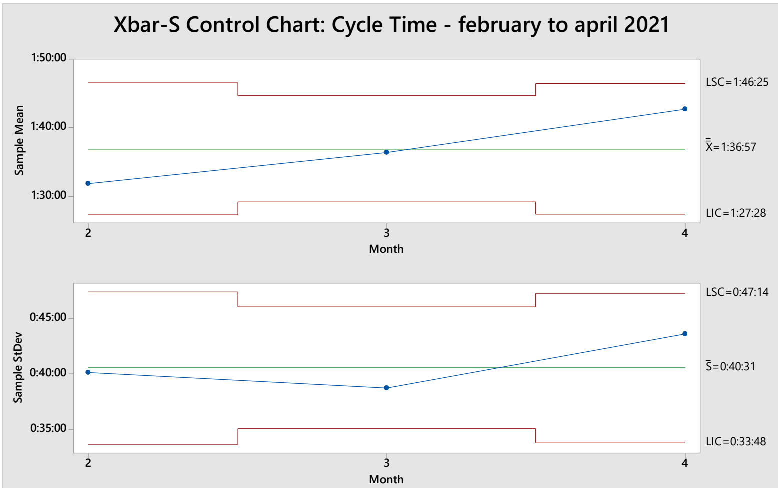

Figure 3: Control chart of the milk-run process after improvements.

Regarding the 5S implementation in the logistic train, it was verified a reduction of transportation and stock waste, mostly due the enhanced visual management, provided by new guidelines of milk-run trains organization. As can be observed by Figure 4, the employment of fixed storage positions of train logistic materials, resulted in the release of storage capacity.

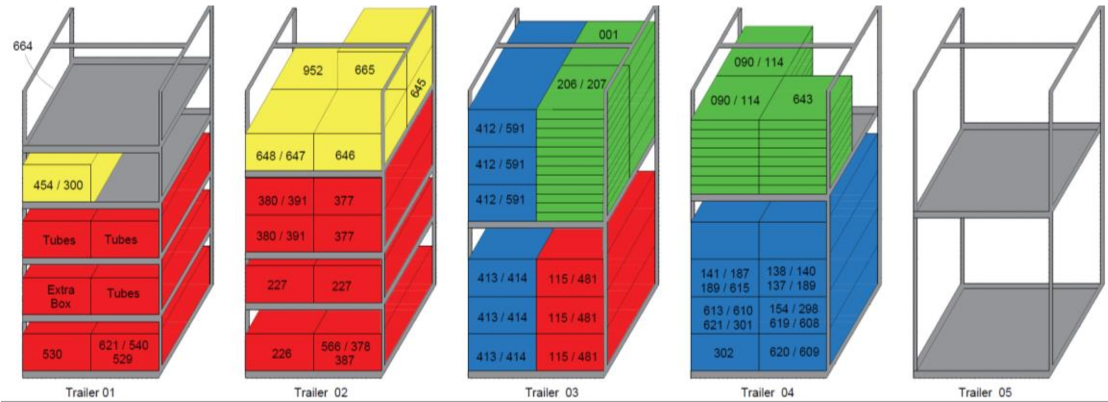

Figure 4: Fixed positions on milk-run train.

In the assembly line, the 5S tool resulted in the reduction of stock waste, by eliminating 2 856 pieces in intermediate stock, which corresponds to 9 220 €, and a gain of 1.92m^2 in the supply area, as well as improvements at visual management level and at materials packaging.

It was also estimated a reduction in terms of wasted movements in the production area, representing a reduction of 24%. In addition to the consequent improvement in productivity, this outcome has implications in minimizing the impacts of excessive movements on the operator's health. Also, it was observed an increase of job satisfaction, whereas it was registered a 32% increase of supply rate per minute.

5 MAIN CONCLUSIONS

The use of the PDCA as a guidance tool for the development of the project facilitated the detection and implementation of improvements. The use of quality tools allowed a broader view of the process and the application of simple, economical, and efficient solutions to improve the process, generating direct and indirect gains for the company. Continuous analysis and monitoring of supply by milk-run process are proposed, in order to reach and maintain the cycle time. The implementation of several Lean tools to the logistic supply on an integrated way, resulted in a reduction of wasted movements, release of storage occupation area as well as unnecessary intermediates stocks. The optimal cycle time for the supplying process of the assembly line was calculated as of 1h10min.

Acknowledgement

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ENHANCING ENVIRONMENTAL SUSTAINABILITY AND E-COMMERCE DELIVERIES THROUGH THE USE OF EPP BOXES IN A DARKSTORE

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Abstract: An unprecedented outbreak pandemic caused disruption around the world. It had a strong impact on economic sector. Although, the pandemic accelerated the growth of e-commerce for specific categories as food retailer. As a result, several companies restructured their structures, in terms of IT and operations. During the first confinement, the operations and the website of SONAE MC were not prepared for the increase that existed due to the pandemic, COVID-19, causing disruption in the supply chain and long lead times.
In this paper, it is explained how SONAE MC reduced its dependence on refrigerated vehicles, simplifying operations and reducing the costs of transporting products from online orders in vehicles with cargo space able to transport positive cold food and negative cold. It is also explained how innovation has ensured that products continue to be transported with quality and safety to all customers of the SONAE MC Darkstore. The result was the implementation of the proposed solution which may grow technologically once information and equipment are available.

Keywords: E-commerce, Transportation, Sustainability, Darkstore

1 INTRODUCTION

At the end of 2019, the world was exposed to an unprecedented event, a pandemic crisis that has cost high human losses characterized by a frightening speed of propagation. As the scientific community developed an answer, the economic impact was quick. Generally speaking, supply and demand decreased as a result of the closing of companies, as a measure to control COVID-19. The need for isolation and new human behavior quickly influenced the nature of business [1]. As result, the online commerce has increasing rapidly which has triggering problems along supply chains, which have been facing operational difficulties and capacity to respond. Within days, the Retail sector began to feel the pressure, increasing delivery times, reducing supply and overloading its technological systems.

In the first phase of the COVID-19 pandemic, we witnessed the purchase associated with panic, then, due to scarcity, the idea emerged that it was necessary to create stock, combining contradictory information. As a result, it was not difficult to observe the breakdown of supply chains all over the world. With the evolution of the pandemic, and the perception of its infectious severity, customers favored online channels for security reasons.

The sector of food retail was expanding in a structured manner with a focus on customer satisfaction and increasing the information spectrum throughout the entire supply chain. In

2019, the sector followed the growth trend of previous years with an EU-wide average of 10%, but 2020 exceeded all expectations with an average of 50%. [2]

Nowadays, people have less and less time and want everything as immediate and simple as possible. The retail industry responds to this reality with a continuous effort to reduce the complexity and the number of actions required by the consumer, from the moment the need arises to the purchase [4] [5].According to Deloitte's Global Powers of Retailing 2017 study, four trends are crucial for the food retail sector, namely the development of value-added digital skills; combining channels to make up for lost time; creating unique and engaging store experiences; the reinvention of retail with new emerging technologies [3].

In this scenario, E-commerce emerges as a good response to this reality, offering a wider range of products (including products that are not available in stores) and providing an unimpeded offer in terms of access, without the consumer having to worry about crowds, decisions transportation, weather conditions, and parking [6]. Also, the technological advances that have been witnessed in recent decades have led to a growing recognition regarding the possibility of online shopping [7]. Before the pandemic, the market was already expanding, it is evident that the convenience for the consumer to be able to buy what they need for their home online.

For instance, the growth of solutions such as Alexa or Siri, linked to the refrigerators and cabinets themselves, in the future with just a voice recognition, it may be even easier to order the items that are missing for the nearest dinner. However, the purchase of fresh items that lack a visualization and touch on the product, still suffer some resistance when buying them.

The advantages of shopping online are numerous, since you no longer spend your precious time to do other more productive tasks than daily going to a supermarket and being bombarded with stimuli to purchase items that are unnecessary or waste time to be with the ones you care about most, and it is evidently safer in times of pandemic. However, there is a need for robots that have an algorithm in your automation that allows you to understand the intensity of touch they should exert when choosing a particular food, nor the color to be easy to associate with the taste registered in the system by the customer (more mature or greener) . Today they are people who work daily to meet the needs of several people and sometimes the article may not come out in ideal conditions or according to expectations.

It is in this context, of the evolution of e-commerce in the retail sector, that the present investigation arises. This combines the need to increase the offer in the distribution channel (reduction of lead time), at the lowest possible cost in association with high levels of service. During the first confinement, operations and the site were not prepared for the surge that existed due to the Covid-19 pandemic. However, in the short term the case study company saw an opportunity related to the distribution of products packaged in positive cold (0º to 5°). This type of distribution requires refrigerated road vehicles, resulting in higher consumption of diesel, and its availability is lower.

Assuming that the costs of providing a service, which includes a driver and a vehicle, are three times higher when comparing a regular vehicle that can transport goods that need positive cold (0° to 5°C) compared to a vehicle that can only transport goods that are at room temperature. The focus on sustainability has increasing over the years, there is an alignment of the company's strategic plan with the 2011 White Paper [8] for the reduction of CO_2 emissions. The integration of a zero-emission vehicle is expected in the short term.

This paper aims to analyse how how SONAE MC reduced its dependence on refrigerated vehicles, reducing the costs of transporting products from online orders in vehicles. In doing so, aspects such as Savings in service provision costs with vehicles with EPP (Expanded Polypropylene) boxes; Savings on diesel costs (in refrigerated vehicles, diesel consumption is higher);Ensure better product quality; Reduce waste products when the delivery is not made; Cost savings in trading on a larger scale with non-refrigerated vehicles (the number of non-refrigerated vehicles increase, so the price per vehicle decreases) were analyzed in the light of the replacement of these regular vehicles. In order to meet these needs, delivery vehicles should have at their rear a truck body capable of receiving a refrigeration system that is directly linked to the vehicle's energy consumption, which in turn implies a greater consumption of diesel during the trip [10].

And a project that promotes the improvement of sustainability does not require an increase in costs. On the contrary, Competitiveness and Sustainability are sides of the same coin; as society strengthens the power of consumers, this relationship is a powerful weapon for innovation and value creation [5]. As is well known, one of the heaviest items in monetary terms of a supply chain manager, which involves the physical movement of a product from one point to another, is transport. For this reason, retailers, and online commerce struggle daily to reduce their costs per unit of movement, without penalizing product quality.

These cost savings must be higher than the investment costs in thermal plates, EPP (Expanded Polypropylene), and BLE (Bluetooth Low Energy) sensors, as well as the manual work of placing the products in these same boxes, associating, and disassociating orders from the respective sensors to obtain temperature tracking per order box. The objective of obtaining this tracking, in addition to the track record provided by the regulatory entity, is to enhance the possibility of in the future. EPP is a Polypropylene foam composed of a cellular structure that is created by the injection of an expanding gas. The consistency of the foam is divided into two different structures: a matrix composed of the polymer and a vacuum bag structure. [9] In EPP foams with a closed cell structure, the gaseous cells are completely encapsulated by the cellular structure created by the polymer, while in the open cell structure, the gas is not confined and is thus in contact through several passages [9]. The properties of EPP include good heat resistance, good chemical resistance and good characteristics as a thermal insulator. EPP does not absorb water but is nevertheless permeable to water vapor and other gases.

The document comprises an introduction which addresses the context, description, and objectives of the investigation.

In chapter 3 the Main Findings are presented, where it is possible to find out more about the company's dynamics and what led it to discover that it could innovate to reduce its ecological footprint and its costs in your operating account.

Finally, the last chapter makes some considerations about this investigation and the next steps for implementing the project at SONAE MC are presented.

2 METHODOLOGICAL APPROACH

This investigation was carried out in the SONAE MC group. In this company, orders are delivered daily to meet the requests of SONAE MC's online store. In these orders, all items must be transported at the required temperature (ambient, refrigerated, or frozen) so as not to lose their characteristics that give them quality or, in certain cases, lose the possibility of being consumed.

The study was developed based on the AS-IS/TO-BE process analysis methodology, starting with the analysis of the current situation, giving rise to the so-called AS-IS model. After its study and identification of inefficiencies, a set of improvements (translated into actions) are presented, thus exposing the desirable situation for the process, conceiving the so-called TO-BE model. The opportunity identified in the context of this research, is linked to the fact that it is necessary to increase the level of customer service at the lowest possible cost in a short period of time, which is why the refrigerated transport replacement project was created, which allows for a reduction in dependence on this type of vehicle, increasing fleet availability associated with cost reduction, on delivery to the final consumer, ensuring that the temperature is maintained throughout the supply chain [5] [3].

For reasons of confidentiality, no cost of SONAE MC will be disclosed. In this chapter, the logistical process within the Darkstore will be presented to understand the changes that had to be made in order to be able to implement the efficiency project.

3 MAIN FINDINGS

A Darkstore is composed of the following areas/departments:

- Reception – is responsible for ensuring the reception of items that are sent to the Darkstore from the Azambuja Distribution Center and the Support store. This department registers in the system all stock or order movement entries (parts of orders). At the end of the flow, reception also acts on the return of empty boxes and their respective cleaning near the loading/unloading docks.
- Picking - is responsible for ensuring the preparation of orders per customer in the following circuits: Sweet and Savory Grocery; Drinks (juices, water, wines, and spirits); Milk and eggs; DPH (Drugshop, Perfumery and Hygiene); Non-food (ironing boards, dishes); Fresh (Fruits & Vegetables, Delicatessen, Butcher and Fishmonger); Frozen.

Each of these circuits has its own team that alternates its area of action as needed. For each circuit there is an expected productivity for which employees compete with themselves in order to win a productivity prize.

Consolidation - At the end of preparation, the boxes of a given order, the CHEP boxes (boxes used for preparing items) are stacked by customer and route (the trip number defined by the router that aims to optimize the delivery of orders by different postal codes), in an area called expedition marshaling.

Shipping - is responsible for ensuring that orders are loaded in the correct order and that the number of boxes shipped is equal to the number of boxes prepared for that route (it's a manual process - still).

Replacement - is responsible for ensuring the replacement of items in the defined locations in order to avoid stockouts or process inefficiencies (example: return from stockout - order preparer returns to the position where the item was missing at the end of preparation or goes to another location of over, but that wastes more time in moving).

Quality Control - it is responsible for ensuring that the items that are sent to the customer are in the conditions defined by the central quality control, within the required validity period and at what temperature the cold transport vehicles leave and return.

In order to reduce all costs inherent to process, transport and product quality inefficiencies, this new process included the investment of two new tares (EPP boxes) where it was necessary to create new functions/tasks within the Darkstore.

Figure 1 presents in a macro way, how the Darkstore layout is divided, identifying the areas related to the new process. During the explanation below, the final process that this research implemented will be analyzed in detail. The processes presented will only refer to positive cold and negative cold goods.

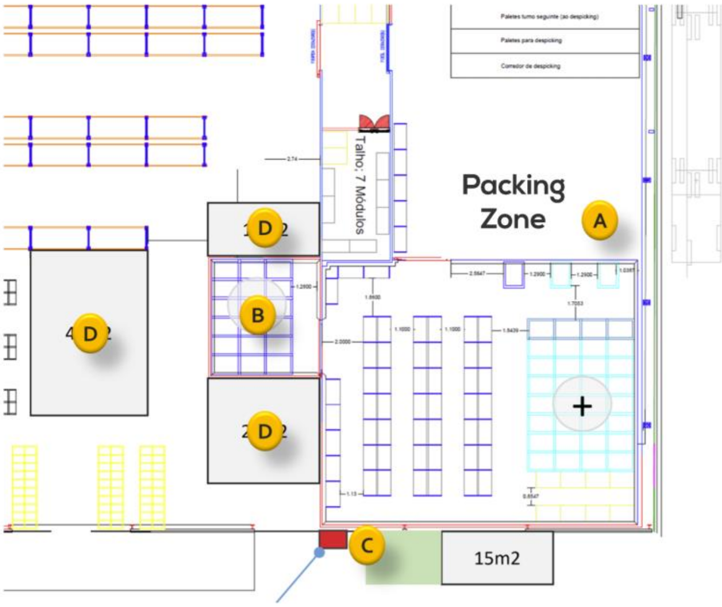

Figure 1. Layout of the process inside the Darkstore. Source: self elaboration

At the end of order preparation (positive cold), the orders are placed inside the respective EPP boxes together with the eutectic plates. This packaging is carried out in the identified zone A. The eutectic plates are supplied whenever necessary from zone B to zone A. In this packaging process, the process is as follows:

Step 1: Preparation of the EP Box - Opening of the respective EPP box and placing a eutectic plate, also corresponding to the type of box at its interior and a plate on the lid.

Step 2: Product Placement - Products from a particular order box (each order can have multiple order boxes) are placed inside the EPP box.

Step 3: Order Tag change location - The order box contains a label that identifies, in addition to its order box identification, the respective order (master) and associated route information. This label is taken from the old box where products are placed during preparation (green CHEP box) and placed in a plastic bag in the respective EPP box.

Step 4: Order Association to EPP box - Through the application created for this research, the process of associating orders to the respective EPP boxes is followed. In this process, the employee must enter the cold box application, choose the option associate order, and then read the bar code of the EPP box and prick the order box code. After entering both codes, the employee must press the associate button.

Step 5: Shipping the boxes - Then, the boxes are taken to the dispatch marshalling to a position identified with its route number. They are stacked in towers that can contain the three different types of temperatures for the same order. When leaving the Darkstore, the number of boxes is counted for future validation on its return. This process also facilitates the driver's work when he arrives at the customer's house and must identify the respective order. Instead visiting two spaces with different temperatures to collect order boxes, now the same order is stacked in 1 or more columns together. When the driver returns to the Darkstore with empty EPP boxes or with product, they are placed in zone C.

Step 6: Verification of number and status - Verification of the number of EPP boxes and their external status. If any box is missing, an alert is triggered to inform the logistics partner. Physical separation of Refrigerated EPP and Frozen EPP boxes, to avoid storage of different boxes in the same place. Checking whether the box contains one or more undelivered items.

Step 7: Checking Current Temperature - If the box has product, the employee who is carrying out this process must have a Zebra ZT57 terminal with him to check if the temperature is within the temperature. Use the app to perform this instant collection.

Step 8: Replacement of the item as in stock - In case it is at a temperature according to this article, it returns to its stock position, avoiding food waste and breakdown costs.

Step 9: Placing the plates back into freezing - The eutectic plates are removed from the boxes and placed in the respective dolis of each type of plate. These, when full, are transported by the wheels that support them to the freezing chambers located in zone B.

4 CONCLUSIONS AND FUTURE RESEARCH

The pandemic scenario we are currently experiencing has bringing to the acceleration of these type of solutions, not only because more online commerce is consumed in its chain with solutions identical to the ones we have seen throughout this paper, but also in the backpacks of the stores. The combination of new technologies that allow collecting information about the product, the implementation of new products for transport (frozen and fresh) and the replacement of vehicles accelerated the growth process of the company's e-commerce channels, allowing for a better level of service , increase operations capacity and a reduction in financial and environmental costs.

This paper is part of an ongoing work, the authors are now proceeding to the replacement of the fleet of electric vehicles continuing the company's policy to contribute to environmental sustainability, using less resources in the process of delivery the products to the consumers,

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METHODOLOGICAL FRAMEWORK FOR MEASURING REGIONAL LOGISTICS PERFORMANCE

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Abstract: This research aims to contribute to bridging the gap between the connection of logistics and regional development. Firstly, based on the available literature, the contribution of logistics to socioeconomic development was analyzed, and having in mind the importance of Regional Development for economic and social development, this research brings to the light the importance of logistics activities to regional social development, and framework to assess these connections is proposed. Then a framework comprising a set of indicators to evaluate logistics performance was proposed. As a main result, a framework for the assessment of regional logistics performance is proposed together with several logistics performance indicators to assess the impact of logistics on regional development.

Keywords: Logistics, Regional development, Indicators, Framework

1 INTRODUCTION

The emerging debate about the development of policies and initiatives devoted to Regional D Development (RD) has been increasing over the years. It can be justified due to available policies did not take effective responses to the current needs of different regions.

In this regard, it is imperative considering the characteristics of each region as well as the goals to be achieved. According to Pike *et al.*, [1] economic development is not an objective in itself, but only a way to achieve well-being. Over the last decades, regional well-being has become a common concern for several countries worldwide. Regional Development allows countries to better balance regional differences by providing communities with the means to prosper [2]. According to OECD [3], RD is a broad term, but it can be seen as a general effort to reduce regional disparities by supporting economic activities (employment and generating wealth) in the regions. This definition is corroborated by Bærenholdt [4], who states that RD is the effort to developing countries in a socioeconomic context.

According to Karayun and Caiming [5], [6]logistics is considered as one of the most important strategic sectors of the 21st century. The authors defends that there is a strong positive relationship between the logistics development and the economic growth in several countries, such as China and Brazil.

This sector has been contributing to RD, through providing companies competitive advantage in their supply chains. In doing so, logistics can be considered as activities that contributes to promote the development of a region. Economic globalization and the social division of labor have transformed logistics into a sophisticated organization and an increasingly important and strategic management technology in the region's economic development [7]. In the light of these views, namely the importance of logistics activities to RD, this research proposes an integrated framework comprising a set of logistics indicators, based on the relevant literature in this topic. In the current literature works such as Gozacan; Khan et al., and Aislu et al., [8]–[10] have been focusing on developing logistics indicators, yet, they do not focus on regional development, which persist as a gap in the literature. This research is divided as follows. Section 2 presents the methodological approach used in researchy. Section 3 demonstrates the main results focusing on the framewor proposed and the indicators for measuring logistics performance . Finally, the last section presents the conclusions and suggestions for future lines of research.

2 METHODOLOGICAL APPROACHES

In this research, the conceptual framework to measure regional logistics performance at organizational level uses the combination of different stages. The design of the proposed framework includes several methodological stages. The work began with a (1) literature review considering two main areas, namely logistics and regional development. In this stage, key aspects related to logistics and RD were analyzed, and were used as the main source of data to design the proposed framework for analyzing regional logistics performance. Then (2) the selection of set of regional logistic indicators which aims to be used as measures for assessing regional logistical performance was conducted. From the scarce literature available, this work aimed to (3) identify the key logistics indicators which can contribute to socio-economic development.

This is the first attempt to (4) develop a methodology that will allow in the future to evaluate the performance of logistics at a regional level. Finally, the main conclusions of the work and suggestions for future research are presented.

3 PROPOSED FRAMEWORK FOR MEASURING REGIONAL LOGISTICS PERFORMANCE

The development of the framework structure contains 3 distinct phases divided into several sequential steps that encompass the following topics:

1. Literature review.
2. Survey of logistics indicators.
3. Definition of criteria for the selection of indicators.
4. Preliminary list of selected indicators.
5. Selection of a set of companies to validate the previously selected indicators.
6. Validation of indicators.

As shown in Figure 1, the first phase, literature review, is based on research of scientific works and publications, it serves as basis for phase 2, which focus on LPI indicators. In this second phase, through the information obtained in the previous phase, interviews, questionnaires, focus group can be designed as tools to allow the identification of the logistics performance indicators that will be part of the framework. After identifying and classifying the indicators, the third and last phase, the logistics performance analysis, begins, focusing on the indicators previously identified in the development phase. Finally, based on the Framework, the intention is to identify the main gaps found at the level of regional logistics. Then, the evaluation tool that can be used to validate the performance of the indicators.

The dimensions of the logistical indicators were constructed based on the LPI (Logistic Performance Index) questionnaire adapted to the regional dimension.

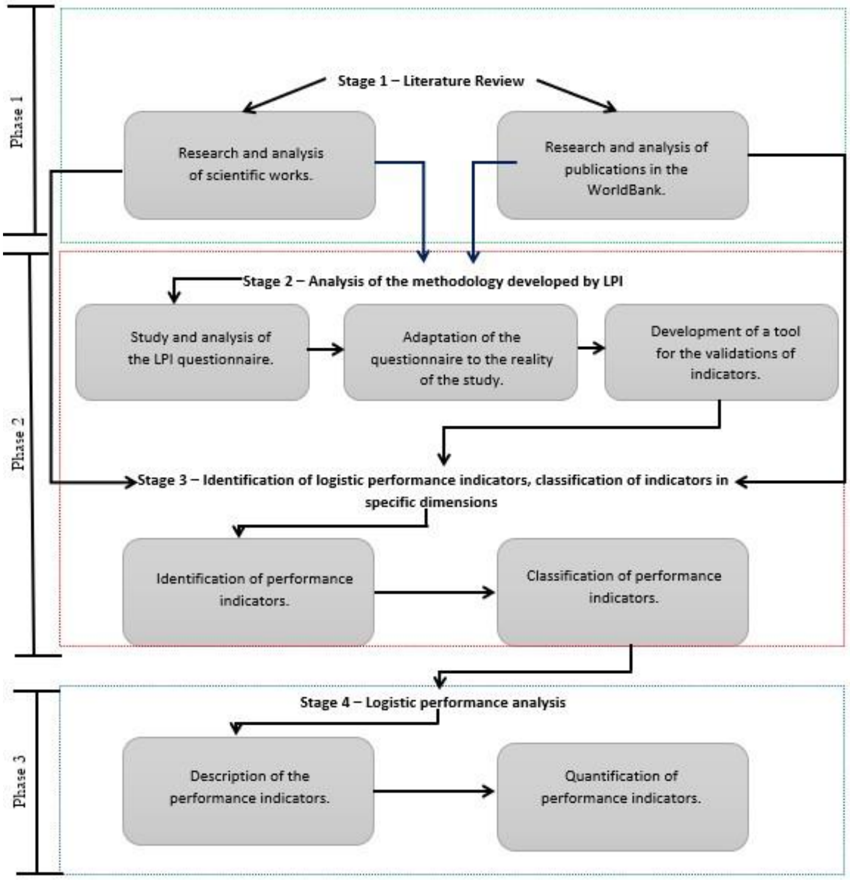

Figure 1: Framework for logistics performance.

Finally, the third and last phase of the Framework, presents the analysis of logistics performance. In this last stage, after obtaining the answers of the questionnaires, the value of each logistic indicator for each dimension will be calculated, which will allow the analysis of the logistical performance of the region. As previously mentioned, the framework was divided into 3 phases as summarized in Figure 5:

Phase 1: Literature review

- Analysis of scientific literature on performance indicators and regional development.

Phase 2: Identification of indicators for logistics performance

- Analysis of the methodology of the LPI
- Selection of a set of performance indicators that can be used and adapted to the reality of the work context (based on previous phase).
- Classification of performance indicators by dimension.
- Development of the questionnaire adapted to regional context, considering the indicators selected in the previous phase.

Phase 3: Logistic performance analysis

- Description of performance indicators by dimension and its way to measure.
- Analysis of regional logistics performance, transforming the answers obtained in questionnaires on a Likert scale from 1 to 5 and making their average.

After the development of the framework, the next topic addresses the assessment tool used in the development of performance indicators. Based on the phases presented in the previous section, a set of indicators were selected and grouped into 6 dimensions. The indicators presented in this section serve as an initial proposal to assess regional logistics performance. The table presented below are based on the methodology proposed by the LPI. It was used due to the methodology has already been validated and used in an international context. The selection of indicators has considered the context in which the companies are inserted, namely, the advantages of applying this type of methodology in the regions, and the potential that a set of indicators can do in favor of the development of the companies and regions where they are located. Table 1 presents the different dimensions for each set of indicators, namely infrastructures, tracking and tracing of goods, customs aspects, punctuality and logistics competence, regional and international shipping, and quality of logistics services. For the infrastructure dimension, 6 indicators were selected. The objective of this dimension is to analyze the conditions of the infrastructures of the companies at the regional level and to evaluate whether the companies evaluate parameters such as the breaks and obsolescence and the complaints of the customers.

Table 1: Logistics performance indicators. Source adapted from LPI World Bank (2018)

Infrastructure indicators		How to measure
I1	Percentage of companies with implemented logistics performance indicators.	(Number of companies with performance indicators implemented / Total number of companies) * 100
I2	Percentage of companies with industrial management software (Ex.: PR, WMS).	(Number of companies with industrial software implemented / Total number of companies) * 100
I3	Percentage of companies that have established loading and unloading schedules.	(Number of companies with loading and unloading hours / Total number of companies) * 100
I4	Percentage of companies with implemented reverse logistics initiatives.	(Number of companies with implemented reverse logistics initiative / Total number of companies) * 100
I5	Percentage of companies that measure breaks and obsolescence.	(Number of companies that measure breaks and obsolescence / Total number of companies) * 100
I6	Percentage of companies that measure customer complaints.	(Number of companies that measure customer complaints / Total number of companies) * 100

Regional and international shipping indicators		How to measure
RIS1	Quality assessment of regional road, rail, sea, air, storage, and regional ICT infrastructures.	Very weak; Weak; Satisfactory. Good; Very good
RIS2	Quality assessment of road, rail, sea, air, storage and international ICT infrastructures.	Very weak; Weak; Satisfactory; Good; Very good
RIS3	Number of documents needed to receive merchandise internationally	0 to 2; 3 to 5; 6 to 10; More than 10
RIS4	Number of documents needed to receive goods domestically	0 to 2; 3 to 5; 6 to 10; More than 10
RIS5	Number of documents needed to send goods domestically	0 to 2; 3 to 5; 6 to 10; More than 10
RIS6	Number of documents needed to send goods internationally	0 to 2; 3 to 5; 6 to 10; More than 10

Timeliness Indicators		How to measure
T1	Import shipments shipped and delivered on schedule	Never; Rarely; Sometimes; Oftentimes; Ever
T2	Export shipments shipped and delivered on schedule	Never; Rarely; Sometimes; Oftentimes; Ever
T3	Delays due to pre-shipment inspection	Never; Rarely; Sometimes; Oftentimes; Ever
T4	Delays due to sea transshipment	Never; Rarely; Sometimes; Oftentimes; Ever
T5	Delays due to mandatory storage/transshipment.	Never; Rarely; Sometimes; Oftentimes; Ever

Customs Indicators		How to measure
C1	Efficiency in transparency in customs clearance	Never; Rarely; Sometimes; Oftentimes; Ever
C2	Efficiency in transparency in the release of goods at the border	Never; Rarely; Sometimes; Oftentimes; Ever
C3	Classification of the competence of customs brokers	Never; Rarely; Sometimes; Oftentimes; Ever
C4	Classification of the competence of customs agencies	Never; Rarely; Sometimes; Oftentimes; Ever

Quality indicators of logistical services		How to measure
QILS1	Receiving timely information on regulations	Never; Rarely; Sometimes; Oftentimes; Ever
QILS2	Experiencing criminal activities (stolen cargo)	Never; Rarely; Sometimes; Oftentimes; Ever
QILS3	Percentage of companies that evaluate the quality of logistics services.	(Number of companies evaluating the quality of logistics services / Total number of companies) * 100
QILS4	Classification of road, rail, sea, air and storage and transport service providers.	Very low; Low; Satisfactory; Good; Very good
QILS5	Monthly collection of port and airport taxes; highways; railway; service and agent service.	0 to 5 times; 6 to 12 times; 13 to 20 times; 21 to 30 times; More than 30 times

Tracking and Tracing Indicators		How to measure
TT1	Average distance of shipments/receipts	Up to 20 km; Up to 100 km; Up to 700 km; More than 700 km
TT2	Export activities	(Number of companies with international shipments / Total number of companies) * 100
TT3	Tracking of shipments by the company	(Number of companies that track / Total number of companies) * 100
TT4	Number of companies using other means of transport than road	(Number of companies using other means of transport than road / Total number of companies) * 100

For the Tracking and Tracing dimension, 4 indicators were selected. Table 1 shows the indicators selected for this dimension. This dimension aims to analyze whether companies in

the region track their goods shipped as received goods, identify the main modes of transport that companies in the region handle and which are the main markets in which they operate.
For Regional and International Shipping dimensions, 6 indicators were selected. Table 1 shows the indicators selected for this dimension that aim to assess the competence and quality of the different logistical services provided in the region and the country, at the level of regional and international shipments and infrastructure.

For the dimension of Customs aspects, 4 indicators were selected. Table 1 shows the indicators selected for this dimension that aim to assess the main difficulties that companies face in terms of the release of goods at customs and borders and how they evaluate the services provided by these logistics agents.

For the Timeliness dimension, 5 indicators were selected. Table 1 shows the indicators selected for this dimension that aim to assess whether companies experience delays in receiving and sending goods.

For the dimension of Quality of Logistical Service, 5 indicators were selected. Table 1 shows the indicators selected for this dimension, which aim to assess whether companies receive timely information about changes in regulations, experience control load theft, how service providers classify and the times they are charged fees for logistical services.

After selecting the indicators referred to in Table 1 an evaluation tool should be carried out, which can be used by companies as an initial attempt to evaluate its logistics performance in a regional level. This tool aims to verify whether companies have difficulties in answering questions and will make it possible to validate the proposed logistical indicators. This work is part of an ongoing work, the results presented here are a summary of the first outcomes from the literature. In the next step the authors developed a questionnaire to be used as tool to validate the proposed indicators through a set of companies in Portugal. The questionnaire was designed inspired by the Logistics Performance Index methodology. This tool aims to verify whether companies have difficulties in answering questions and will make it possible to validate the proposed logistical indicators.

5 CONCLUSIONS AND FUTURE RESEARCH

In this research, logistics activities and RD were discussed behind economic and social aspects**.** The work was based on a review of the scarce literature concerning logistics and RD. The conclusions presented in this section summarizes the novelty of this research, which lies in two main aspects, namely, bringing to the light the need for further discussion concerning the contribution of logistics activities to regional development; and the importance of developing frameworks to support companies and regional governments on measuring logistics performance at regional level. Due to the lack of research matching these topics, the research attempted to analyze data from governmental reports and scientific literature. The results of this research showed that indicators presented here can be considered as key measures to evaluate the contribution of logistics activities for different regions. If applied as good practices between companies supported by stakeholders, it can be used as positive leering process as well a benchmarking strategy among regions in a micro and macro level. As a main result, a framework for the assessment of regional logistics performance is proposed together with several logistics performance indicators to assess the impact of logistics on regional development.

The results presented here is part of ongoing work, aiming to demonstrate the benefits of logistic activities to RD. Although being initial research, the approach used here is essential for future developments integrating logistics into socio-economic development. The authors are now proceeding to develop a model resorting to a set of logistic indicators to be used in a real case with a set of companies from a region in Portugal, aiming to understand their logistics behavior in the different regions.

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VOLUNTEERING IN HUMANITARIAN LOGISTICS: A STRUCTURAL EQUATION MODELING

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Abstract: Humanitarian logistics uses logistic concepts to respond to the countless assists, minimize the improvisations and be effective, in terms of response time. The role of the volunteers is crucial to the efficiency of all the logistic processes. Thus, the volunteer managers need to understand how to capture and motivate the volunteers for humanitarian causes. To perceive the volunteers' motivations, a survey was developed for a food bank. A Structural Equation Modeling (SEM) was implemented, that enabled the simultaneous examination of a series of interrelated dependence relationships between the measured variables and latent constructs.

Keywords: Volunteering, Humanitarian Logistics, SEM, Human Capital, Social Capital, Physical and Economic Capital.

1 INTRODUCTION

Based on the understanding of the International Federation of the Red Cross, Nogueira *et al.* [12] define humanitarian logistics as processes and systems involved in the mobilization of people, resources, and knowledge to help vulnerable communities affected by natural disasters or complex emergencies. It intends to respond to a large number of people, avoiding waste. At the same time, acting within a limited budget, organize the various donations received.

From all the resources needed, the human resource is of the utmost importance, since the people that practice humanitarian logistics are almost all volunteers, who donate their time to help others and don't demand any payment for that.

The defining features of volunteerism as voluntary, sustained and ongoing helpfulness suggests that it may be interesting to inquire about the motivations that may dispose individuals to seek out volunteer opportunities, to commit themselves to voluntary helping, and to sustain their involvement in volunteerism over extended periods ([4], [11]).

Clary *et al.* [3] identified six different motivational functions: social, value, career, understanding, protective and esteem and presented an inventory designed to measure these motivations and provided recommendations for volunteer administrators who seek to increase the number of people who volunteer and to improve their human resource management. Wilson and Musick [16] construct an integrated theory of formal and informal volunteer work based on the premise that volunteer work is (1) productive that requires human capital, (2) collective behavior that requires social capital, and (3) ethically guided work that requires cultural capital. They estimate a model in which formal volunteering and informal helping are reciprocally related but connected in different ways to different forms of capital.

The International Labour Office, in Geneva, elaborate the "Manual on the measurement of volunteer work" [6] and they refer that volunteer work delivers significant benefits to society and the volunteers themselves such as economic impact; provides important employment training and access to the labor force; enhances social solidarity, social capital, political legitimacy and the quality of life in society; can help to promote social inclusion and integration and gives the volunteers themselves a sense of personal satisfaction, fulfillment, wellbeing and involvement in society. Also, the Institute for Volunteering Research developed the Volunteering Impact Assessment Toolkit in late 2004 to help organizations undertake their research to assess the impacts of volunteering, categorizing these impacts into five key capitals [13]: Economic capital; Physical capital; Human capital; Social capital; and Cultural capital.

Miller [10] describes the student volunteers' perceptions of the impact their volunteering in a Medical Center. It divide on human capital (acquisition of skills and personal development), social capital (creation of relationships, building strong bonds, and networking), physical and economic capital (professional skills to enhance future career path), and cultural capital (new perspectives of different cultures). Recently, a wide number of research publications have been dedicated to addressing the issue of volunteer satisfaction and its dependence on motivation ([1], [5], [11]) related to these dimensions.

Food banks are not-for-profit organizations that aim to minimize the hunger problem in society by working with contributors on the upstream and associations on the downstream of their supply chains. These organizations operate in highly complex environments due to the uncertainties associated with supply and demand [2]. The use of volunteers is a huge challenge for these organizations since this human resource doesn't demand payment but adequate motivation.

In this research, it is intended to observe the principal motivations and expectations of the volunteers in a food bank, located in the north of Portugal, on the dimension: Human Capital, Social Capital and Physical and Economic Capital. To understand the relationship between these expectations, a Structural Equation Modeling approach was performed.

2 METHODOLOGY

The methodology used in this research was quantitative, with a survey applied to the volunteers of a Bank Food against Hunger located in the North of Portugal. The main objective was to analyze the motivations of the individual that give their free time to help others.

The survey is composed of two parts: one related to socio-demographic characteristics of the volunteers aiming to sketch a volunteer profile [15]; a second part is concerned with the personal motivations to practice volunteering, giving focus on the three dimensions previous explained (Human Capital, Social Capital and Physical and Economic Capital). This last part was adapted from Miller [10] work, and a five-point Likert scale was used (where 1 - Decreased a lot; 2 - Decreased; 3 - Stayed the same; 4 – Increased; 5 - Increased a lot) for several items per dimension (see Table 1). The choice of latent variables corresponding to the Miller works, as the observed variables were selected/adapted from the food bank reality.

To analyze the survey, a set of tools under the Structural Equation Modeling (SEM) was used. SEM is a confirmatory approach to data analysis involving a priori assignment of inter-variable relationships [17]. SEM approach is composed of two parts: a measurement model, which contemplates the relationship between the latent factors and the observed variables, and the structural model that produces the path direction and strengths of the relationship between the latent variables [9]. Model fit was assessed using several goodness-of-fit indices, namely the ones suggested by Hu and Bentler [8]: Mean Square Error of Approximation (RMSEA < 0.06), Standardized Root Mean Squared Residual (SRMR < 0.80), and a Comparative Fit Index (CFI>0.95).

Table 1 –Human developing measures for the volunteering

Latent variable	*Observed variable*	*Item description*
Human Capital	H1	Confidence in my abilities
	H2	Sense of self-esteem
	H3	Sense of self-management
	H4	Sense of making a useful contribution to the community
	H5	Awareness of the effects of my actions on the others
	H6	Sense of motivation
	H7	Willingness to try new things
	H8	Trust in other people
	H9	General well-being
Social Capital	S1	Ability to communicate with other people
	S2	Social and interpersonal skills
	S3	Friendships
	S4	Support networks
	S5	Sense of community
	S6	Interest in volunteer work
Physical and Economic Capital	PE1	Direct access to training/learning related to a future career
	PE2	Direct access to experience related to a future career
	PE3	Ability to use my skillset
	PE4	Recognition received
	PE5	Ability to get a job
	PE6	Number professional contacts

3 RESULTS AND DISCUSSION

The sample is a convenient one, having obtained 144 completed surveys, distributed by volunteers in the warehouse, and collected in supermarkets during a weekend of the food collection campaign. The statistical analysis was performed in IBM SPSS and AMOS, vs 27.

3.1 Descriptive Statistics and Principal Component Analysis

The sample had both genders (60% female and 40% male), where most of the volunteers are under 30 years old (60%), and 16% have more than 50 years old. Only 19% of inquiries have bachelor or higher education, while 44% and 37% have a middle and high school, respectively. Most of the volunteers are students (51%), and only 7% are retired. The remaining are employed. Most of the volunteers live near to the Bank Food (less of 30km distance).

The three dimensions for the volunteers' motivations were resorting to descriptive statistics and Principal Component Analysis (PCA), as Tables 2, 3, and 4 show.

Table 2 - Human capital: descriptive statistics, reliability, and PCA

Observed Variable	*Min*	*Max*	*Mod*	*Mean*	*St. Dev*	*Sk*	*Kurt*	*Cronbach's alpha*	Commu-nalities	Loadings	KMO Measure	Bartlett's test
H1	3	5	4	4.14	0.628	-.109	-.492	0.925	.688	.830	0.847	< .001
H2	3	5	4	4.08	0.687	-.101	-.861		.686	.828		
H3	3	5	4	4.19	0.622	-.155	-.520		.620	.787		
H4	3	5	5	4.47	0.579	-.538	-.659		.555	.745		
H5	3	5	4	4.30	0.606	-.253	-.604		.638	.799		
H6	2	5	4	4.30	0.661	-.556	.000		.685	.827		
H7	3	5	4	4.33	0.640	-.430	-.675		.590	.768		
H8	1	5	4	4.04	0.763	-.455	.408		.462	.680		
H9	3	5	4	4.27	0.641	-.316	-.678		.736	.858		

Table 3 - Social capital: descriptive statistics, reliability, and PCA

Observed Variable	*Min*	*Max*	*Mod*	*Mean*	*St. Dev*	*Sk*	*Kurt*	*Cronbach's alpha*	**Commu-nalities**	**Loadings**	**KMO Measure**	**Bartlett's test**
S1	3	5	4	4.22	0.675	-.294	-.809	0.892	.603	.777	.801	< .001
S2	3	5	4	4.13	0.678	-.172	-.816		.620	.788		
S3	3	5	4	4.20	0.701	-.299	-.935		.629	.793		
S4	3	5	4	4.04	0.736	-.067	-1.135		.658	.811		
S5	3	5	4	4.35	0.642	-.462	-.671		.733	.856		
S6	3	5	5	4.44	0.589	-.501	-.652		.658	.811		

Table 4 - Physical and Economic capital: descriptive statistics, reliability and PCA

Observed Variable	*Min*	*Max*	*Mod*	*Mean*	*St. Dev*	*Sk*	*Kurt*	*Cronbach's alpha*	**Communalities**	**Loadings**	**KMO Measure**	**Bartlett's test**
PE1	3	5	3	3.71	0.704	.484	-.870	0.918	.785	.886	.849	< .001
PE2	3	5	3	3.64	0.686	.609	-.713		.791	.889		
PE3	3	5	4	3.90	0.632	.079	-.477		.746	.864		
PE4	3	5	4	3.82	0.662	.215	-.725		.699	.836		
PE5	3	5	3	3.53	0.726	.984	-.416		.634	.796		
PE6	3	5	3	3.54	0.648	.792	-.403		.612	.782		

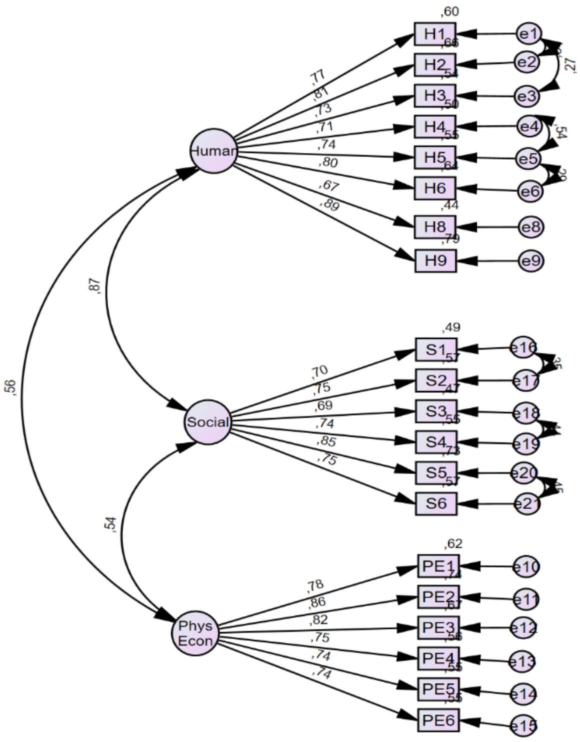
The minimum value of responses in most observable variables is 3, which indicates the experience was at least neutral or positive. Human and social capital dimensions (Tables 2 and 3) have means above 4 for all items, meaning that this experience increases their personal development. The responses related to physical and economic capital (Table 4) are lower, where mode and mean are located around 3**,** which indicates that volunteer does not produce significant effects for the physical and economical capital. One of the reasons could be the amount of very young volunteers, which are not thinking about economic aspects for the future.

The answers distribution for each variable is considered normal, taking into account the conservative approach of Kline [9]: the absolute values of skewness is less than 3 and the absolute values of kurtosis are less than 8. The scale reliability of studies by Cronbach's alpha; each latent variable reached values higher than 0.7, pointing out good internal reliability of the dimension [14].

A Principal Component Analysis (PCA) was conducted to understand the relationship between variables. The commonalities achieved allows the maintenance of almost all the variables in the analysis. Hair *et al.* [7] argue that a variable that presents communality below 0.5 should not be maintained in the factor analysis. In this research, only H8 didn't reach this value. It was an option to maintain due to the feeling (trust) entails in a volunteering practice. The factorial weights (loadings) indicate that all the items present high values and a positive correlation with the latent variables. Besides, the Kaiser-Meyer-Olkin (KMO) measure is near to 1 for all latent variables. Bartlett's test gives a significant level of less than 0.001, which indicates a possible relationship between observed variables.

3.2 SEM Approach

For the estimation of the measurement model of each of the constructs, the maximum was used the likelihood method. The first results generated did not show good fit indices. Table 5 shows the adjustment measures, which are based on the acceptance levels suggested by Kline [9]. Thus, there was a set of steps done to improve the model. Through the Mahalanobis distance, one observation was removed because it was considered an outlier. Item H7 shown the lowest results, and it was dropped from the model**.** Besides, modification indices were applied to improve the model's goodness-of-fit with evidence of misspecification associated with pairing error terms. The analysis of the modification indices suggested that there is a set of pairs in each construct that influenced each other. The new values demonstrated that the respecified model presented better levels of adjustment, as can be seen in Figure 1. Even so, one of the fit measures is not reached the acceptable level. However, removing more indicators or preparing new correlations between the links, could lead to a model misrepresentation.



Name of index	*Initial model*	*Final model*	*Level of Acceptance (Kline, 2005)*
Chi-square/df	2.39	1.63	< 5
RMSEA	0.114	0.077	<0.08
CFI	0.845	0.936	>=0.90
GFI	0.719	0.813	>=0.95

Figure 1 – Standardized coefficients and covariance (Final model)

Figure 1 shows the final model related to human development in volunteering practices. All coefficients are significant at 0.01 level, and the model indices indicate that fits well the data sample. All items have high factor loadings. There is a considerable relationship between human and social constructs (with a correlation of 0.87). Each standardized regression weights have a value higher than 0.66, each reinforce the presence of these items in the initial scale.

4 CONCLUSIONS

There are numerous challenges that the human being has to be able to respond to, namely his assistance in a correct manner and at an appropriate time, as only in this way is it possible for humanitarian logistics to be efficient. The results achieved by the model allow us to state that the reason for such behavior of the Bank Food volunteer can be explained by a set of interactions between these three constructs: human, social, and physical and economic capital. By modeling the structural equation, it was found that all the connections between the constructs are statistically significant. The inquiries agree that the experience is positive, and can contribute to improve their human and social capacities. These results are following the ones achieved by Miller [10], in a different context. The volunteers agree that gain more experience, more social connections, and more motivation to help to construct a better community. These could help in future fundraising for volunteers for the Food Bank campaigns to have more data to motivate other individuals to come and offer their free time.

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THE SOCIAL VALUE OF SPECIALISED HOUSING FOR OLDER ADULTS

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Abstract: In this paper, we developed a new modelling approach and to predict the social value of investments in specialised social housing, adequate for all EU Member States. From forecasting the different demands for different kinds of specialised housing as the social infrastructure for older adults which mitigates public expenditures for HC and LTC services, the multistate transitions are described, and actuarial present values (APV) are calculated. There are no documents by the European Commission for the same yet, although the Commission stresses the need to develop such a model. The model has been designed to support policymakers decide whether to increase the HC and LTC expenditure or to invest in this specialised housing for older adults as part of the social infrastructure.

Keywords: specialised housing; ageing; multiple decrements; actuarial present value; social value; Long-Term Care; public expenditures

INTRODUCTION

There is a contingency among housing and the independent living, autonomy and quality of life of residents since different living arrangements mitigate differential disability risks (Henning-Smith et al., 2018). Housing and public space in the vicinity where people live are essential determinants for the residents' safety, health and wellbeing, reducing health care (HC) expenditures. Therefore, sustainable development and investments in an age-friendly environment should be somehow evaluated from these aspects. There are many attempts to evaluate this using multicriteria functions [7], but the social value (SV) of specialised housing with proper solutions for the surrounding public space had never got an assessment as an increase of the actuarial present values (APV), which could also influence better insurance products. We aim to develop such a model to evaluate the SV of investments in specialised social housing and to apply it in the Slovenian development programmes. In the literature review of Age-Friendly Cities, we identified the following gaps and further research areas: (a) Optimization and control theory models supporting optimal planning, operations and control of services for older adults; (b) Model of the database for supporting supply networks, housing with care and lifetime neighbourhoods; (c) Model of valuating the social value creation with the development of supply networks and housing with care. Wood [14] has been researching the social value of sheltered housing by bringing together all the qualitative and quantitative data related to the savings generated by the residents of the sheltered housing and to the National Health System while lowering the demand for healthcare and social care services. This report shows that sheltered housing saves the UK's cash-strapped NHS and its social services at least £486m per year. But the author states that there does not yet exist a proper model that is aimed at social value creation through the development of age-friendly environments and housing stock; (d) Appropriate mathematical model, which would support the financial and fiscal mechanisms for the development of specialized housing with care does not exist yet as stated also by ILO [13]; (e) Human resources are not adequate for supporting supply and facility management of specialized housing with care. Therefore, also the education and employment policy will need to be developed [8].

SURVEY ON THE HOUSING NEEDS OF VERY OLD ADULTS IN SLOVENIA

A survey was conducted among 198 recipients of LTC, out of whom 100 recipients were from home care and 98 from nursing homes in four Slovenian municipalities. The caregivers administered the questionnaire [4]. Even though in 2018 the average monthly pension income in Slovenia was 620 EUR, pension benefits of some groups of retirees such as farmers were lower than 300 EUR per month; therefore, they could not pay the rent for specialised housing even in the case that it would cost only 200 EUR per month, which is the case in our program for Municipality Krško [4]. Among the home care users, the preferential dwellings and services were as follows: 44% of seniors would have liked to stay in their old homes in any case; 40% of older adults wanted to live autonomously in ambient assisted arrangements; 13% of them insisted on living autonomously in any case till the end of their life, and only 1.6% respondents were willing to spend the end of life in a nursing home. Based on these results, one can conclude that more than 40% of Slovenian older adults expect their municipalities to start the development of specialised housing with old age-friendly environments and barrier-free, walkable housing units (*p-value* $\cong$ 0.01) with the existing income structure and that they are ready to pay the rent or buy such units without expecting state social subventions. However, we can assume that if the rent of ambient assisted arrangements (AAL arrangements) of housing units were financially accessible (publicly subsidised) to older adults with low pension benefits, the percentage would be even higher. Table 1 shows that a relatively large proportion of older adults with low pension benefits (up to 500 EUR per month) want to stay in their current family home in any case. From their response, it was understood that in a large number of cases, this answer is influenced by their awareness that the pension they receive is too low to consider anything else other than staying in their existing homes or going into institutional care in a nursing home [11, 12], AAL housing was the preferred option among those with higher pension incomes.

Table 1: Number of seniors, according to the type of desired dwelling and the pension benefit

Pensions in EUR/month	AAL+ + Retirement Community+ +Adapted independent home	To stay till the end of life at the family home (no adapted)
0-500	15	17
800+	9	4

From Table 1, one can prove the hypothesis that older adults in the income classes of 800+, who can afford rent and care in specialised housing, want to stay in their family home in a smaller proportion regarding seniors who have lower pension income when their functional capacity declines significantly. Because of the small sample, the test was performed using the Agresti-Caffo method [1]. We have performed a z+4-test to compare two proportions based on the normal distribution z_{AC}. From Table 1, the statistic is as follows:

$$SE = \sqrt{\frac{p'_1 q'_1}{n_1+2} + \frac{p'_2 q'_2}{n_2+2}} = 3{,}64; \quad z_{AC} = \frac{p'_1 - p'_2}{SE} = 1{,}648 \rightarrow p - value = 0{,}05 \tag{1}$$

So, with the *p-value* = 0.05, we can confirm the hypothesis: *Slovenian elderly people in the income classes of 800+, who are better able to afford community care in AAL, want to stay at their current home in a smaller proportion when their functional capacity drops significantly than those in the lowest income brackets (up to 500 euros).* These are important data for forecasting the demand for AAL housing accurately.

MULTIPLE DECREMENT MODEL

To evaluate the SV of investments in new, more accommodative housing stock structure and its dynamics, the following is developed and demonstrated in the model: (a) extension of the basic model, introduction of a new type of dwelling. Further, new probabilities of transitions are expected in the extended transition matrix; (b) introduction of APV of health and LTC cost as a function of the housing stock structure; (c) introduction of the probability distribution of 'time to failure' or when residents reach disability threshold which is the duration of the tenure in a dwelling of type i, [3]. (d) As a novelty, we have developed a method for calculation of the SV created with the development of specialised social housing stock for older adults. SV is the positive externalities created for HC and LTC systems in the form of decreased expenditures. Our method evaluates the SV of investment in social housing stock as the difference between APV of HC and LTC expenditures between two different housing stock structures, both with and without specialised housing for older adults. According to Wood [14], such a model is essential for policymakers and has not been developed yet.

In a multi-state transition model with *m* dwelling options for those with reducing functional capacities, there are possibilities of m-1 transitions from one type of dwelling to another. We denote the initial state as state 0 and transition which requires housing of type j with the line of the graph from this parent node to the child node j, j = 1, 2, ..., m-1. The paths to j determine the required dynamics for the development of the specialised housing stock with the required number of dwellings of type j (meaning the development of a required number of dwellings of type j which should be completed in a certain time τ). In the multiple decrement model, transitions between any two states from i to j, i > j, are not possible (directed graph).

The transitions are successive according to the functional capacities, the available category (intensity) of care and related housing. Let us denote: i = 0: family home (FH) housing unit without special facilities for seniors and with residents without the need for care, where the residents live with functional capabilities that are autonomous; i = 1: homecare in the adapted family home (adFH); i = 2: housing unit in the independent living community (SH); i = 3: housing unit in an assisted living community (HwC); i = 4: nursing home (NH); j = 5: graveyard (D). Let us denote by i the type of dwelling in which the older adult is currently residing (i = 0 to 4); and by j the sort of housing into which they move after reaching disability threshold due to declining functional capacity (resettlement from the kind of dwelling i to j; j = 1 to 5). Based on the data from the National Health Institute and Statistical Office, one can derive the expected needs of seniors at the national, regional or city/municipality level. Development of specialised housing stock can be financed from savings (decrease in expenditure) to the national HC system (from the budget or national health insurance system) and national LTC system (from the budget or national LTC insurance). To predict the various dwelling needs of seniors and therefore the optimal structure of the housing stock, based on the decreasing functional capacities and the effective demand, the probability distribution of $T_i(x)$, the time that a senior resident will spend in the dwelling of type i, $i \in H$ must be known. The probability $q_x^{(i,j)}$ of relocating from the dwelling of type i to type j due to declining functional capacity for resident x years old is written by:

$$q_x^{(i,j)} = \frac{M_x^{(i,j)}}{S_x^{(i)}}; j = 1,2,3,4,5: j > i \tag{2}$$

Where $M_x^{(i,j)}$ is the number of older adults that move from i to j, and $S_x^{(i)}$ is the total number of residents who were previously living in i-1. Here $p_x^{(i)}$ is the probability that the person is staying in the same home. In the year τ, the final structure of the residents by type of housing needed for each age x person in the cohort is described by the matrix (3). The basics of such a transition are described in Deshmukh [5]; however, it is not developed for housing structure but only for age – dependency structure. The net migration from other areas $\mathbf{MN}_{x\tau}$ should be added. The data were taken from the National Statistics Office. Therefore we can write:

$$\left[S_{x+1}^{(0)}\ S_{x+1}^{(1)}\ S_{x+1}^{(2)}\ S_{x+1}^{(3)}\ S_{x+1}^{(4)}\ \right]_{\tau+1} = \left[S_{x}^{(0)}\ S_{x}^{(1)}\ S_{x}^{(2)}\ S_{x}^{(3)}\ S_{x}^{(4)}\ \right]_{\tau} \cdot \begin{bmatrix} p_x^{(0)} & q_x^{(0,1)} & q_x^{(0,2)} & q_x^{(0,3)} & q_x^{(0,4)} & q_x^{(0,5)} \\ 0 & p_x^{(1)} & q_x^{(1,2)} & q_x^{(1,3)} & q_x^{(1,4)} & q_x^{(1,5)} \\ 0 & 0 & p_x^{(2)} & q_x^{(2,3)} & q_x^{(2,4)} & q_x^{(2,5)} \\ 0 & 0 & 0 & p_x^{(3)} & q_x^{(3,4)} & q_x^{(3,5)} \\ 0 & 0 & 0 & 0 & p_x^{(4)} & q_x^{(4,5)} \end{bmatrix}_{\tau} +$$

$$+\left[MN_{x+1}^{(0)}\ MN_{x+1}^{(1)}\ MN_{x+1}^{(2)}\ MN_{x+1}^{(3)}\ MN_{x+1}^{(4)}\ \right]_{\tau+1} \tag{3}$$

The total needed housing structure is: $\left[S^{(0)}\ S^{(1)}\ S^{(2)}\ S^{(3)}\ S^{(4)}\ \right]_{\tau} = \sum_x \left[S_x^{(0)}\ S_x^{(1)}\ S_x^{(2)}\ S_x^{(3)}\ S_x^{(4)}\ \right]_{\tau}$. $\mathbf{ME}_{x,\tau}$ depends on differences in the taxation policies and subventions among areas (municipalities), as developed by Janež et al. [10].

ACTUARIAL MODEL FOR THE EVALUATION OF THE SOCIAL VALUE OF DIFFERENCES IN THE HOUSING STOCK

The optimal care services and the housing stock for an older adult with decreasing functional capacity depend upon the following: legal systems, fiscal systems, financial mechanisms and system of LTC provisions and insurance. We will use the following notation:

APV_x	the APV of lifetime expenditures for LTC services for person *x* years old
${}_jp_x$	the probability that older adult *x* years of age will survive *j* years
$p_x^{ltc(i)}$	the probability that older adult *x* years of age is in the category of care *i*
c_i	yearly expenditure on LTC services in the category of care *i*
ir	the interest rate; We have used an interest rate of 1.75 %
$\vartheta = 1/(1+ir)$	the discount rate
HS_1	housing stock without specialised dwellings for older adults
HS_2	housing stock with specialised dwellings for older adults
SV	social value

DAV 1987 mortality rate table and the probability tables of the intensity of care have been used. The APV can be written in general as follows:

$$APV_x = \sum_{j=0}^{100-x}\ {}_jp_x \cdot \vartheta^j \cdot \left(p_{x+j}^{ltc\,I} \cdot c_1 + p_{x+j}^{ltc\,II} \cdot c_2 + p_{x+j}^{ltc\,III} \cdot c_3\right) \tag{4}$$

Let us write the APV for lifetime LTC expenditures for a 65-year-old person (in EUR) when there are only two options of housing stock (HS_1) are as follows:

$$APV_{65}(HS_1) = \sum_{j=0}^{100-65}\ {}_jp_{65} \cdot \vartheta^j \cdot \left(p_{65+j}^{ltc\,I}(HS_1) \cdot c_1 + p_{65+j}^{ltc\,II}(HS_1) \cdot c_2 + p_{65+j}^{ltc\,III}(HS_1) \cdot c_3\right) \tag{5}$$

and in case of more options for housing stock (HS_2), it is as described above:

$$APV_{65}(HS_2) = \sum_{j=0}^{100-65}\ {}_jp_{65} \cdot \vartheta^j \cdot \left(p_{65+j}^{ltc\,I}(HS_2) \cdot c_1 + p_{65+j}^{ltc\,II}(HS_2) \cdot c_2 + p_{65+j}^{ltc\,III}(HS_2) \cdot c_3\right) \tag{6}$$

The literature in many cases says that there is no method to evaluate the SV of the construction of housing stock of sheltered housing (SH) and housing with care (HwC) [13, 14] and also that a proper information system is not available (European Commission, 2014) We found out that the LTC expenditures are highly dependent on the housing stock availability, but in practice, the housing stock and services are considered and managed separately. In all EU Member States, these two areas are even regulated independently. In our theoretical research and our fieldwork, we have realised that the social value (SV) of the sheltered housing (SH) and housing with care (HwC) is the difference between APV of HC and LTC expenditures:

(1) in the case of housing stock without SH and HwC (HS_1), and (2) housing stock with SH and HwC

$$(HS_2):\ SV = APV_{65}(HS_1) - APV_{65}(HS_2) \tag{7}$$

SV is the difference between the APV in original housing stock and more accommodative housing stock with the specific housing solution for older adults with declining functional capacities. In our model, we have entered only two categories of housing stock in the structure of available types of housing. These are not available in many European countries at present. Based on the number of users of HC services in Slovenia, provided by the Slovenian Municipalities, and the number of users and applicants for the institutional care of LTC in Slovenian NHs, data for people aged 65+ by age, gender, category of care and considering their financial constrains calculate the probability that an older person will be in a particular category of care in an NH. Berrington [2]) and Wood [14] calculated the savings of the national healthcare per year if the seniors were living in the adapted housing and well-organised community. The study exposes facts such as the absence of a method to evaluate the SV of the construction of SH and HwC housing stock. In this research, we calculated the SV of the SH where HwC is the difference between the APV of HC and LTC expenditures in the case of housing stock without SH and HwC and housing stock with SH and HwC which based on the Slovenian data we got different values for female SV_F and male SV_M :

$$SV_F = APV_{65} \cdot (HS_1) - APV_{65} \cdot (HS_2) = 15{,}133.20€ - 12{,}830.45€ = 2{,}282.75€$$

$$SV_M = APV_{65} \cdot (HS_1) - APV_{65} \cdot (HS_2) = 6{,}504.80€ - 5{,}564.93€ = 939.87€$$

The SV was here calculated as the difference between the APV of care, in case of availability of existing housing stock and a situation where there are more accommodated housing units available with specialised housing solutions.

CONCLUSION

Based on the conclusions which follow from the calculation (1), we suggest building a sufficient number of homes in AAL housing and similar community buildings and developing social programmes, financing policy and insurance schemes (social housing and reverse mortgage products) for older adults to enable them to move into AAL housing and other community dwellings. This is a new challenge for the municipality administration and construction industry. So, it is worthwhile to consider a strategy and other measures to better meet the needs of the ageing population. Demand for AAL and other specialised housing for seniors with declined functional capacities could be forecasted based on the population projections, using the multiple decrement model, if we know the categorisation of needs and the financial abilities of the older adults in the studied area. Therefore, we can determine the needed structure of housing stock based on the multiple decrement approaches developed by Bogataj et al. [3], using the principles of actuarial mathematics. In further research, both the SH and HwC groups of housing stock are to be calibrated in detail. We must permanently follow the study of their impact.Thus, we must pave the way for a more detailed picture of SV in individual types of use.

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OLDER ADULTS PERSPECTIVES IN OPTIMISATION OF MIGRATION FLOW

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Abstract: Ageing and shrinking of the European and Slovenian population also influence the shrinking of central places and other municipalities in national and European spatial structures. Migrations between municipalities additionally influence shrinking and growing. Various factors influence migration flows and thus the population and economic stability of spatial units. Nevertheless, the age structure of future citizens in a municipality might change not only because of the ageing of the total population, but also because these factors affect migrants of different ages differently, which we have not investigated so far. In this study, we used inter-municipal internal migration data in Slovenia for 2018-2019 to develop a cohort-based spatial interaction modelling approach for estimating future migration among the municipalities in the country. Our modelling approach addresses the differences in attractiveness and stickiness between municipalities and seeks to answer the question of how to mitigate the processes of shrinkage and ageing in these spatial units by exploring the potential opportunities as the population rapidly ages.

Keywords: migration flows, optimisation of flow intensity, environmental gerontology, town centres, remodelling.

1 INTRODUCTION

According to the baseline (BSL) of the EU population projection, the number of employed people in Europe will fall from more than 288 million to 242 million over the next 40 years and to 198 million in the scenario without immigration (Figure 1). But it is not just the working population that is shrinking, other cohorts are shrinking too. From Urban Audit - a European database for the comparative analysis of EU cities - it appears that we lost 57% of the population from 220 large and medium-sized European cities between 1996 and 2001. In addition to the almost 81% of cities in the countries of Central and Eastern European, many German, Italian and Spanish cities, among others, are also on the list of shrinking cities. Moreover, this dynamic also increased in the second decade of the 21st century.

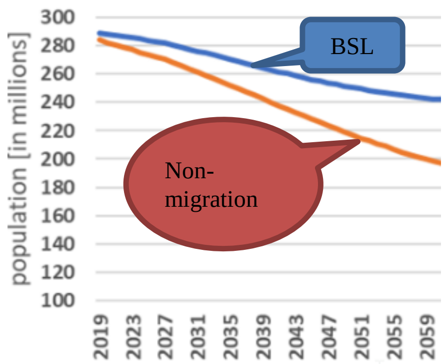

Figure 1: EU projection of the number of people in employment (source: [8]).

As Wiechmann and Pallagst [14] pointed out, urban shrinkage is not primarily due to suburbanization. Therefore, the main idea is that we should look at the total number of municipalities when we study the shrinkage of their central places (see Figure 2, where the shrinkage of LAU2 regions - municipalities - is shown in %). We should determine the methods of attracting residents to shrinking areas to achieve the desired population dynamics. It is important to study the factors that significantly affect the flows of human resources. The fact is that cities and settlements are increasingly competing for new immigrants and must try to retain old populations. While for younger cohorts, municipalities will compete with better jobs and better schools, for older ones, better health and social services will be a key influence for them. Since these factors have different forces for different cohorts, we should examine each cohort separately and consider their interrelationship, which is not the case in the long list of articles dealing with the law of social gravity in academic journals. It is recommended to study these flows. For this purpose, it is recommended to use one of the models of social gravity.

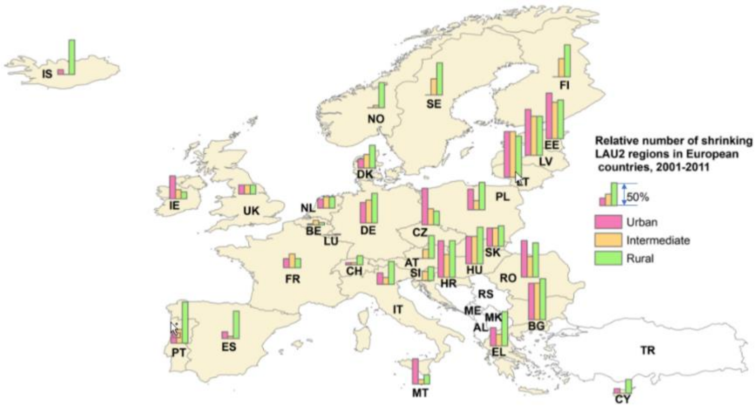

Figure 2: Percentage of shrinking LAU2 regions in EU member states in 2001-2011 (source of data: [7:4]; own calculation and graphics).

The law of social gravity is widely applicable in population migration and commuting. However, this simple law is still under investigation in many complex social systems. Recently, for example, Wang et al. [13] presented a model of free utility that helps us understand the spatial interaction patterns in complex social systems and provides a new perspective for understanding the potential function given by the game-theory approach. The fact is that cities and settlements have to compete more and more for new immigrants and try to keep the old population. Residents are looking for future prospects in the communities they want to move to, and communities can compete for them to avoid unwanted shrinkage. Among the values of factors as decision variables influencing attractiveness and stickiness, the level of wages and taxes, the availability and cost of housing units, amenities and other social infrastructure are often mentioned as making municipalities more attractive [1, 10]. But recently, these are not the main factors in Slovenia.

Our study focuses on the transformation and regeneration of town centres and their retail cores, understanding their role as places of consumption and employment, as well as supporting tourism linked to cultural heritage and leisure. As the proportion of older adult cohorts rapidly increases, we should consider the potential multiple roles of older people in revitalising and rejuvenating town centres, given the centrality of places for health and safe living for all generations [12]. Age-friendly cities as community environments also for older adults is a concept frequently used in gerontological studies and policies to describe the extent to which cities and their centres are appropriate places to grow old, i.e. 'ageing in place'. The evidence is increasingly stimulating debate about the silver economy of a city or place. Our research assumes that more care and investment is needed to support housing, community and social participation and 'ageing in place', as environmental gerontology puts it.

2 SPATIAL INTERACTION MODEL

We study the gravity characteristics, attractiveness and stickiness of Slovenian municipalities separately, based on the general spatial interaction model (SIM), as previously developed by Cesario [2, 3] and later improved by many authors [4, 5, 6, 11]. The model is extended to include economic, housing, ageing, and municipal revenue factors, which are mainly used to finance social infrastructure. These factors influence three cohorts: residents younger than 65, residents aged 65–74, and the 75+ cohort. The model helps us answer the question of how to assess the influence of these factors on the shrinkage of LAU2 regions. Finally, it presents the policies to be adopted in order to achieve population sustainability in LAU2 areas.

To estimate the influence of the analysed factors, the sim was introduced:

$$M_{ij}^{(t)} = k\, K(d_{ij})^{\beta} \prod_r K(r)_i^{\gamma(r)}\, K(r)_j^{\alpha(r)}\ , \tag{1}$$

where $M_{ij}^{(t)}$ was the estimated intensity of migration flows in age cohort t from a municipality of origin i to a municipality of destination j. Age cohorts were defined as follows: t = 0–65, 66–74, 75+, k is the constant of proportionality, $K(d_{ij})$ is the coefficient of the fastest time-spending distance by state road network between the centre of the municipality of origin i and the centre of the municipality of destination j, $K(r)_i$ and $K(r)_j$ are coefficients of factors r in origin i or destination j, defined as the value of factor in municipality i and municipality j, respectively, divided by the average value of this factor in Slovenia, as described in Table 1. Considering the factors that were analysed in the normalised spatial interaction model (NSIM) for three cohorts of migrants, model (1) can be written in detail as:

$$\begin{aligned} M_{ij}^{(t)} == k\, K(d_{ij})^{\beta} K(POP)_i^{\gamma(POP)}\, K(POP)_j^{\alpha(POP)}\, K(GUEMP)_i^{\gamma(UEMP)}\, K(UEMP)_j^{\alpha(UEMP)} \cdot \\ \cdot K(GEAR)_i^{\gamma(GEAR)}\, K(GEAR)_j^{\alpha(GEAR)}\, K(NDWE)_i^{\gamma(NDWE)}\, K(NDWE)_j^{\alpha(NDWE)} \\ \cdot K(PDM2)_i^{\gamma(PDM2)}\, K(PDM2)_j^{\alpha(PDM2)}\, K(MREV)_i^{\gamma(MREV)}\, K(MREV)_j^{\alpha(MREV)} \\ \cdot K(AGEI)_i^{\gamma(AGEI)}\, K(AGEI)_j^{\alpha(AGEI)}\, K(HELD)_i^{\gamma(HELD)}\, K(HELD)_j^{\alpha(HELD)} \end{aligned} \tag{2}$$

Model (2) was linearized and solved by IBM SPSS using OLS regression analysis.

Table 1: Factors in spatial interaction models (1) or (2).

Notation	Factor value	Additional description	Sources
$M_{ij}^{\prime(t)}$	Number of migrants of age cohort t from municipality of origin i to municipality of destination j	Average of yearly values for 2018 and 2019	SORS
$M_{ij}^{(t)}$	Estimation of the number of migrants of age cohort t from origin municipality i to destination municipality j	The estimation (expected value) of the real value regarding equations (1) or (2)	Authors' calculation
$K(d_{ij})$	Coefficient of the fastest time-spending distance in minutes between origin municipal centre i and destination municipal centre j	The ratio between the factor value for a pair of municipal centres and the average factor value for Slovenia for 2019	SRA and authors' calculation
$K(POP_\circ)$	Coefficient of the number of inhabitants in the municipality	The ratio between the factor value for the municipality and the average factor value for Slovenia for 2019	SORS and authors' calculation
$K(UEMP_\circ)$	Coefficient of the registered unemployment rate in the municipality	The ratio between the factor value for the municipality and the average factor value for Slovenia for 2019	SORS and authors' calculation
$K(GEAR_\circ)$	Coefficient of gross earnings per capita in the municipality	The ratio between the factor value for the municipality and the average factor value for Slovenia for 2019	SORS and authors' calculation
$K(NDWE_\circ)$	Coefficient of the number of dwellings per 1000 inhabitants in the municipality	The ratio between the factor value for the municipality and the average factor value for Slovenia for 2018	SORS and authors' calculation
$K(PDM2_\circ)$	Coefficient of the average price per m^2 of dwelling in the municipality	The ratio between the factor value for the municipality and the average factor value for Slovenia for 2018 and 2019	SMARS and authors' calculation
$K(MREV_\circ)$	Coefficient of the municipal revenue per capita	The ratio between the factor value for the municipality and the average factor value for Slovenia for 2019	MFRS and authors' calculation
$K(AGEI_\circ)$	Coefficient of the ageing index in the municipality	The ratio between the factor value for the municipality and the average factor value for Slovenia for 2019	SORS and authors' calculation
$K(HELD_\circ)$	Coefficient of the capacity of old people's homes in the municipality	The ratio between the factor value for the municipality and the average factor value for Slovenia for 2019	Breznik et all (2019) and authors' calculation

3 RESULTS

Table 2 shows the regression coefficients of the linearized model (2) according to the age cohorts 0–65, 66–74, and 75+ years (the values of the regression coefficients where the p-value is higher than 0.05 are in parentheses; detailed statistics are available from the authors upon request). From Table 2 follow the net migration impacts (Table 3) calculated for the case where each factor increases by 20% when in-migration and out-migration are balanced.

Table 2: Regression coefficients and their statistics for cohorts 0–65, 66–74, and 75+ year-olds (inter-municipal migration in Slovenia in 2018–2019).

Age cohort	0–65 years	66–74 years	75+ years	0–65 years	66–74 years	75+ years
R	0.786	0.600	0.622	**Expected change of flow intensity in % if the value of the factor increases by 20%**		
R^2	0.617	0.360	0.387			
Adjusted R^2	0.617	0.354	0.383			
Standard error	0.776	0.531	0.666			
No. of observations	14,096	1920	2481			
ANOVA stat. F	1336.89	62,84	91,46			
ANOVA p-value	0	0	0			
Regression coefficient	**Value of stand. regression coefficient**					
β	-.649	-.475	-.560	-11.16	-8.30	-9.71
$\gamma(POP)$	.464	.401	.445	**8.83**	**7.58**	**8.45**
$\alpha(POP)$	.448	.181	(.030)	8.51	3.36	0.55
$\gamma(UEMP)$	.016	(.001)	-.054	**0.29**	**0.02**	**-0.98**
$\alpha(UEMP)$	.025	.056	(.022)	0.46	1.03	0.40
$\gamma(GEAR)$	.057	(.011)	(.003)	**1.04**	**0.20**	**0.05**
$\alpha(GEAR)$	.043	(.026)	(.036)	0.79	0.47	0.65
$\gamma(NDEW)$	.130	.122	.068	**2.40**	**2.25**	**1.25**
$\alpha(NDEW)$	.147	.128	.060	2.72	2.36	1.10
$\gamma(PDM2)$	-.027	(.012)	(-.027)	**-0.49**	**0.22**	**-0.49**
$\alpha(PDM2)$	(-.007)	(.049)	(-.003)	-0.13	0.89	-0.05
$\gamma(MREV)$	.037	.054	.074	**0.68**	**0.99**	**1.36**
$\alpha(MREV)$	.016	(-.002)	(.020)	0.29	-0.04	0.36
$\gamma(AGEI)$	.029	(.023)	.086	**0.53**	**0.42**	**1.58**
$\alpha(AGEI)$	(.015)	(.017)	(.038)	0.27	0.31	0.69
$\gamma(HELD)$	(.015)	(.005)	-.060	**0.27**	**0.09**	**-1.09**
$\alpha(HELD)$	.018	.131	.282	0.33	2.42	5.28

Notes: (a) The values of the regression coefficient where p-value > 0.05 are in parentheses. (b) Expected changes of flow intensity are denoted in bold for the origins and in grey for the destinations. (c) Detailed statistics are available from authors per request.

Table 3: Net migration in a municipality in case the individual value of the factors in this municipality increases by 20% compared to other municipalities at the balanced input-output flows.

factor	0-65	66-74	75+		factor	0-65	66-74	75+
dij	-11.16	-8.30	-9.71					
POP	-0.32	-4.23	-7.90		*PDM2*	0.36	0.67	0.44
UEMP	0.17	1.01	1.38		*MREV*	-0.38	-1.03	-1.72
GEAR	-0.26	0.27	-0.60		*AGEI*	-0.26	-0.11	-0.89
NDWE	0.32	0.11	-0.15		*HELD*	0.06	2.33	6.36

4 DISCUSSION

Table 2 shows that the values of the standardised regression coefficients of the linearized model, which assess the strength of the effects of individual factors on migration flows, differ between cohorts. Older people aged 66 to 74 are more likely to opt for longer migration distances ($\beta = -0.475$) than the youngest population group ($\beta = -0.649$), as are those aged 74 and over ($\beta = -0.56$). At the 20% longer time distance, the proportion of those willing to migrate is 11.16% lower for the 0–65 cohort, 8.30% lower for the 66–74 cohort, and 9.71% lower for the oldest population group.

The size of the emigrant municipality influences the emigration of 66–74-year-olds less than that of older and/or younger cohorts. Comparatively, the size of the municipality attracts them less than younger cohorts. Individuals over the age of 74 are insensitive to this factor when choosing a municipality to emigrate to. Municipalities with larger average populations cannot expect greater net in-migration than out-migration. This is even more true the larger the municipality. It follows that cities and other larger central towns are shrinking intensively and their "main streets" are increasingly empty.

European Long-Term Investors Association initiated Investing in Social Infrastructure activities in Europe that could encourage residents to stay in inner cities [9]. The initiative is supported by the European Commission, the European Investment Bank, the Council of Europe Development Bank and many National Promotional Banks. It emphasizes the importance of focusing policy attention on the role of social infrastructure and related services, with the aim of increasing investment in education, health and affordable housing, as well as other social infrastructure essential for Member States' economic growth and people's well-being. In the final report by Fransen et al. [9] in this association, a comprehensive collection of facts and figures on social infrastructure and social services and related funding opportunities and needs are considered, and many recommendations are made on current funding instruments and future programmes, including for municipalities.

Therefore, we examined how municipal revenues, which are mostly invested in the social infrastructure of the municipality, can increase the attractiveness and stickiness of the municipalities. This answer can also be obtained from the gravity model results. Our research shows that where the revenue of the municipality is higher, the number of inhabitants decreases, which is characteristic for all three cohorts. 20% higher revenue on average reduces net migration by 0.38% (cohort 0–65), 1.03% (cohort 67–74) and by 1.72% (cohort 75+) with no change in other relative values of factors. The factor influencing municipal growth is the number of housing units available for cohorts younger than 75 and the lower price of housing units (per m^2) for cohorts of residents 66–74 years old. However, both those under 66 and those over 74 prefer to migrate to places where the ageing index is lower. In municipalities with a 20% lower ageing index, all other things being equal, net migration was on average 0.8% higher for the under 66 population and 2.27% higher for the very old population (over 74), while a 20% lower ageing index results in a 0.11% lower net migration for the population between 66 and 74. The positive impact on the growth of municipalities has the coefficient of capacity of housing for the elderly in the municipality. For example, 20% higher housing capacity for older adults increases net migration for 0.60% of those under 66, 2.51% of those 66–74, and 6.36% of the oldest cohort (75+).

5 CONCLUSIONS

Among 14,096 observations of migrations of residents younger than 66 years between municipalities in Slovenia, 1920 observations of migrations in the 66–77 cohort, and 2481 observations of migrations of the oldest residents, we realised that the most crucial influence on population growth in municipalities is investment in housing for the oldest cohorts. Such investments also influence new jobs for nurses, social workers, and other workers involved in services and care for older adults, which can have a significant impact. Such investments could have a significant impact on stopping the shrinkage of communities and their central places by ensuring a better quality of life for older people and employment for young people.

The initiative to activate investment in social infrastructure in Europe, which could encourage residents to stay in urban centres, is essential to mitigate the shrinkage of member state communities and increase the well-being of the population. Based on the gravity model developed and implemented in Slovenian municipalities, we can conclude that infrastructure for the older adults, especially investments in their better housing, can significantly contribute to the sustainability of population growth and silver economy.

Municipal revenues in the past have not had a sufficient influence on the attractiveness and stickiness of the territories. In fact, their impact on sustainability is negative (equal to -0.38, -1.03, -1.72 to the age cohorts, respectively, at 20% higher revenues). Therefore, we should know better what happened to these revenues in the past and what we should do in the future. We should find better community investment policies, especially now that the new Long-Term-Care legislation is on the Slovenian Parliament tables and puts more responsibility on the shoulders of municipalities.

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EFFICIENCY OF CROATIAN NURSING HOMES - DEA ANALYSIS

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Abstract: This paper uses the input-oriented DEA models to estimate overall technical efficiency (OTE), pure technical efficiency (PTE) and scale efficiency (SE) of Croatian for-profit nursing homes in 2019. Thus, data set consists of three inputs (tangible assets, staff costs and material costs) and one output (total revenues). The results reveal that average OTE and PTE are between 0.815 and 0.858, due to different SE. By identifying top performance on the market (NH24 and NH14), paper provides valuable information on different ways to raise efficiency for relatively inefficient nursing homes since demand for this service will inevitably raise due to aging of population.

Keywords: nursing homes, efficiency, data envelopment analysis, Croatia.

1 INTRODUCTION

On world level, percentage of population older than 65 is 9.56%, and those older than 85 is under 1% [15]. These numbers do not seem to reflect problems that developed countries face regarding aging of population, low fertility rates, growing public health care and pension system expenditures. Namely, in European Union percentage of population older than 65 is significantly higher (21.81%) and share of population over 85 is 3.03% [15]. Therefore, higher life expectancy, a fact that senior citizens in most cases are not active on labour market and often require more care, as well as changes in size and shape of modern families, cause development of different formal and informal types of care for elderly.

Beside gerontology studying physical, mental and social implications of aging, thirty years ago gerontechnology expanded the focus on adjusting technological environments to health, housing, mobility, communication, leisure and work of older people [9]. Consequently, analysis of different aspects of care for elderly evolved into a prolific scientific niche. Regarding related economic aspects, studies dealing with efficiency of nursing homes for elderly are becoming more important due to earlier mentioned reasons. Main purpose of nursing homes is to provide housing and needed care for senior citizens and often they are financed from public sources. Hence, it is understandable why many studies on efficiency of nursing homes analyse used resources in terms of labour and capital input employed to take care of different types of residents of respective nursing homes. In that sense, Tran et al. [18] provide extensive literature review of efficiency measurements in nursing homes showing that majority of these studies use non-parametric method (data envelopment analysis - DEA) and are mainly focused on nursing homes in the USA, several highly developed European countries, Canada and Taiwan. Their work covered three electronic databases (ECONLIT, PubMed (Medline) and Web of Science – evidently not all studies have been included in analysis. Additionally, [17] state that Australia has the longest tradition of assessing quality of institutional care of senior citizens. Beside plain numbers of different types of residents in nursing homes many studies [e.g. 2, 6, 8, 16] include quality measures acknowledging that this activity should not be done or observed without having in mind that taking care of human beings affects their quality of life. Therefore, introducing innovations Mali [10] in her work analysed innovations in long-term care in old people's homes in Slovenia and summarised innovations into three groups: a) social innovations, b) innovations in social welfare and c) old people's homes innovations. In long-term care for senior citizens should be a guiding point for both mangers of these homes and policy makers. Further, resources that governments allocate to dependent care system should not be regarded solely as an expense, yet they should be understood as an economic investment into creation of jobs and wealth, as well as a vehicle for social cohesion and individual and collective well-being [3].

Beside non-profit nursing homes, in many countries this activity is becoming more interesting as an investment opportunity resulting with increase in number of for-profit nursing homes and it is important to have in mind that non-profit organizations follow civil society logic, while for-profit sector seeks efficiency to compete in the market [19]. Formal residential care for elderly in Croatia is divided on

- institutional care: (a) homes with founding rights on a government level, (b) on a county level, (c) homes with other founders, (d) other legal entities without the establishment of a nursing home and
- non-institutional care: (a) family homes and (b) social farming [11].

In that sense, this paper is focused on efficiency of for-profit nursing homes in Croatia. Our aim is to use data envelopment analysis (DEA) to analyse how efficient are these nursing homes since they are competing on a growing market. To the authors' best knowledge, efficiency of nursing homes in Croatia has not yet been analysed. There are studies on quality of institutional care for residents [17] and quality of living, cognitive and functional abilities of residents [7] in selected nursing homes in Zagreb. Further, attention has been given to family homes as an entrepreneurial activity [11] as well as to governmental financing of nursing homes [1] while Koružnjak [9] provides theoretical interdisciplinary approach to the development of a general model of residential care facilities. Hence, this paper adds to the field by analysing how efficient are for-profit nursing homes in Croatia, as well as by providing a different perspective for efficiency analysis of nursing homes in general by using variables that are most often selected for other business activities that the one in focus here. Demand for service provided in nursing homes will inevitably rise, and it would be beneficial to explore characteristic of this business to provide valuable insights for both managers of these homes and policy makers regardless of whether non-profit or for-profit homes are analysed. Namely, if funds invested in nursing homes, regardless of their origin (public or private), are not efficiently used, economic repercussions are negative. Therefore, authors hope to contribute to better understanding of this niche that is important as an investment opportunity and as a public spending direction, as well as a significant determinant of a quality of life on a country level.

Second section describes the sample, used methodology and provides results along with discussion. Last section encompasses conclusion with direction for future research.

2 METHOD AND RESULTS

2.1 Data description and the method

According to data available on official web site [12] of Croatian Ministry of Labour, Pension System, Family and Social Policy, on March 5th, 2021, there were 36 private limited liability companies and 31 simple private limited liability companies providing social service of accommodation, i.e. residential care for elderly. Data on these companies have been collected from Croatian Chamber of Commerce (digital source of data available on Digitalnakomora.hr) for 2019 as the latest available year. After removing companies that have not been operating in 2019 and those with unsuitable relevant data for DEA analysis (if input or output equals zero) our sample included 41 company.

Different input-oriented DEA models have been used to analyse the efficiency of Croatian for-profit nursing homes in 2019. The DEA methodology uses mathematical programming to process empirical data on multiple inputs and outputs for a set of decision-making units (DMUs). By solving linear programming problem for each DMUs, it estimates an efficiency frontier. [5] Furthermore, to analyse overall technical efficiency this study was conducted by using Charnes – Cooper – Rhodes (CCR) model which assumes constant returns to the scale (CRS), while in order to investigate the causes of technical inefficiency Banker – Charnes – Cooper (BCC) model, which assumes variable returns to the scale (VRS), was used as well [14].

Data set for measuring relative technical efficiency of nursing homes consist of three inputs: tangible assets, staff costs and material costs, and one output: total revenues (see Tab. 1).

Table 1: Descriptive statistics of inputs and output

	Tangible assets	***Staff costs***	***Material costs***	***Total revenues***
Min	213.00	97 441.00	13 247.00	168 016.00
Max	3 685 542.00	1 699 280.00	3 428 239.00	4 475 591.00
Mean	452 789.54	338 358.23	368 078.59	794 735.90
SD	859 480.5588	275 906.2271	565 897.0941	864 362.4958

The efficiency analysis was conducted using computer software Frontier Analyst Banxia Software and the results of DEA are summarized in following section.

2.2 Results

Efficiency scores, calculated through CCR (for calculating OTE) and BCC input oriented models (for calculating PTE) are displayed in Table 2. On the basis of their values, it is possible to calculate SE as the ratio of OTE to PTE [13]. Each nursing home (NH) is assigned a value within interval (0,1).Those having efficiency score equal to 1 are efficient and form the efficiency frontier, while those having efficient score lower than 1 are inefficient in relation to the nursing homes on the frontier. In this way, the efficiency of each nursing home is evaluated with respect to other nursing homes in the sample [4] (see Tab. 2).

According to CCR model, nine nursing homes are OTE. The remaining 32 nursing homes are relatively inefficient. Those inefficient ones can improve their efficiency by reducing their inputs (since we run an input-oriented DEA). This means that, on average, nursing homes must reduce their inputs by 18.5% maintaining the existing level of output to become efficient. In order to detect whether OTE is due to inefficient management or inappropriate scale size, following columns present PTE and SE scores. It can be observed that, compared with OTE, more nursing homes are PTE. Namely, 16 nursing homes are PTE. For example, overall inefficiency of NH1 is due to the scale-size, i.e. in order to operate on optimal scale size NH1 needs to adopt new technology or new service production processes. PTE of other inefficient nursing homes is a managerial problem, where reduction of inputs is required for the given level of output.

Hence, in order to detect ways to raise efficiency of inefficient nursing homes Table 3 shows reference set which presents benchmarks for inefficient nursing homes. In doing so, because the CRS assumption is valid only if SE score is equal to one [5], in the following analysis an emphasis was placed on PTE by highlighting managerial inefficiency.

Table 2: Overall, technical and scale efficiency of Croatian for-profit nursing homes in 2019

DMUs*	***OTE***	***PTE***	***SE***	***DMUs***	***OTE***	***PTE***	***SE***
NH1	0.823	1	0.823	NH22	0.820	0.931	0.881
NH2	0.625	0.650	0.961	NH23	0.756	1	0.756
NH3	0.992	1	0.992	NH24	1	1	1
NH4	0.713	0.739	0.965	NH25	0.880	0.934	0.942
NH5	0.702	0.753	0.932	NH26	0.526	0.550	0.956
NH6	1	1	1	NH27	0.752	0.901	0.835
NH7	0.849	0.904	0.939	NH28	1	1	1
NH8	1	1	1	NH29	0.784	0.798	0.982
NH9	0.938	1	0.938	NH30	0.811	0.882	0.920
NH10	0.827	0.872	0.948	NH31	0.955	1	0.955
NH11	0.568	0.588	0.966	NH32	0.845	0.845	1
NH12	0.803	0.862	0.932	NH33	1	1	1
NH13	0.793	0.796	0.996	NH34	0.440	0.738	0.596
NH14	1	1	1	NH35	1	1	1
NH15	0.705	0.723	0.975	NH36	0.909	1	0.909
NH16	0.860	0.883	0.974	NH37	0.683	0.822	0.831
NH17	0.453	0.575	0.788	NH38	1	1	1
NH18	0.848	0.915	0.927	NH39	0.820	0.845	0.970
NH19	0.719	0.761	0.945	NH40	0.731	0.936	0.781
NH20	0.905	1	0.905	NH41	0.866	0.950	0.912
NH21	1	1	1	Average	0.815	0.858	0.948
* Database with names of nursing homes is available upon request.							

Table 3: Referencing units (input-oriented BCC model) in 2019

Reference set	***Number of referencing units***	***Referencing units***
NH24	18	NHs: 2, 4, 5, 11, 13, 15, 22, 24-27, 29, 30, 32, 34, 37, 39, 41
NH14	13	NHs: 2, 4, 7, 10, 12-16, 19, 25, 30, 32
NH20	9	NHs: 2, 4, 10, 12, 15, 16, 20, 25, 30
NH31	9	NHs: 2, 5, 12, 16, 18, 22, 31, 37, 41

Based on the set of the reference values, two of them turn out to be leaders with the best performance (NH 24 and NH 14). As it was mentioned before, nursing homes in reference set are a basis for the determination of efficiency frontier but also are the basis for the establishment of goals for the inefficient nursing homes (see Tab. 4).

Using the example of NH2, it can be concluded that with existing output it needs to reduce all inputs by 35% to become PTE. Additionally, despite the input orientation, NH34, to achieve an efficient score, needs to reduce all inputs for 26.2% and at the same time increase the total revenues for 55.3%. Although nursing home managers should be aware that some of these options may not be feasible, especially in short run, this analysis offers valuable information about the possibilities for improving the efficiency.

Table 4: Target values for inputs and output of relative inefficient nursing homes (% of changes)

DMUs	*Tangible assets*	*Staff costs*	*Material costs*	*Total revenues*	*DMUs*	*Tangible assets*	*Staff costs*	*Material costs*	*Total revenues*
NH1	0	0	0	0	NH22	-6.9	-9.8	-6.9	0
NH2	-35	-35	-35	0	NH23	0	0	0	0
NH3	0	0	0	0	NH24	0	0	0	0
NH4	-77.7	-26.1	-26.1	0	NH25	-73.2	-6.6	-6.6	0
NH5	-24.7	-29.2	-24.7	0	NH26	-45	-45	-46.5	0.7
NH6	0	0	0	0	NH27	-9.9	-9.9	-9.9	13.4
NH7	-9.6	-9.6	-9.6	0	NH28	0	0	0	0
NH8	0	0	0	0	NH29	-20.2	-20.2	-20.2	0
NH9	0	0	0	0	NH30	-42.7	-11.8	-11.8	0
NH10	-12.8	-12.8	-12.8	0	NH31	0	0	0	0
NH11	-84.7	-41.2	-41.2	0	NH32	-15.5	-15.5	-15.5	0
NH12	-13.8	-13.8	-13.8	0	NH33	0	0	0	0
NH13	-20.4	-20.4	-20.4	0	NH34	-26.2	-26.2	-26.2	55.3
NH14	0	0	0	0	NH35	0	0	0	0
NH15	-81.1	-27.7	-27.7	0	NH36	0	0	0	0
NH16	-11.7	-11.7	-11.7	0	NH37	-17.8	-34	-17.8	0
NH17	-42.5	-42.5	-42.5	0	NH38	0	0	0	0
NH18	-8.5	-8.5	-8.5	0	NH39	-15.5	-15.5	-15.5	0
NH19	-23.9	-23.9	-23.9	0	NH40	-47.6	-6.4	-24.2	0
NH20	0	0	0	0	NH41	-5	-13.9	-5	0
NH21	0	0	0	0					

3 CONCLUSION

The paper evaluates the efficiency of nursing homes in Croatia analysing their performance in 2019. Idea was to study data and give recommendations on what needs to be improved in order to achieve higher level of efficiency. For that purpose estimates of efficiency have been obtained by input oriented CCR and BCC models, using operating approach in defining inputs and output.

The results showed that out of 41 analysed nursing homes, 25 are relatively pure technically inefficient and need to reduce their inputs to become efficient. Furthermore, seven nursing homes need to adopt new technology or production process to become overall technically efficient. Although it is on nursing home managers to consider which options to use in order to improve efficiency, this analysis offers valuable information about possible activities that would help nursing homes achieve the desired performance. In addition, the study results are valuable for policy makers since they provide evidence-based research, which could help policy makers to foresee and articulate future development scenarios. Namely, nursing homes provide service that has both economic and social repercussions and their efficiency should be observed from multiple angles, especially when it comes to countries with rather large portion of citizens older than 65, such as Croatia.

Obtained results provide the framework for future research that are based on the limitation of the study, i.e., the future improvement of the research is possible using other (different) inputs, outputs and most important - outcomes. Namely, by using different outcomes in data set it would be possible to calculate effectiveness. Additionally, the extension of the study is possible by applying two-step analysis to investigate determinants that influence nursing homes' efficiency.

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MULTI-CRITERIA SELF-CARE DECISION MODEL OF PATIENTS WITH CHRONIC DISEASES

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Abstract: Self-care of patients can significantly reduce the burden on healthcare systems and have a positive impact on patients' health outcomes. The paper presents a multi-criteria self-care decision model of patients with chronic diseases. The model is developed on the DEX method. The solutions support patients in on-time recognising relevant symptoms and decision-making regarding disease management and self-care. It is a basis for planning interdisciplinary professional work in the field.

Keywords: decision support, patient at home, community health nursing, DEX

1 INTRODUCTION

The social burden of chronic non-communicable diseases (CNDs) is high. Therefore one of the cornerstones of approaches to reducing this burden is empowering individuals, families, and communities for self-care [20]. Professional support for patients to self-care is crucial in treatment, as it represents an important starting point for interventions to reduce the need for formal care [8]. It represents a reserve that is under-recognized and exploited [5].

Self-care is defined as the ability of individuals, families, and communities to promote health, prevent disease, maintain health, and successfully cope with illness and disability with or without the support of healthcare providers [21]. It also includes self-management, which is an individual's ability to manage disease symptoms [3].

Patients with CNDs at home are alone most of the time; on average, they have only one hour of professional care and the rest of the time they left to themselves and their abilities to self-care [13]. In order to actively manage their health, patients with CNDs need to acquire the knowledge and skills to solve problems, use resources, established appropriate formal and informal relationships, take action and adapt, and also make health-related decisions which are an essential part of self-care [1, 19]. This allows them to maintain an optimal health level when they are ill, manage CNDs, control disease symptoms and act independently based on expert recommendations and/or their own decisions [9]. Patients' active participation in decision-making (DM) regarding their health is associated with empowerment and self-efficacy, which have positive impact patients' health outcomes and quality of life [6].

Health and wellbeing related DM and thus self-care, requires sufficient working memory capacity and the ability to focus, pay attention and understand and weigh information contextualization. [16, 17]. The complexity and multidimensionality of DM challenges faced by patients with CNDs can result in their decision often being based on simplistic intuitive or heuristic foundations, which is characterized by automaticity, impulsivity, and contextualization [16]. The consequences of such decision-making are that they may overlook important information, take it too little into account or exclude it from the decision-making process, so that decision made is based on wrong priorities [2]. Therefore, the use of algorithms and (digital) decision-making support is necessary in the implementation of certain elements of self-care [15].

In health care, there is a great need for transparent and optimal decisions, which can be achieved through the use of multi-criteria decision-making methods [10], and thus used for digital support of the decision-making process. This should also include patients who take an active role in health care processes.

The aim of this paper is to present a developed a multi-attribute self-care decision model for patients with CNDs in home settings through regular assessment of expressed symptoms by patients or their lay carers. The approach also enhances the interdisciplinary collaboration required to address complex health and social problems, such as a holistic approach to patients.

2 METHODS

A literature review was conducted with the aim to identify relevant criteria for DM in self-care of patients with CNDs. In the context of self-care, we included in the decision model those symptoms that could be perceived by patients or lay carers and are clinically important. Criteria were also the relevance of the specific symptom to the topic and to health-related decisions, author credibility, patient perspective, and applicability to practice.

The described parameters together with the expert knowledge formed the starting point for the design of the model and decision rules. Based on this, the multi-attribute decision model was designed using the DEX method (Decision EXpert) and the freely available software tool DEXi, version 5.02 [4]. The qualitative and quantitative attributes were organized hierarchically in a tree structure. They are located at several levels and represent the input parameters of the decision model at the basic level. Options are firstly described by leaves in the tree of attributes. Second, the values of the aggregated attributes above them are calculated according to their utility functions. The weights of the attributes are not pre-fixed but may depend on the values of the attributes.

The theoretical and conceptual verification of the model was done by independent persons, by experts with various expertise. The group consisted of three nurses, general practitioner, psychologist, and sociologist, last two with years of professional experience in health care. Each member of the expert group was asked to provide an opinion on the appropriateness and scope of the model and decision criteria. Feedbacks were used to improve the self-care decision model. Verification of the model was conducted in March 2019.

The presented self-care decision model includes specific symptoms relevant to patients' timely DM about whether to perform appropriate self.care activities or to seek professional help if symtomps. Six phases of solving the decision problem [4, 14] were implemented: 1) identification of the problem; 2) determination of decision group; 3) identification of criteria (elements) including composing a list of criteria, structuring of the criteria tree) and determining measuring scales; 4) identification of utility functions; 5) description of variants; and 6) evaluation and analysis of variants.

3 RESULTS

The designed the self-care decision model consists of two main sections for assessing attributes of physiological and psychosocial health. The tree of attributes has 33 final attributes and 16 aggregated attributes. The hierarchical structure of the designed model is presented in Figure 1.

Self-care
- Physiological health
  - Cardiovascular system and lungs
  - Digestive system
  - Skin and sense organs
  - Movement and rest
- Psychosocial health
  - Depression and anxiety
  - Mental ability
  - Well-being

Self-care
- **Physiological health**
  - **Cardiovascular system and lungs**
    - **Heart and vessels**
      - Blood pressure
      - Heart beat
      - Swelling
      - Bleeding
    - **Breathing**
      - Cough
      - Sputum
      - Heavy breathing

Figure 1: Overview and part of hierarchical tree structure of attributes of the self-care decision model

Utility functions were assigned to individual attributes because not all attributes contribute equally to estimated self-care. The estimated overall ability to self-care is derived from evaluating the impact of specific attributes contribution to physical and psychosocial health. The model can be used to support patients or their lay carers to assess their ability to self-care. The Figure 2 shows how the estimated risk differs depending on patients' health status or expressed symptoms.

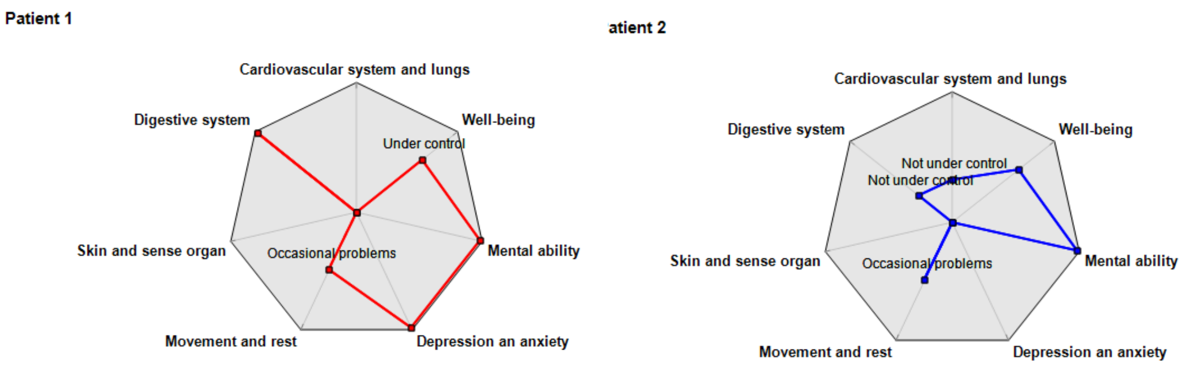

Figure 2: Self-care assessment for two patients, one has urgent situation and other need professional help

In the "Self-care" parameter, which is the main outcome of decision model, the descriptions of the value domains are designed to guide patients to further activities. "Emergency" tells patients that their health condition is life-threatening according to their selections of value domains. The descriptions for the "Self-care" value domains are:

- "Emergency": Due to my poor health condition, I need to seek immediate medical attention. I visit nearest emergency medical unit immediately or call ambulance.
- “Professional support”: I need professional help; my health is poor. I make an appointment immediately with my GP or seek other professional help.

- “Insufficient self-care”: I have some health problems that I can’t always manage. I need to check symptoms daily or more often if needed. In case of deterioration, I seek professional help.
- “Sufficient self-care”: I have some health problems, but I manage my symptoms well. I follow the recommendations of healthcare providers. I need to check symptoms monthly or more often if necessary. I take some preventive measures. In case of deterioration, I seek professional help.
- "Good self-care": I feel healthy. I am completely independent in my self-care. I need to check my health every six months or more often frequently if needed. In case of worsening symptoms, I will take preventive measures, and check my health more frequently.

	Physiological health	Psychosocial health	Self-care
	42%	58%	
1	**Urgency**	*	**Urgent**
2	*	**Urgency**	**Urgent**
3	**Not under control**	>=**Not under control**	Professional help
4	**Not under control**:Partly under control	**Not under control**:Under control	Professional help
5	>=**Not under control**	**Not under control**	Professional help
6	Partly under control	***No problems***	Insufficient self-care
7	Under control	>=Under control	Sufficient self-care
8	>=Under control	Under control	Sufficient self-care
9	***No problems***	***No problems***	***Good self-care***

Table 1: Part of decision rules

The designed multi-attribute self-care decision model aims to support patients’ decisions regarding timely seeking help or performing activities on their own to improve or maintain health and well-being. The inclusion of decision rules which represent normative expertise in a consistently regulated form, ensure the transparency and comprehensibility of the model. The rules were developed based on our own expertise and on literature review and were reviewed by experts. The rules can be easily reviewed and modified if necessary. Part of DM rules is presented in Table 1.

The decision criteria are intended to ensure that self-care decision model is able to make the "right" suggestions to patients and lay caregivers depending on the values of the input parameters. In our case, the variants are represented by elderly patients with CNDs living in home settings.

4 DISCUSSION

DM is a fundamental part of the self-care process in times of health and illness and adds complexity because of the large amount and often unstructured nature of data [11, 16]. When patients have the right information about how their bodies are functioning, they can make decisions and choose behaviours that support their health and well-being. It is critical for them to have credible and high-quality data [12], so it is important for patients to obtain data systematically. The presence of disease places an additional burden on health-related DM, which becomes more complex with multimorbidity and escalates with worsening CNDs. The difficulty of DM increases with the proliferation of choices or options, which also increases the number of decisions. Using a structured DM model, where complex decisions are broken down into smaller and more manageable ones, we enable patients with CNDs to better monitor their own health and make more transparent decisions.

Self-assessment of health status of expressed disease symptoms represents a subjective general assessment of one's health. The newly presented model considers the patients' experience of their own health and involves an interweaving of the physiological, sociological, and psychological dimensions of health, which are incorporated into the proposed model. This approach is subsequently useful to professionals for detecting poor preventive measures and identifying risk dimensions that could lead to frequent ER or GP visits and could be prevented by other non-medical interventions, e.g., more social involvement in case of loneliness.

Patients' morbidity requires vigilant monitoring of symptoms and intensive self-care [6]. As disease states become more complex, patients often intuitively opt for self-care measures. The cognitive activation enabled by the proposed model can replace spontaneity and intuitive responses to problems and decisions, reducing the likelihood of errors and leading to better, more effective DM [7, 18].

Self-assessment of present symptoms is not always an ideal solution compared to professional assessment but can be an important aid or support when patients decide to seek professional help. The proposed model is based on the assumption that patients, as experts in their own health, can or need to make independent decisions. With the proposed model, we aim to support them with digital professional support in responding to health changes in a timely and appropriate manner, and to encourage them to take appropriate self-care measures or seek professional help if their illness worsens. It provides support in making important life, health and wellbeing decisions, but the final DM remains with patients.

This model represents a novel approach that could promote more continuous support for patients with CNDs living at home, incorporating other dimensions of health in addition to physiological ones. At this stage of model development, empirical data have not yet been analysed to determine its usefulness for patients at home, which is the main limitation of our study. Future work on this topic should therefore focus on empirical research and modifications to the model to ensure adequate validity. It is also important to keep in mind that this approach to patients' self-care is a unique interdisciplinary field that should involve ongoing efforts by nurses, medical professionals, and social workers to ensure optimal outcomes.

5 CONCLUSIONS

The presented multi-attribute decision model is focused on self-care specific data and presents a novel method in supporting patients with CNDs. Simplicity of data gathering regarding patients' health enables timely and transparent decision that contribute to better quality of life and healthcare outcomes. Empirical research and interdisciplinary approach should be applied to fully develop the potential of this approach to support patient with CNDs living at home.

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FORECASTING THE HOMECARE UTILIZATION: CASE FOR VARAŽDIN COUNTY

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Abstract: Ageing of the populations of EU member states influence demand for homecare (HC) services. Various models are used to forecast the health care utilisation for older adults, defining variables and relationships between them. The utilisation models are essential for evaluating programs and policies of health care services. To forecast HC utilisation, this paper considers the socio-economic approach. It is based on the assumptions given by EUROSTAT in the EUROPOP2019 and the experiences of the HC nursing services of Varaždin County. The results show that the projections of the required number of HC users in the periodical Ageing Reports, published by the European Commission are underestimated according to the forecasting the demographic projections and healthy life longevity assumptions in Croatia and the Varaždin Count as a part of it, which is valid at least for the no-migration scenario.

Keywords: utilisation model, demographic projection, homecare demand, geographical gerontology, forecasting, human resources

INTRODUCTION

Estimates by the United Nations (2019, 18) show that, globally, the current proportion of people aged 65 and over is around 9%, with an increasing trend in the coming decades. This increase in the number of older people is linked to the ageing of the baby boom generation, longer life expectancy and reduced fertility, which will lead to increased demand for health and long-term care services (OECD 2020, 3; European Commission 2020, 8-12; European Commission 2021a, 16). Current age-related costs represent 25% of GDP at the EU level, with a projected increase of 1.1% over the next 50 years, mainly due to long-term and age-related healthcare costs (European Commission 2021a, 20). Life expectancy is also projected to increase in people over 85 with dementia or other health problems (Lewis and West 2014, 1). It is estimated that almost one in two people aged 65 and over has a disability or long-term mobility impairment (European Commission 2021a, 15). Older people often have joint pain and suffer from chronic diseases, and almost one in two has two or more chronic diseases, the most common of which are heart disease, diabetes, and lung disease.

The demand for homecare (HC) services is increasing as the number of persons 65+, especially those aged 80 and more, is rising. Therefore, the demand for nurses will increase further. The projection of demand helps us to determine needed education capacities for HC providers. Various models are used to forecast health care utilisation, defining variables and relationships between them. The utilisation models are essential for evaluating programs and policies of health care services. One of the most important variables is the number of required nurses in this system. This paper considers an approach to forecasting the HC utilisation, based on the assumptions given by EUROSTAT in the EUROPOP2019 and the methodology presented in the Ageing Report 2021 regarding the population projection and its consequences. The model will improve the HC utilisation projections based on the experiences of managers of HC services in Varaždin County. We found that the projected number of HC users in the Ageing Report 2021 for Croatia is underestimated. According to their forecasting, the HC demand of older adults in Croatia will grow only by 6,25%. In the next chapter, we suggest the model which will support decisions on the dynamics of investments in the social infrastructure for the older adults and the number of vacancies in the education system for nurses in Varaždin County.

HOMECARE UTILISATION MODEL

As the first step, let us consider the population projection in Croatia and on this basis also in Varaždin County, where the age structure of inhabitants older than 65 is described in Table 1. In Table 1 and further, we are using the notation as giving in Table 2.

Table 1: Age structure in Varaždin County* and the probability of being in HC in year *t*=2020**

age	Number of inhabitants male	Probability of being in HC	Number of inhabitants female	Probability of being in HC	age	Number of inhabitants male	Probability of being in HC	Number of inhabitants female	Probability of being in HC
x	*N(m,x,t)*	*p(m,x)*	*N(f,x,t)*	*p(f,x)*	*x*	*N(m,x,t)*	*p(m,x)*	*N(f,x,t)*	*p(f,x)*
65	1144	0,02098	1157	0,01844	82	373	0,07507	709	0,08275
66	965	0,02487	1125	0,01778	83	293	0,14562	662	0,13494
67	982	0,01222	1021	0,01437	84	206	0,16828	578	0,15917
68	924	0,02886	1009	0,02511	85	191	0,09773	500	0,14667
69	874	0,03661	1087	0,02576	86	38	0,59649	453	0,16188
70	839	0,04450	1035	0,02963	87	30	0,75556	394	0,17259
71	747	0,04462	895	0,03426	88	25	0,53333	327	0,17941
72	728	0,02930	957	0,03344	89	20	0,46667	277	0,18291
73	595	0,05602	865	0,05241	90	14	0,66667	203	0,20361
74	487	0,08214	708	0,04708	91	10	0,53333	158	0,20253
75	489	0,03817	753	0,04250	*92+	16	1,0000	108	0,20988
76	548	0,05109	800	0,05500	93	***only for male		88	0,27273
77	556	0,03837	924	0,05916	94			60	0,35556
78	420	0,08571	753	0,10270	95			45	0,08889
79	425	0,07529	779	0,08558	96			30	0,13333
80	348	0,06897	756	0,09347	97			18	0,00000
81	333	0,06406	684	0,09357	98			12	0,33333
82	373	0,07507	709	0,08275	99			6	0,22222

*Sources: *Croatian Bureau of Statistics; **Internal statistics of the HC network (collected by authors)*

The total HC demand per year t in hours at the same intensity of care (norms and standards) is, therefore:

$$HCD\ (h,t) = \sum_x p(m,x) \cdot N(m,x,t) \cdot IC(m,x) + \sum_x p(f,x) \cdot N(f,x,t) \cdot IC(f,x)8 \quad (1)$$

In this case the required number of nurses would be:

$$HCD(n,t) = HCD\ (h,t)/1700 \quad (2)$$

Table 2: Notation of the HC Utilization Model (HCU Model)

x	age		*IC(m,x)*	The expected intensity of care for a man who is x years old, included in HC
N(m,x,t)	Number of inhabitants in Varaždin County- male x years old in year t		*IC(f,x)*	The expected intensity of care for women who are x years old, included in HC
p(m,x)	Probability of man x years old being in HC		*HCD(h,x)*	Total HC demand per age x in hours
N(f,x,t)	Number of inhabitants in Varaždin County- women x years old in year t		*HCD(n,x)*	Total HC demand per age x in the number of nurses employed
p(f,x)	Probability of women x years old being user of HC services		*HCD(m,h), HCD(f,h),*	Total HC demand per year in hours- for a man *(m)* and women *(f)*, respectively
RN(t)	Required number of nurses		*C(t)*	Yearly costs of human resources - nurses

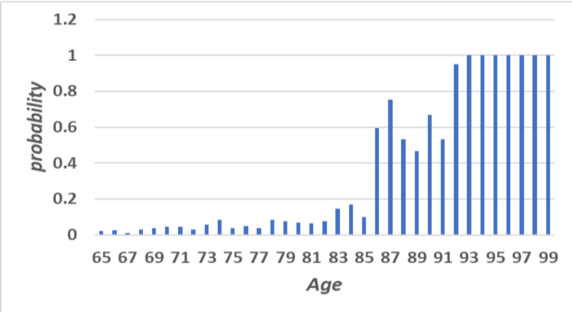

Figure 1a: Probability that inhabitant of Varaždin County will be a user of home nursing care in 2020 for male

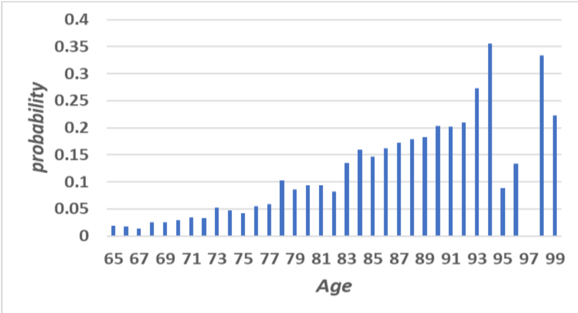

Figure 1b: Probability that inhabitant of Varaždin County will be a user of home nursing care in 2020 for female

While the total cost of human resources at a given annual salary of a nurse equal to *C* would be

$$C \cdot HCD(n,t) = C \cdot HCD\ (h,t)/1700 \tag{3}$$

Data collected by the public Varaždin County home nursing care network were processed by authors. The data on the probability that inhabitant of Varaždin County will be a user of the home nursing care services as the relative frequency of these users, by sex and age cohorts (Figure 1a: male and 1b: female) the utilisation model was implemented. We also found that these probability figures do not change much over the years. Therefore, these probability values will be subject to further consideration and projections.

Figure 2a presents the projection of cohorts 65+ and 2b gives us the projections of cohorts 80+ of Varaždin County if the structural dynamics are similar as given in the projections for Croatia in EUROPOP2019 (Eurostat, 2020). The methodology as presented in EUROPO2019 includes the no-migration scenario. The intensity of care is varying regarding the needs of individuals. The average intensity of care for the clients in the Varaždin public HC network in 2020 is given in Figures 3a (male) and 3b (female).

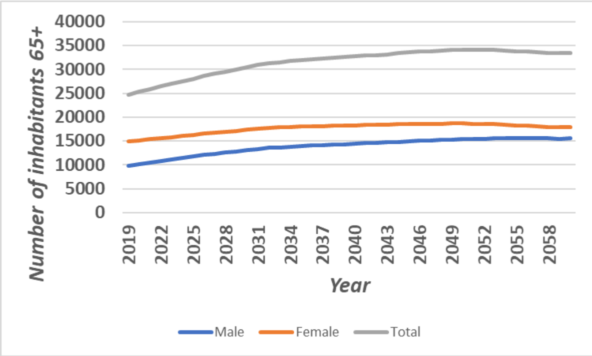

Figure 2a: Population projection ***N(65+, t)*** for Varaždin County 2020-2050- cohorts 65+, no-migration scenario

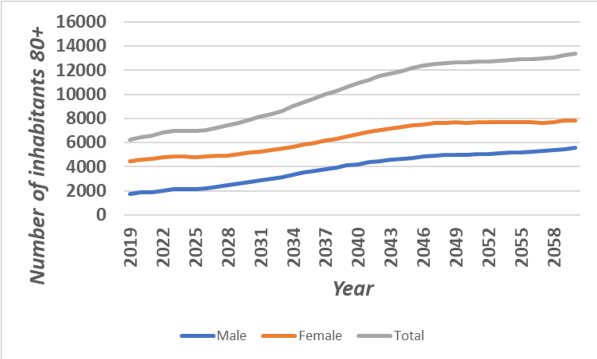

Figure 2b: Population projection ***N(80+, t)*** for Varaždin County 2020-2050- cohorts 80+, no-migration scenario

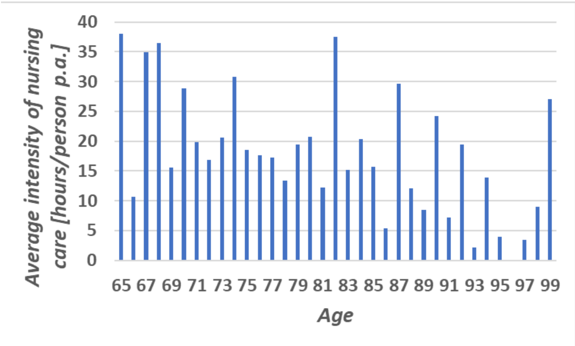

Figure 3a: Age dependence of the intensity of HC for Varaždin County in 2020 for male

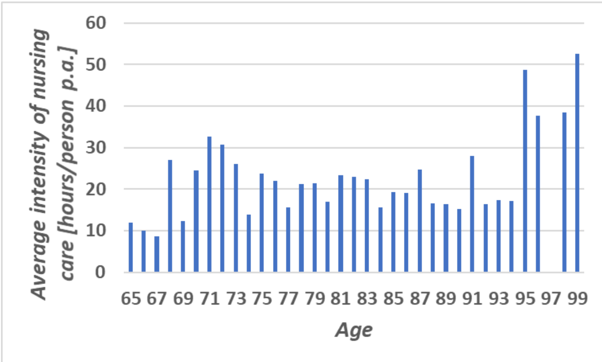

Figure 3b: Age dependence of the intensity of HC for Varaždin County in 2020 for female

From Figure 3 it follows the total yearly HC utilisation for male and female by ages in 2020, as given in figure 4a (men) and 4b (women).

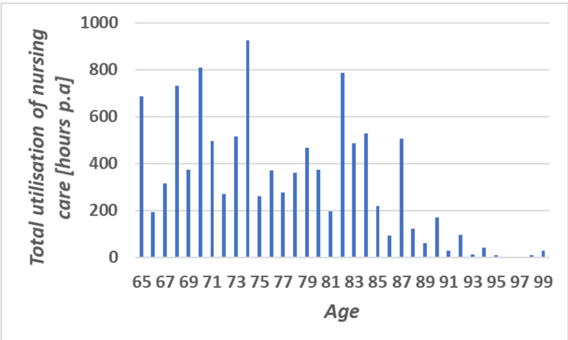

Figure 4a: Total yearly HC utilisation for males by ages in 2020

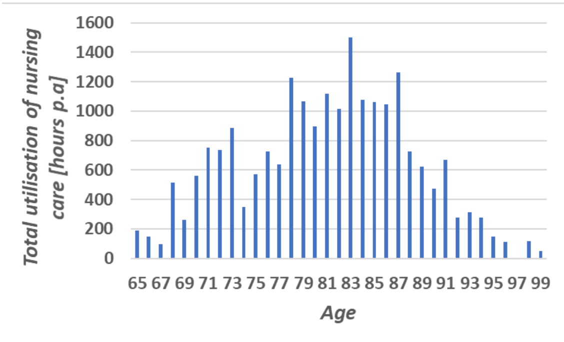

Figure 4b: Total yearly HC utilisation for females by ages in 2020

From population projections and study of the HC utilisation, the projections of the number of users of home nursing care for Varaždin County, *HCD(n,t),* for the period 2019-2060 was calculated. In addition, projections of the required number of nurses and projections of public expenditures for human resources have been considered according to the existing norms and standards. The results are presented in figure 5 and figure 6, respectively.

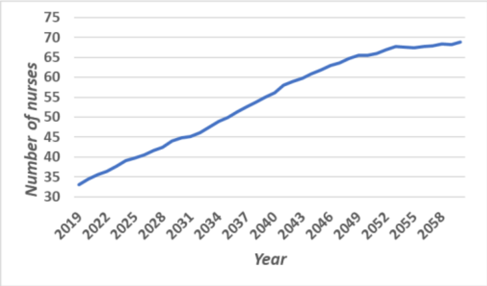

Figure 5: Projections of the required number of nurses for home nursing care - *RN(t)* in Varaždin County for period 2019-2060.

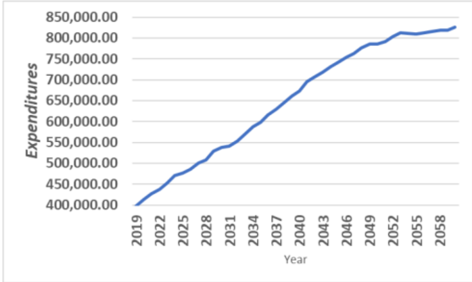

Figure 6: Projections of public expenditure for wages of nurses in Varaždin County for period 2019-2060 [€].

DISCUSSION

It follows from our analysis that the requirements for greater nursing care utilisation are rapidly increasing also in case of the unchanged standard of care for the ageing population in the Varaždin County. From the current situation, with the unchanged indicator of healthy living and according to EUROSTAT demographic projections for Croatia, the number of patients will increase from approximately 2,500 to 5,500 by 2060, the number of care hours will rise from less than 50,000 to almost 100,000, and the number of caregivers will increase from 35 to nearly 70. This rapid growth will require extensive public expenditures, especially for nurses' salaries, in an annual amount of over EUR 820,000, if nurses' wages remain unchanged. This, in turn, means an enormous expenditure for the public budget, which raises questions about new care policies for older adults. The search for optimal solutions with limited financial resources also raises the question of approaching the search for adequate and sustainable solutions with mathematical programming, which will be the subject of our further research. An important unresolved issue is also how to ensure enough nurses. Therefore, it is also worth considering how to attract nurses from the broader area to Varaždin County who would decide to immigrate to the region or travel daily to work in Varaždin County. The approaches developed by Drobne and Bogataj (2012, 2014, 2015) and embedded in the models of optimal policies for human resources utilisation (Bogataj et al., 2019) should be used to support this kind of policy.

CONCLUSION

The research problem exposed in this paper was how to design and further develop an HC utilisation model for the older adults living in the community. The model and its implementation tried to project the demand for HC nursing services in the next 40 years on a county level. Data obtained from the national statistical database and provided by the HC providers are the basis for the development of a regional and national model of health and social infrastructure and services to support deinstitutionalisation and community living for older people in case that the percentage of inhabitants of given age being in HC does not change. The service level also stays the same over the next 50 years. As provided in the model, both parameters can be easily changed in the future policies of regions and states. The paper shows how to create the HC nursing utilisation model, forecasting the use of health care resources. The model generates projections of the number of the potential users and working hours of care at the same or changed intensity (service level) of home health care per inhabitant and the required number of nurses to care for them. In the article, we assumed that the duration of healthy life would not increase with the general extension of life in Varaždin County, which is also predicted by European projections. If this assumption is changed, the probabilities of care will be reduced for the lower ages. The model will continue to be equally valuable at the level of Varaždin County and the level of the whole of Croatia beyond. This model is needed for the long-term projection of the utilisation of the health system and long-term care system concerning the needs of the elderly and the norms and new standards of home health care to establish a long-term care system, which is not developed in Croatia. Based on this model, health policymakers will develop better projections and a long-term plan for the LTC development, including home healthcare.

Acknowledgement

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Special Session 11:

Operations Research in Agricultural Economics and Farm Management

FARM MODEL AND RISK MANAGEMENT STRATEGIES ON A MIXED FARM TYPE

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Abstract: This paper addresses the problem of farm planning considering production and price risk. The extent of risk, possibilities of risk reduction and also its efficiency were studied on a hypothetical semi-size farm, with a typical mixed production plan including different livestock activities, fodder production as well as cash crops. For this purpose a farm model based on LP (linear programming) and QRP (quadratic risk programming) has been developed. The risk performance of farm production was analysed in the expected value and variance E,V efficient set. Results show that there are different strategies how risk on such a farm could be mitigated. With a slightly changed production plan, it could increase the EGM (expected gross margin) by 10% at the same level of risk.

Keywords: farm model, diversification, risk management, linear programming, quadratic programming, E-V efficient set

1 INTRODUCTION

In the last decade, the development and use of farm-level models has become an important activity of agricultural economists [4]. There is a critical need for data, models, and knowledge products that provide user-friendly data collection and analytical capability for decision makers at different levels. Developed cases range from farm-level decision support to decision support for policy makers whose goal is sustainable management of natural resources [2]. Louhichi et al. [6] have observed that most of the applied models are implemented at an aggregate level (regions, countries) and are not able to fully capture the impact of new policies at a farm level. Namely, there is obvious changes in the shift toward a more result-oriented agricultural policy and a clear commitment to policy that is based on facts and an established intervention logic [7]. This attributes to the increasing demand for tools and methods for micro-level policy analysis, in addition to a better understanding of farm-level decision making [4]. The rationale for the farm-level model is mainly based on the growing demand and need for a micro-simulation tool that can design and analyse different policies at the level of each individual farm, thus capturing the heterogeneity of farms [6] as well as possibilities that farms have in regard to risk management. So far numerous farm models based on different techniques have been developed to address a variety of questions in agricultural systems [4]. For that several approaches have been used. The most often applied is mathematical programming (MP), including linear programming (LP), non-linear programming (NLP), mixed integer programming (MIP), and positive mathematical programming (PMP), as well as also models based on econometric approach, simulation approach and also agent-based models (ABM) [4]. The type and quality of available data as well as scope of the research most often defines which approach fits the best to address farm-level modelling [4].
Risk is becoming a significant factor in agricultural production. There are different sources of risk threatening farm businesses [5]. Production risk reflects a change in the quantity and quality of crops and production mainly due to adverse weather conditions and pests [5].

Important source of risk are unstable prices, which have become increasingly volatile in the last decade. Reforms of the Common Agricultural Policy have led to a market-oriented farm sector that is increasingly exposed to market price volatility [10]. Moreover, inappropriate risk management decisions can cause potential selling of assets, which reduces savings and decreases employment. Due to the inefficiency of inappropriate risk management, farmers are forced to reduce their investments to mitigate risk, which can have an unpleasant effect on production. The adoption of an appropriate risk management strategy is essential for farmers in reducing the adverse effects [5]. In the first place this could be diversification of production plan as the first measure to mitigate risk.

Literature suggests that most farmers are risk averse when facing with risky outcomes [9]. Someone who is risk averse is willing to accept a lower average return for less uncertainty, with the trade-off depending on the individuals' level of risk aversion. This means that strategies cannot be evaluated solely on the basis of average or expected return, but that risk must be factored into decisions. Knowledge of farmers attitudes towards risk and its management is important in determining the appropriate strategies. There are a number of challenges how to effectively organize production and which activities to select to reduce risk or to achieve better economic results at the given level of risk [11].

Risk management analysis can be approached in different ways. This paper is about a possible reduction at the farm level, particularly concerning those possibilities that the farmer has available in the field of the production planning. It is an issue of diversifying the production plan, considering normal risks that farm should be able to manage.

To model this problem, the expected value and variance (E,V) model, based on the risk balancing hypothesis proposed by Markowitz, is going to be used. It uses the mathematical concept of variance to quantify risk. It is assumed that the decision maker relies only on the mean and variance. Different varieties of such approaches could be found in the literature [5]. One of them is QRP, which minimizes the sum of total variance while the certainty equivalent (e.g., expected gross margin) is parameterized over the feasible region. Main advantage, which also explains the popularity of the E,V approach, is that only information on expected value and variance of the outcome distributions is needed to allow at least a partial ordering of the alternatives. Variability is measured according to different states of nature defined by different sources of instability (yield, price, variable costs, subsidies etc.) [5].

2 MATERIAL AND METHODS

The main objective of this study is to analyse the efficiency of different possibilities of risk reduction through diversification of a production plan on a hypothetical semi-size farm. It is a case of a farm with a typical mixed production plan including different livestock activities, fodder production as well as cash crops. In general, it is a problem of optimal allocation of production resources, considering also riskiness of production activities. For this purpose, farm model based on mathematical programming has been developed. It is an example of a spreadsheet model developed in Microsoft Excel. Such models can be solved through mathematical programming using Excel Solver to solve linear and non-linear models [3].

The farm model is based on mathematical programming and enables optimisation of production plan. The model enables the integration of various production activities (livestock, crop and vegetable/fruit products), different levels of production intensity, as well as change in technological parameters. For the needs of defining individual production activities technological coefficients, farm model is supported by the model calculations, developed by the Agricultural Institute of Slovenia [1]. The basic set of constraints deals with the available production resources, describing the characteristics of analysed farm. Basic set of constraints includes labour requirements, tillage area, crop rotation, conservation technologies for grass land, nutrition and ration balance and stable capacity (number of places for different categories of animals). The developed farm model consists of three sub-models.

The **first sub-model** is a simple simulation model that calculates the economic and technical parameters for all production activities that could enter production plan. It generates technological cards for each of the production activities and calculates revenues, variable costs and gross margins for different states of nature, considering integrated production functions. We assumed that technologies remain fixed, however prices and costs could change, through different time periods (2011 - 2020). These data were obtained from Agricultural Institute of Slovenia [1].

The **second sub-model** is based on **linear programming (LP)**. The main purpose of it is to find the optimal solution that provides the highest gross margin (GM), which represents the starting point for the parametric constraint in the third sub-model that considers also risk. The objective function with the EGM is subjected to maximization. On that basis optimal production plan is determined, considering the price-cost ratios of the ten years period (2011 - 2020).

$$\mathbf{GM}_f = \max\left\{\sum \mathbf{X}_f \mathbf{EGM}_{\mathrm{A},f}\right\} \tag{1}$$

s.t.

$$\mathbf{X}_f \mathbf{TC}_f \leq \mathbf{R}_f \tag{2}$$

$$\mathbf{X}_f \geq \mathbf{0} \tag{3}$$

Where X_f is the decision vector of activities and EGM_f is the scalar of the expected maximum gross margin per farm. TC_f represents the matrix of technical coefficients for the analysed farm.

The **third sub-model** is based on **quadratic risk programming (QRP)**, which considers also the riskiness of production activities. It enables calculating optimal solution at a given level of risk that in set of optimal solutions forms efficient production frontier. Thus, the basic idea for formulating the efficient E-V frontier is to minimize the variance as an argument of the objective function, achieving a certain expected gross margin, which is expressed as a constraint in the model [5].

$$\mathbf{SD(GM}_f\mathbf{)} = \min\left\{\sqrt{\mathbf{X}'_f\,\mathbf{(VARCOV(GM_{Aij})}_f\mathbf{)X}_f}\right\} \tag{4}$$

s.t.

$$\mathbf{GM}_f\boldsymbol{\lambda} = \sum_{A=1}^{i} \mathbf{X}_f \mathbf{EGM}_{\mathbf{A}}, \lambda \text{ varied } 1 \textit{ to } n \tag{5}$$

$$\mathbf{X}_f \mathbf{TC}_f \leq \mathbf{R}_f \tag{6}$$

$$\mathbf{X}_f \geq \mathbf{0} \tag{7}$$

Where SD (GM_f) represents the scalar of the standard deviations of the expected gross margins for a farm *f* and is computed as the square root of the sum product of the decision vector of solutions X_f and the variance-covariance matrix ($VARCOV(GM_{Aij})_f$) of activities gross margins.

2.1 Analysed farm

Described farm model has been utilised on a typical semi-size farm. It is a mixed livestock and crop production farm, where the main economic activity is cattle breeding, dairy (18 dairy cows and 5 breeding heifers) and meat production (8 cattle for fattening). Besides cattle, hens (30 heads), pigs (3 heads) and goats (2 heads) are also kept on the farm. This is a farm that was developed within another study [12]. The main idea of those typical farms is that they should be representative for a group of farms and in such a manner also reflect situation in the field. Therefore, production plan is not necessary economically optimal (regarding the given resources), but should reflect situation as it is in practice. To achieve this, special calibration process has been applied presented in [12]. From mathematical programming concept this means that additional set of constraints is included into the model to fix mainly economic activities that define farm type (livestock in our case study).

The analysed farm belongs in the less-favoured area (LFA) and among the agricultural land meadows predominate with 10 ha of own meadows and possibility to rent another 8 ha. Farm also has 2.5 ha of own fields with the possibility to rent additional 4 ha of arable land if needed. Cereals, corn, clover-grass mixtures, and a small proportion of potatoes are grown in the fields. There is also an orchard of apple trees. The workload on the farm accounts for 1.7 full-time equivalent (FTE).

2.2 Analysed Scenarios

However, since this is a typical farm and production plan in that sense is relatively fixed (Baseline - BL), we included some adjustments to the management strategy and possibilities in the analysis through different planning concepts. To analyse the possibilities of effective risk management strategies that the farm has, we analysed different cases.

At the first stage we were interested i) what the farmer could do to increase economic result at the same level of risk (A), or ii) to reduce risk at the same level of EGM (B). Further we analysed two strategies of possible production plans to reduce risk. First strategy was minor change in current production capacity and assumes that it is not possible to increase animal production capacity over baseline (NoAP), but only to decrease or reshuffle within given capacity. In the second strategy, we assumed also eventual increase of animal production activities capacity (InAP). For both strategies we have calculated numerous production plans. In all of them, we gradually reduced the EGM with the described procedure of the farm model, while minimizing the total risk (QRP).

3 RESULTS

In this chapter we present the main results for the analysed farm. In the first part we present the summary of the production plan and economic indicators for the baseline (BL) and analysed (optimal) risk management strategies achieving maximal EGM through the diversification of the production plan (Table 1). For main production activities we present also EGM (calculated as ten years average) and expected production intensity for the same period. Further we present efficient frontiers in the E,V context (Figure 1) and for relative comparison of two different strategies (NoAP and InAP). For both (NoAP and InAP) we include also percentage comparison for decrease in EGM and risk (Figure 2).

In the Baseline scenario (BL) the farm could reach total revenues of 65 323 € and EGM of 41 289 €. In such a case it breeds 18 dairy cows and needed number of heifers, 7 cattle for fattening and as assumed 30 laying hens, three pigs for fattening and two goats. Needed fodder is produced mainly on grass land and corn with cereals also on the arable land. As typical for such a farm, there is a small sale of cereals production and also a small apple orchard. As shown in table 1, standard deviation (SD) in all scenarios is relatively low in comparison with the level of expected gross margin (EGM). Namely, economic conditions were relatively stable in observed period. Such a plan in first scenario (BL) has coefficient of variation (CV) of 0.17, however with increase and diversification of animal production activity in scenario C it increases for 0.72%.

Table 1: Production plan for hypothetical farm and optimal solutions and economic indicators for maximized expected gross margin

Production activities ***Animal production***	***(unit)***	***Scenario*** ***Baseline (BL)***	 ***A***	 ***B***	 ***C***	***EGM of activity (€)***	***Expected intensity (kg/head, kg/ha)***
Dairy cows	(heads)	18	18	16	24	2 161.6	6 000
Breeding heifers	(heads)	5	4	3	5	-56.9	550
Cattle for fattening	(heads)	7	9	9	4	1 298.4	700
Laying hens	(heads)	30	50	50	50	38.5	270
Pigs for fattening	(heads)	3	10	10	10	117.4	150
Goats	(heads)	2	5	5	5	195.9	67
Crop production – fields							
Triticale	(ha)	0.6	0	0	1.0	-180.9	5 000
Potatoes	(ha)	0.2	0	0.1	0.2	2 808.0	35 000
Corn	(ha)	2.0	1.9	1.6	1.6	-853.7	9 000
Corn for sillage	(ha)	1.4	1.4	1.2	1.8	-809.0	50 000
Barley	(ha)	0.6	1.5	1.3	0.7	-240.8	5 500
Wheat	(ha)	0.2	0.3	0.3	0.3	53.7	5 500
Fruit growing							
Apples	(ha)	0.5	0.5	0.5	0.5	451.5	7 000
Crop production – grassland							
Grass silage	(ha)	7.3	7.0	6.3	9.7	-687.1	21 857
Pasture	(ha)	0.2	0.2	0.2	0.3	-55.9	48 971
Hay	(ha)	2.9	3.9	3.7	3.9	-405.0	8 895
Economic indicators at farm level							
Total revenue	(€)	65 323	70 525	65 808	80 066		
Total variable costs	(€)	24 034	24 891	24 543	31 519		
EGM	(€)	41 289	45 634	41 265	48 547		
SD of EGM	(€)	6 952	6 943	6 192	8 525		

Further, if the farm has the opportunity to diversify the production plan and expand the current barn and the number of animals in the herd (except dairy cows), this could improve the farm results. Scenario A shows that the farm can increase the EGM (+10.5%) with a change in the production plan, while the risk, expressed as SD of EGM, can remain almost the same. This can be achieved by retaining the number of dairy cows, reducing the number of breeding heifers by 1, increasing the number of beef cattle by 2. However, the major influence is by including less risky production activities: laying hens (+20), fattening pigs (+7) and goats by 3 heads.

In the second example (B) we present how the farm can reduce risk while maintaining the same level of EGM. This can be achieved by reducing the number of cows (–2) and heifers (–2) while increasing the number of beef cattle by 2, laying hens (+20), fattening pigs (+7) and goats (+3), so that in this scenario the EGM remains at a similar level while the farm has a lower risk. In the third option (C) we present an extreme, namely what the farm could achieve regarding the production resources if we only maximize EGM and don't consider risk as such and also we allow to increase number of dairy cows. In such a case the farm can increase its EGM by 18% while increasing its risk by 23%. The main binding constraints for further improvements in such a case are barn capacity (cattle), current market capacity (for laying hens, fattening pigs and goats) and also availability of arable land.
For both strategies of reducing risk (not possible to increase animal production activities (NoAP) and eventual increase of animal production activities (InAP)) we have calculated numerous production plans, parameterising EGM and minimising risk (SD) (Figure 1). As it is apparent from Figure 1, NoAP has significantly minor possibilities of reducing risk as well as increasing EGM. This shows how important is dairy on such a farm as this one from risk management perspective. Both points (BL and C) in the upper right on Figure 1 represent an

optimal LP solution that maximizes the EGM. These solutions represent situations where the farmer would be indifferent to risk with the main objective of maximizing the EGM. As shown in Figure 1 and described above, by exploring the potential of the farm and diversifying the production plan on the farm, we can significantly increase EGM with a similar level of risk.

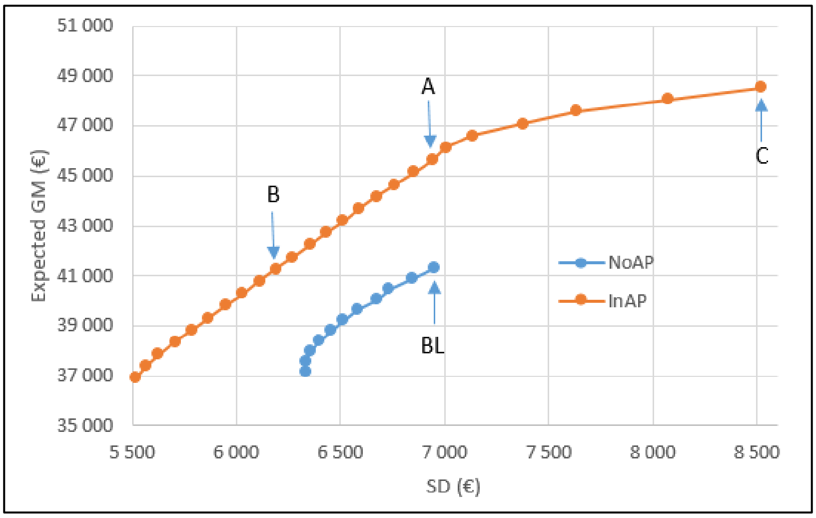

Figure 1: E-V efficient frontiers for NoAP with baseline (BL) and InAP (Scenarios (A, B, C))

However, to analyse how efficient a farm could be regarding circumstances at reducing risk we show in Figure 2. The steeper the curve, the less efficient the farm is at reducing risk and more EGM the farm must give up to reduce risk for one unit. The results show that the NoAP is significantly more risky and less efficient than scenario InAP with possible diversification of the production plan with increasing animal production activities, mainly in favour of granivores. In reduction of risk by 9%, we can see that NoAP has a decrease of EGM by 10%, while the same reduction in InAP scenario has only 2% decrease in EGM.

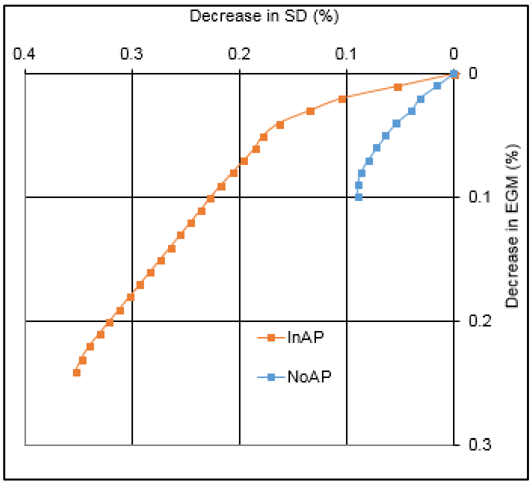

Figure 2: Diversification efficiency for NoAP and InAP

4 CONCLUSIONS

In the paper farm model for analysing farm production plan considering different strategies of risk mitigation is presented. Numerous authors suggest that overall risk could be significantly reduced through diversification [8] and in such a manner efficiency of diversification strategies could be measured as the movement of risk reduction through whole-farm planning. We present the results for a mixed typical farm, which by itself has a diversified production plan. In doing so, we were mainly interested, what are its main possibilities in relation to the current circumstances (production resources) and how much of normal risks could be managed through diversification.

Based on the results, we can conclude that diversification strategy, even on such a mixed farm type, has positive potential and farm could achieve significantly better economic results and especially higher efficiency in risk management. If the farm has the opportunity to change the production plan and (slightly) increase its infrastructural potential, the results suggests that it could increase the EGM by 10% at the more or less the same level of risk. On the other hand, if the farmer is willing to take higher risk, based on the current situation, the farm's EGM could increase by up to 18%. The results show that with a slight flexibility in management (possible increase in the scope of activities involved), which would also mean that the farmer has to make an effort and find an additional market (eggs, pig meat and goat meat), he can significantly improve the efficiency of risk management or reduce the risk of such a strategy.

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MULTI-CRITERIA EVALUATION OF ALTERNATIVE SCENARIOS FOR CLOSING LOOPS OF AGRICULTURAL AND FORESTRY BIOMASS

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Abstract: In this research, we developed a multi-criteria decision model for expert evaluation of three alternative scenarios for closing loops of agricultural and forestry biomass: (1) within the production unit (farm, enterprise); (2) industrial symbiosis and (3) bioeconomy clusters. We used a qualitative multi-criteria decision method DEX that was additionally supplemented with the Analytic Hierarchy Process (AHP) method. The results reveal a difference in the performance of alternative scenarios between agri-food and forestry-wood value chains. With respect to the agri-food value chains, evaluation results suggest that all alternative scenarios are suitable, but none is optimal, which indicates that stakeholders in agri-food sectors are somewhat reticent towards more complex forms of organizations, but are aware of the prospects. Contrastingly, more complex organization forms (bioeconomy clusters) were identified as optimal in the case of the forestry-wood sector.

Keywords: Bioeconomy, multi-criteria decision modelling, method DEX, analytic hierarchy process (AHP)

1 INTRODUCTION

Weak cooperation among actors along value chains arising from agricultural production [7] and forestry-wood resources [6] is one of the key structural weaknesses in the Slovenian bioeconomy. This is reflected in unfavorable structure of biomass flows with untapped potential for adding value. For example, for some key products of the Slovenian primary sectors more than a third of primary production is processed abroad (e.g. agriculture – beef and milk production; forestry – coniferous wood), while in the case of forestry – deciduous wood, most of the primary production is directly processed for energy use [9].

The cooperation of industrial actors along the value chains in line with the principles of circular bioecoomy (ie. adding value through the cascading use of biomass and by closing material and energy loops) is a rather multifaceted process that can proceed at different levels of complexity, which can be captured in the following scenarios [5]:

a) *Scenario A: Closing biomass loops within the production unit ('improved production practices')* represent cases where the side streams or waste biomass are used for the production of new products or services within the production unit (eg. farm or manufacturing firm).
b) *Scenario B: Industrial symbiosis ('improved technologies and processes')* represent examples of vertical (sectoral or cross-sectoral) cooperation, where the side and waste biomass become a secondary raw material for products of another production unit or sector.
c) *Scenario C: Bioeconomy clusters ('improved organization')* represents network structures based on sectoral, vertical, and horizontal cooperation among various stakeholders (entrepreneurs, knowledge institutions, policymakers, consumers and other organizations) to achieve complementary objectives.

This research aims to develop and test a multi-criteria model that will help to determine and evaluate the optimal scenario for four previously identified [9] perspective value chains in the Slovenian bioeconomy: (i) residues in agricultural production and landscape management; (ii) residues in food production and consumption; (iii) residues in logging and primary processing of wood and (iv) residues in the industrial processing of wood.

We used a qualitative multi-criteria decision method DEX that was additionally supplemented with the Analytic Hierarchy Process (AHP) method.

2 METHODOLOGY

2.1 Multi-Criteria Decision Modelling

Multi-Criteria Decision Modelling (MCDM) [4] is concerned with structuring and solving decision problems that involve multiple and possibly conflicting criteria. To support a decision-maker, a primary problem Y is divided into subproblems. Subproblems are presented as parameters X (criteria, attribute) that define alternatives (variants). Utility function F merges values of parameters in the final evaluation (utility) of the primary problem (Figure 1).

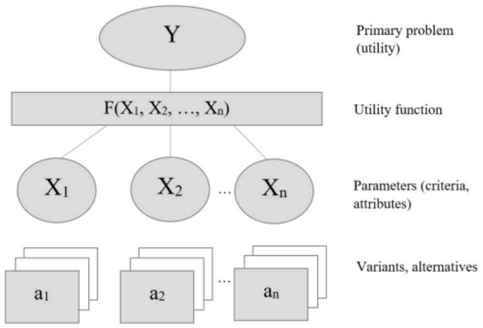

Figure 1: Multi-criteria decision model (MCDM) [1]

DEX (Decision EXpert) is a hierarchical, qualitative and rule-based MCDM method. The DEX model consists of hierarchically structured attributes that are symbolic, taking linguistic values, and the hierarchical aggregation of values is defined with decision rules, acquired and represented in the form of decision tables [2]. The DEX method is implemented in DEXi software [10]. To determine the importance of criteria used in the DEX model, we used the quantitative MCDM method AHP (Analytic Hierarchy Process) [8]. AHP is based on arranging the criteria in a hierarchy by selecting only a small number of criteria (3-5) at each level. The importance of criteria at a certain level is determined by paired comparisons. Namely, the relative importance of criteria i and criteria j is assessed with values from 1 to 9, where 1 indicates that criteria i and j are equally important, and 9 indicates that criteria i is absolutely more important than criteria j [8].

2.2 Development of a multi-criteria model for evaluating the scenarios

2.2.1 Selection of evaluation criteria and value scales

The evaluation of alternative scenarios for closing biomass loops of agricultural and forestry origin was based on four main groups of criteria (1st order criteria) (Figure 2). The first group defines the following economic criteria: (i) *improvement of market performance* defines whether the closure of biomass loops per scenarios (A, B, C) enables better market performance of the main product of the company or farm; (ii) *improving the business operations* defines whether scenarios (A, B, C) enables the improvement of operations (e.g. increased added value, reduction of costs) of the entire company or farm; (iii) subcriteria "*costs*" refers to the level of additional costs that would be required to implement the scenario (A, B, C). It covers two categories of cost, namely, the required level of additional *investments* and *running costs* (e.g.

materials, cost of labour, operating costs); (iv) subcriteria "*innovativeness"* refers to the level of innovativeness (of *technologies* and *products or services)* that could be achieved by implementing the scenario (A, B, C).

The second group includes environmental criteria: (i) subcriteria "*energy use*" refers to changes in energy use (fossil energy and renewable energy) that are expected to occur with the implementation of the scenario (A, B, C); (ii) the "*waste*" criteria define the change in waste management; (iii) the "*environmental resource"* subcriteria includes changes of the four categories (air pollution, water resources, soil quality and biodiversity state) that would be brought by the implementation of scenarios (A, B, C).

The third group defines social criteria: (i) *new products and services* define the potential of the scenario (A, B, C) for the introduction of new products or services on the market; (ii) the *customer satisfaction* criterion includes the expected change in the user experience or customer or service satisfaction; (iii) the *additional employment* criterion covers the impact of the scenario (A, B, C) on the growth potential of additional employments. (iv) *social innovation* defines whether the introduction of the scenario (A, B, C) represents a social innovation, i.e. an innovation that supports social progress, in terms of e.g. improving working conditions, education and community development.

The last set of criteria assesses the performance of scenarios in terms of circularity: (i) *utilization of side streams* derive from the basic bioeconomy concept, i.e. cascading use of biomass. The subject of the assessment is the number of utilized side streams that can be used within the implementation of the scenario (A, B, C); (ii) *stages of processing* refer to the possible number of biomass processing stages before end use of biomass (usual energy) that can be exploited with the scenario implementation (A, B, C); (iii) *business cooperation* criteria assess the impact of scenarios (A, B, C) on business cooperation with other economic entities; (iv) linking to the previous criteria, the *total value-added* assesses the impact of the scenario (A, B, C) on the growth of the aggregate value added of the participating companies.

Criteria	Value scales
Scenario assessment	**Less suitable**; Suitable; ***Optimal***
├ **Economic criteria**	**Low utility**; Medium utility; ***Significant utility***
├ ├ Improvement of market performance	**No**; Partly; ***Yes***
├ ├ Improving the business operations	**No**; Partly; ***Yes***
├ ├ **Costs**	**Higher**; Remain similar; ***Lower***
├ ├ ├ Investments	**High level**; Medium level; ***Low/negligible level***
├ ├ └ Running costs	**Higher**; Remain similar; ***Lower***
├ ├ **Innovativeness**	**Low**; Advanced; ***High***
├ ├ ├ Innovativeness of technology	**Low**; Advanced; ***High***
├ ├ └ Innovativeness of products/services	**Low**; Advanced; ***High***
├ └ Enquiry	**Lower**; Remain similar; ***Higher***
├ **Environmental criteria**	**Low utility**; Medium utility; ***Significant utility***
├ ├ **Energy use**	**No changes**; Moderate improvement; ***Significant improvement***
├ ├ ├ Fossil energy	**No changes**; Moderate reduction ; ***Significant reduction***
├ ├ └ Renewable energy	**No changes**; Moderate increase; ***Significant increase***
├ ├ Waste	**No change**; Minor change; ***Major change***
├ └ **Environmental resources**	**Aggravation**; No changes; ***Improvment***
├ ├ Air	**Aggravation**; No changes; ***Improvment***
├ ├ Water resources	**Aggravation**; No changes; ***Improvment***
├ ├ Soil	**Aggravation**; No changes; ***Improvment***
├ └ Biodiversity	**Aggravation**; No changes; ***Improvment***
├ **Social criteria**	**Low utility**; Medium utility; ***Significant utility***
├ ├ New products and services	**Low**; Moderate; ***High***
├ ├ Customer satisfaction	**No changes**; Slightly higher; ***Significantly higher***
├ ├ Addidtional employment	**No changes**; Moderate growth; ***Significant growth***
├ └ Social innovation	**No**; ***Yes***
└ **Circularity criteria**	**Low utility**; Medium utility; ***Significant utility***
├ Utilization of side streams	**One**; ***Two or more***
├ Stages of processing	**None**; One; ***Two or more***
├ Business cooperation	**No changes**; With one company; ***With two or more companies***
└ Total added value	**No cooperation**; Moderate growth; ***Significant growth***

Figure 2: Criteria tree and value scales for evaluating the alternative scenarios for closing biomass loops of agricultural and forestry origin

2.2.2 Determining the importance of criteria and scenario evaluation

The importance (weights) of criteria were determined with the AHP method. For this purpose, we designed an online survey using the online survey tool 1KA. The paired comparisons of criteria based on a 9-point measurement scale were assessed by six experts. The results were entered into the MS Excel tables, which were developed for AHP implementation [3]. The consistency ratio (CR) was lower than 10 %, so no reassessment was required and the obtained weights were entered into the DEXi model to determine the decision rules (utility functions).

The evaluation of scenarios for each value chain was based on the results of a questionnaire completed by stakeholders (bioeconomy experts from industry, academia and governmental institutions) at a public workshop conducted on 14 June 2021. Performance of the three scenarios along four value chains was assessed on-line (application Mentimeter). In the first part of the questionnaire, the participants stated the bioeconomy sector or activity that is in line with their professional competencies or their professional interest. Respondents were asked to imagine that for the sector they had chosen, they would implement the scenarios (A, B, C). Subsequently, the questionnaire guided them through a set of factors (decision model criteria) for scenario assessment.

Based on the selected sectors by respondents, we aggregated the results of scenarios assessments into four value chains. We used the mode (i.e. a value that appears most often in a set of data values) to combine the results for each value chain. A total of 14 workshop participants completed the questionnaire, of which 2 (14.3%) represented the chain "residues in agricultural production and landscape management", 2 (14.3%) "residues in the food production and consumption", 4 (28, 6%) "residues in logging and primary processing of wood" and 6 (42.9%) represent the chain "residues in the industrial processing of wood". The pooled values were the input data for the evaluation of scenarios in the DEXi model.

3 RESULTS AND DISCUSSION

The assessment of alternative scenarios for closing loops of agricultural and forestry biomass, according to the results of pair comparisons (AHP), is mostly influenced by environmental criteria (43% of 1st order of criteria) (Table 1). Among these, experts attributed the greatest weight to the criteria “waste” (42 %) and “environmental resources” (40 %). In order of importance, the next group of criteria refers to circularity performance (22% of 1st order of criteria), among which the criteria “utilized side streams” has the greatest importance (51 %). Social (19% of 1st order of criteria) and economic criteria (17% of 1st order of criteria) have less impact on the overall evaluation of the scenario.

Table 1: Criteria weights obtained based on paired comparisons

1st order	***Weight (%)***	***2nd order***	***Weig ht (%)***	***3rd order***	***Weight (%)***
Economic criteria	17	Improvement of sales conditions	12		
		Improvement of business operation	40		
		Enquiry	25		
		Costs	16	Investments	68
				Running costs	32
		Innovativeness	9	Technology	68
				Products/services	32
Environmental criteria	43	Waste	42		
		Energy use	18	Fossil energy	33
				Renewable energy	67
		Environmental resources	40	Air pollution	15
				Water resources	36
				Soil	24
				Biodiversity	25

Table 1 (continued)

Social criteria	19	New products and services Customer satisfaction Additional employments Social innovation	17 19 41 23		
	22	Utilised side streams Stages of processing Business cooperation Total added value	51 20 12 17		

Table 2: Scenario evaluation results based on DEXi model

	Scenario A	***Scenari B***	***Scenario C***
Residues in agricultural production and land. management	**Suitable**	**Suitable**	**Suitable**
Economic criteria	M*	S**	M
Environmental criteria	M	M	M
Social criteria	M	M	S
Circularity criteria	M	M	S
Residues in food production and consumption	**Suitable**	**Suitable**	**Suitable**
Economic criteria	M	M	M
Environmental criteria	M	M	M
Social criteria	M	M	M
Circularity criteria	M	M	S
Residues in logging and primary processing of wood	**Suitable**	**Optimal**	**Optimal**
Economic criteria	M	S	S
Environmental criteria	M	S	M
Social criteria	S	M	S
Circularity criteria	M	S	S
Residues in the industrial processing of wood	**Suitable**	**Suitable**	**Optimal**
Economic criteria	S	M	S
Environmental criteria	M	M	M
Social criteria	M	S	S
Circularity criteria	S	S	S

* M - medium utility
** S - significant utility

The results of the DEXi model highlight a notable difference in the assessment of alternative scenarios in the value chains considered (Table 2). In the case of value chains that originate from agricultural biomass all considered scenarios (A, B, C) were identified as suitable. However, the model indicates that implementation of the scenario C - Bioeconomy clusters in case of the value chain “residues in agricultural production and landscape management” would bring an optimal level of social benefits and would largely meet the criteria of circularity. Similarly, in the case of “residues in food production and consumption” scenario C would largely meet the circularity criteria. This suggests that stakeholders in agri-food production are somewhat reticent towards such, more complex forms of organizations, but are aware of the prospects of these forms of organization. The diversity and dispersion of biomass of the agri-food sector to some extent prevent developing in the direction of such a business organization. Often, the energy use of agri-food chain biomass side streams is the only sensible use, so the closure of biomass loops often remains at the production unit level, as envisaged in scenario A.

According to the multi-criteria evaluation of scenarios, side streams and waste biomass of forestry-wood value chains offer greater potential for more comprehensive integration of bioeconomy actors than envisaged in scenarios B - Industrial symbiosis and C - Bioeconomy clusters (Table 2). The latter may be related to the abundance of biomass managed by such chains in Slovenia. In the value chain "residues in logging and primary processing of wood" the implementation of scenario B would bring an optimal level of economic and environmental benefits, and it would largely meet the criteria of circular orientation. The situation would be similar in the case of the implementation of scenario C, but in contrast, environmental criteria would be of medium benefit and social ones would be optimal. In the case of the "residues in the industrial processing of wood" chain, the optimal scenario for closing biomass loops would be scenario C.

4 CONCLUSION

In this research, we developed and tested a multi-criteria model that is able to determine and evaluate the optimal scenario of closing (material and energy) loops of biomass in four perspective value chains based on agricultural, or forestry-based biomass.

The results of the DEXi model highlight a difference in the assessment of alternative scenarios between agri-food and forestry-wood value chains. In the case of ther agri-food value chains all considered scenarios (A, B, C) were identified as suitable. Contrastingly, more complex organization forms that are envisaged in scenarios B and C were identified as optimal in the value chains under consideration in the forestry-wood sector. The results also indirectly indicate stakeholders' awareness of prospects of more complex organizational forms that combine sectoral, vertical and horizontal integration between industrial actors and other stakeholders (RDI actors, policymakers, consumers, civil society).

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MULTI CRITERIA ASSESSMENT OF SUSTAINABLE DEVELOPMENT OF ETHNO-VILLAGES IN BOSNIA AND HERZEGOVINA

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Abstract: This study describes ethno-villages in Bosnia and Herzegovina which are an important element of rural and cultural tourism. Natural and cultural heritage is important for sustainable rural tourism development [1]. To improve the process of decision making in enabling sustainable development of ethno-villages, a multi criteria assessment model has been devised. The methodology is based on qualitative modeling using multi-criteria analysis with the use of DEXi software. The model applies hierarchical relations including three main criteria representing sustainable tourism development as follows: economic, social and environmental. The model in this study was aimed at evaluating six ethno-villages in Bosnia and Herzegovina. The results of the study show the contribution of ethno-villages to sustainable development.

Key words: tourism, sustainable development, ethno-villages, DEXi, decision support, multi criteria model assessment

1 INTRODUCTION

Recently, tourism has become an important contribution to economic development [2]. Tourism creates income, new jobs and expansion of local economy [3]. The alternative forms of tourism are growing much faster than the remaining tourism [4]. Such an alternative form of tourism is etho-tourism which is a significant part of sustainable tourism [5]. Ethno tourism is a prospective opportunity for tourism development because of its unique and diverse content. It is a base feature of local tourism development and is supposed to attract investors and promote interest in the unique culture of the local inhabitants [6].

The ethno-tourism in Bosnia and Herzegovina applies particularly to development and promotion of ethno-villages. This research is focused on rising quality of ethno-tourism by means of a suitable strategy based on the following factors: a) preserving local tradition and culture; b) using and preserving natural resources; c) establishing of infrastructure d) involving and eployment of local population; e) raising the satisfaction of tourists and f) sustainable business [7].

The goal of this paper is to present an aid for assessment of the ethno-tourist offer with respect to sustainable development. The approach is based on multi attribute DEX methodology containing parameters for assessing the sustainable development of ethno-tourism through economic, social and ecological criteria. On the basis of the sustainability criteria and their sub-criteria the decision support model for assessing the state of ethno-villages in Bosnia and Herzegovina was developed and applied to six ethno-villages as follows: ethno-village Stanišić, ethno-village Herceg, ethno-village Babići, Ethno-village Kotromanjić, ethno courtyard Mačkovac and the Begovo village [7].

2 METHODOLOGY

The Decision EXpert (DEX) method used for evaluation of ethno-villages [8] and representing a method for qualitative multi-attributive modeling consists of hierarchically structured attributes [9, 10]. The DEX method combines traditional methods for multi-criteria decision-making (MCDM) with elements of the experimental system [11]. The most important feature of the DEX method is the ability to use qualitative variables given by descriptive courts with values: low, high, acceptable, unacceptable, etc. [12]. Using the "if-then" decision-making rules, it is possible to transform quantitative variables into qualitative ones and use them in the DEX method. The DEX method is applied using the DEXi program [13].

2.1 MODEL STRUCTURE

The model for tackling sustainable development of ethno-villages in Bosnia and Herzegovina comprises 36 hierarchical structured attributes (Figure 1). The basic model as proposed by Gibson [14] was used. The economic, social and ecological criteria are the basic attributes of sustainability which were used several researchers [15, 16, 17]. These 3 criteria are divided into sub-criteria and those, in turn, into the leaves. Each of these main attributes is divided into additional attributes that are presented as follows:

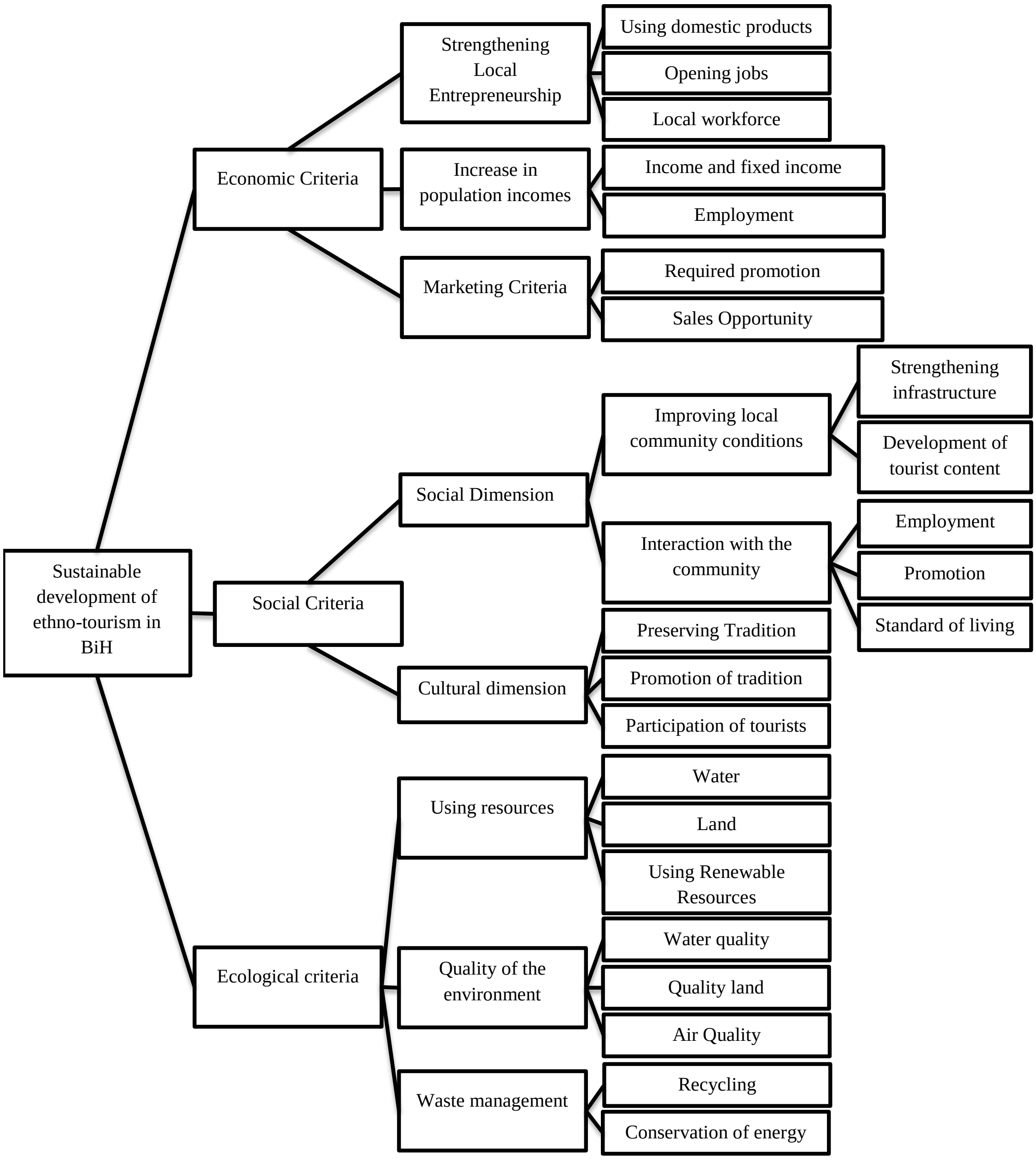

Figure 1: Structure of sustainable development of ethno-villages in Bosnia and Hercegovina

2.2 VALUE SCALES

All attributes used in this paper are described by symbolic value scales. They have acquired discrete values that are represented by words. The maximum scale was used for the main evaluation of the model and it consisted of five levels of value from unacceptable to very good. The first two values were considered bad while the last two were good. The main criteria were evaluated by a scale of four levels of value, where the last two were considered good. Other attributes are evaluated according to their characteristics. In total, there are 11 valuable scales used in this model as follows [7].:

Table 1: Value scales used in the model

	Value scale
1.	**unacceptable**; **bad**; middle; ***good***; ***very good***
2.	**bad**; middle; ***good***; ***very good***
3.	**influence**; partial influence; ***no influence***
4.	**bad**; middle; ***good***
5.	**small**; medium; ***big***
6.	**small**; middle; ***high***
7.	**not using**; ***using***
8.	**using**; ***not using***
9.	**does not exist**; ***exists***
10.	**in need**; ***no need***
11.	**bad**; ***good***

3 RESULTS

The ethno-villages Stanišić, Herceg and Mačkovac are rated as "middle" while the ethno-villages Begovo selo, Babići and Kotromanjić as "bad". None of the six ethno-villages was rated as the best in terms of sustainable development, since every presented ethno-village has its advantages and disadvantages in relation to the other village. Figure 2 presents a detailed assessment of the selected ethno-villages. Considering that this image represents a collective assessment of the model by all attributes, it is possible to execute it on certain criteria and thus compare the ethno-villages in more detail. The ethno-villages have a different number of good attributes while the same number of bad attributes.

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Evaluation results

Attribute	Stanisic	Begovo selo	Herceg	Babici	Mackovac	Kotromanjic
Sustainable development of ethno-tourism in BiH	middle	bad	middle	bad	middle	bad
Economic Criteria	very good	middle	very good	middle	good	middle
Strengthening Local Entrepreneurship	very good	good	very good	very good	very good	very good
Using domestic products	using	using	using	using	using	using
Opening jobs	good	bad	good	middle	middle	middle
Local workforce	exists	exists	exists	exists	exists	exists
Increase in population incomes	good	bad	middle	bad	bad	bad
Income and fixed income	good	bad	middle	middle	middle	bad
Employment	middle	bad	middle	bad	bad	bad
Marketing Criteria	very good	bad	good	bad	good	bad
Required promotion	not using	using	not using	using	not using	using
Sales opportunity	good	middle	middle	middle	middle	middle
Social Criteria	very good	middle	very good	bad	good	bad
Social Dimension	very good	bad	very good	bad	middle	bad
Improving local community conditions	good	bad	good	bad	middle	bad
Strengthening infrastructure	no need	in need	no need	in need	in need	in need
Development of tourist content	no need	in need	no need	in need	no need	in need
Interaction with the community	good	middle	good	middle	middle	middle
Employment	big	small	medium	small	small	medium
Promotion local community	good	middle	good	middle	good	middle
Standard of living	medium	medium	medium	medium	medium	medium
Cultural dimension	middle	very good	middle	middle	very good	middle
Preserving tradition	middle	high	middle	middle	high	middle
Promotion of tradition	middle	good	middle	middle	good	middle
Participation of tourists	middle	middle	middle	middle	middle	middle
Ecological criteria	bad	middle	bad	middle	middle	good
Using resources	bad	middle	bad	middle	middle	good
Water	partial influence	no influence	partial influence	no influence	no influence	no influence
Land	influence	partial influence	influence	no influence	partial influence	no influence
Using renewable resources	not using	not using	not using	not using	not using	using
Quality of the environment	middle	good	middle	good	good	good
Water quality	middle	good	middle	good	good	good
Quality land	good	good	good	good	good	good
Air quality	bad	good	bad	good	good	good
Waste management	bad	bad	bad	bad	bad	bad
Recycling	bad	bad	bad	bad	bad	bad
Conservation of energy	bad	bad	bad	bad	bad	bad

Figure 2: Rating of six ethno-villages

The economic criterion has three main sub-attributes: Strengthening local entrepreneurship, Increase in population incomes and Marketing criteria. In relation to the economic criterion, Ethno-village Stanišić is best rated, followed by other ethno-villages. As the social criterion had only two sub-attributes, it was presented together with the ecological criterion. The social criterion is represented by Social and Cultural dimension, while the ecological criterion is represented by other criteria. According to the social criterion, the ethno-villages Stanišić and Herceg are evaluated as "very good", Mačkovac with "good" score, while the ethno villages Begovo selo, Babići and Kotromanjić with "bad" score. Regarding the cultural dimension, the best rated ethno-villages are Begovo selo and Mačkovac with the rating "very good", while the other ethno-villages are rated as "middle". With respect to the ecological criterion with the sub-attribute "Using resources", the ethno-village Kotromanjić is rated "good" and others with "middle" and with “bad” score. Using the "Quality of the environment" sub-attribute, the results showed that best rated ethno-villages are Begovo selo, Babići, Mačkovac and Kotomanjić. The result refers to the sub-attribute "Waste Management" where all ethno-villages are rated as "bad" because they do not apply this attribute.

4 CONCLUSION

In this study a model for assessing sustainable development of ethno-tourism was used. Accordingly, the model of evaluation of sustainable development of tourist offer in ethno-villages was builtby the DEX method. Using the decision-making model, an expert assessment of the sustainability of six ethno-villages in Bosnia and Herzegovina was performed. From this study we found that none of the selected ethno-villages has received an aggregate score of "very good" or "good". Thus, we have not found an example of sustainable tourist offer from the selected sample. This model could be used to improve a balance of three criteria of sustainable development. Using this model local authority could improve further development of ethno-tourism according to the given criteria.

We propose to use this model also as a guideline for future research in other segments of tourism. In addition, ethno-villages from Bosnia and Herzegovina should be compared to obtain analysis of current state of tourist offer. This model could be developed in cooperation with other multi-criteria methods for more precise result.

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TESTING MCDM MODEL FOR EVALUATING THE POTENTIAL OF COORDINATED AGRI-ENVIRONMENTAL APPROACHES AMONG FARMERS ON TWO CASE STUDIES FROM NETHERLAND

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Abstract: In this article a test version of multi-criteria decision-making model for investigating the potential of coordinated agri-environmental measures (AEM) among farmers in EU is presented. Its analysing the parameters included in the test Decision Expert (DEX) model, the sensitivity of the test DEX model and suggesting corrections for the final DEX model. It was showed that the test DEX model lacks in sensitivity of the parameters which can be tackled with a group decision making approach-the Delfi method-for levelling the importance ratio between parameters and an analytical hierarchical process (AHP) pair wise technique weighting.

Keywords: collective approach, agri-environmental public goods, group decision making approach, weighting techniques

1 INTRODUCTION

The use of Multi-Criteria Decision Making (MCDM) is suitable for solving problems of agri-environmental programs and multifunctional issues of agriculture [8]. MCDM is also an appropriate tool for assessing environmental services and for comparing types of land use in relation to their implementation of environmental services [4]. Furthermore, MCDM methods are used in the field of environmental management and stakeholder involvement [2] and help many stakeholders to assess often conflicting criteria (objectives), communicate their different preferences and classify or prioritize goals, strategies, opportunities, etc. [7]. These methods can facilitate the resolution of trade-offs between environmental objectives [10]. This research is exploring the potential of using the MCDM method for ranking suitability of different types of coordinated agri-environmental measures (AEM) among farmers in providing agri-environmental public goods. The first section of this preliminary research is an overview of the input data for the selected Decision Expert (DEX) method [3], the second section is to present the test DEX model with the results. In the third and last section, based on test results and literature review we discuss how to improve the methodology for the final DEX model.

2 METHODS

The DEX method was chosen because we can use qualitative data from already existing SWOT analyses [9] of selected cases (hereinafter alternatives). Alternatives (Oost Groningen and Limburg) are based on collective approaches and result oriented AEM and have similar characteristics [5]. The DEX method enables the classification of attributes, criteria and sub-criteria into a decision tree and the weighting of criteria at all levels. In the test model, we used the equal weights and individual decision-making approach, as Ahtainen et al. [1] argue that social, economic and environmental objectives of agriculture are equal for stakeholders. This was done to examine the weaknesses of the test model and decide on potential weighting methods and group decision making approaches for the final DEX model.

In the first part of the modelling, a decision tree was made with individual decision-making approach based on qualitative analysis of the relevant literature [1,5,9]. A hierarchical top-down approach has identified the main objective, attributes, criteria and sub-criteria that should influence the level of potential of coordinated agri-environmental measures among farmers to provide agri-environmental public goods in the EU. The characteristics were systematically entered into Excel spreadsheet. Fig. 1 shows an excerpt from Excel spreadsheet at the level of the S_BENEFITS criterion, which indicates the objective “social benefits of coordinated approaches”. At the level of sub-criteria, the table is filled in by determining the qualitative value of the sub-criterion or the absence / presence of it (see yellow circle in Fig. 1) for each sub-criterion (black circle). If there is no information about the sub-criterion, it is marked "don't know" (blue circle), otherwise the qualitative value (blue circle) is selected from the drop-down list. In the black square, qualitative data for each alternative is presented (derived from existed SWOT analyses [9]). Each selected answer is transformed into a value of 1, 2 or 3 (green circle), where 1 means bad, 2-medium and 3-good characteristics. The arithmetic mean of the numerical factors of the sub-criterions (green asterisk) are considered for the evaluation of S_BENEFITS criteria. The result is then transformed into qualitative values of 1-poor, 2-medium or 3-good (red asterisk) via the IF function. The rule for this IF function is as follows; if the result of arithmetic mean of sub-criterions is in the first quartile (Q1) then it is changed to the factor 1, if the result of mean is in the 2nd and 3rd quartiles (Q2 or Q3), then it is changed to the factor 2 and if the result of mean is in the 4th quartile (Q4) then it is changed to the factor 3.

Figure 1: The example of systematic gathering of qualitative data for alternative in the Excel spreadsheet

Fig. 2 shows the decision tree of the selected attributes and criteria in DEXi. The decision tree is built from the main evaluation aim, five attributes, and ten criteria.

The evaluation aim has three values: "low", "medium" or "high", which indicates the level of potential of coordinated agri-environmental measures among farmers. The main goal is to study four objectives (hereinafter attributes) that can affect the level of potential: "Social", "Agri-environmental", "Economical" and "Political and monitoring".

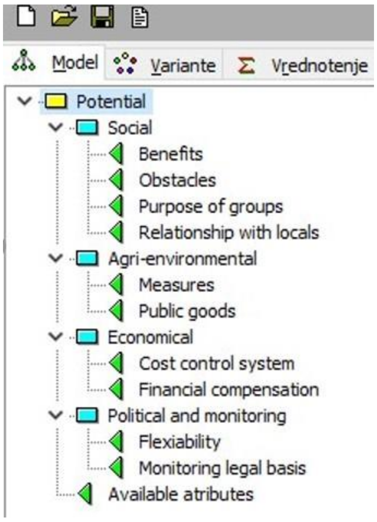

Figure 2: Showing the decision tree of the test DEX model for evaluating the potential of coordinated agri-environmental measures among farmers

Numeric factors 1, 2 or 3 of criterion were transferred from Excel spreadsheet into the test DEX model as descriptive values following specific transformation rules as shown in table 1.

Table 1: Transformation rules of numeric factors from the Excel spreadsheet into qualitative values for the criteria in the test DEX model

Criteria in the test DEX model	**Transformation rules of numeric to descriptive values**
Benefits, Public goods	1-small, 2-medium, 3-large
Obstacles	1-large, 2-medium, 3-small
Purpose of groups, Relationship with locals	1-poor, 2-moderately, 3-well
Measures, Cost control system, Financial compensation, Flexiability, Monitoring legal bases, Available attributes	1-innapropriate, 2-aceptable, 3-adequate

For each alternative (NL_Oost Groningen and NL_Limburg), a formation of its own range of values (see Fig. 3) was based on the output of the Excel spreadsheet. Green, black and red colour visually emphasize the qualitative data from the range of values, red colour means 1 or poor, black colour means 2 or medium and green colour means 3 or good characteristic.

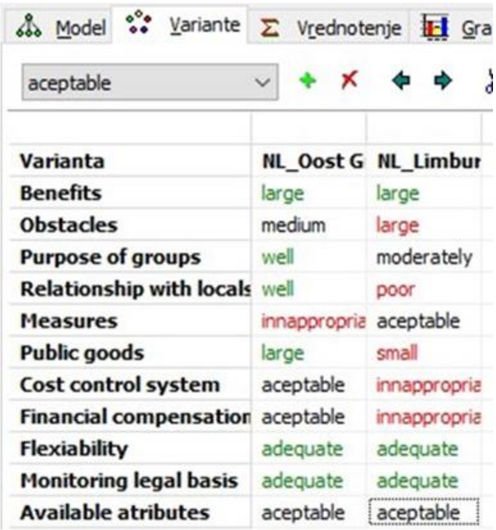

Figure 3: Characteristics of alternatives and their range of values in the test DEX model

The value of alternative characteristics in the DEXi program is mapped to the upper level with a system of "if-then" rules, which were determined in the test DEX model by individual decision-making approach, considering the general order of data and the same level of weights for all criteria. The bold letters in Fig. 4 show the qualitative values of the attributes following the “if-then” rules. “If-then” rules for the attributes were as follows: a value “inappropriate” was assigned to lower 25 % of possible combinations, a value “acceptable” to middle 50 % of possible combinations and a value “adequate” to upper 25 % of possible combinations of criteria characteristics. “If-then” rule for the main objective/goal was as follows: a value “low” was assigned to lower 25 % of possible combinations, a value “medium” to middle 50 % of possible combinations and a value “high” to upper 25 % of possible combinations of attribute’s values.

3 RESULTS

The Fig. 4 shows the consequences of the “if-then” rules for qualitative determination of attributes and the goal of the test DEX model. We can see that the potential is evaluated as “medium” for both alternatives. According to the “if-then” rules, DEXi program also allows the comparison of alternatives by its attributes and criteria as shown in Fig. 4. Here we see that the attributes “Social”, “Agri-environmental” and “Economic” are for alternative NL_Oost Groningen in advantages over NL_Limburg, while the attribute “Political and Monitoring” has equivalent value for both alternatives.

Varianta	NL_Oost Groningen	NL_Limburg
. Potential	**medium**	**medium**
. . Social	**aceptable;adequate**	**aceptable**
. . . Benefits	large	large
. . . Obstacles	medium	large
. . . Purpose of groups	well	moderately
. . . Relationship with locals	well	poor
. . Agri-environmental	**aceptable**	**innappropriate;aceptable**
. . . Measures	innappropriate	aceptable
. . . Public goods	large	small
. . Economical	**aceptable**	**innappropriate**
. . . Cost control system	aceptable	innappropriate
. . . Financial compensation	aceptable	innappropriate
. . Political and monitoring	**adequate**	**adequate**
. . . Flexiability	adequate	adequate
. . . Monitoring legal basis	adequate	adequate
. . Available atributes	aceptable	aceptable

Figure 4: Consequence of the “if-then” rules for qualitative determination of attributes and the goal of the test DEX model

3.1 Spider webs of the decision model

It is clear from the spider web that the weakness of the collaborative form of the NL_Limburg case is mainly in the economic factor (Fig. 5), where the model shows poor target pursuit. In the case of NL_Oost Groningen, on the other hand, we can observe that all factors have at least a positive effect on the main objective, with society and politics being the strongest factors (Fig. 6). The model suggests that the differences between these two forms of cooperation are mainly in social and economic factors.

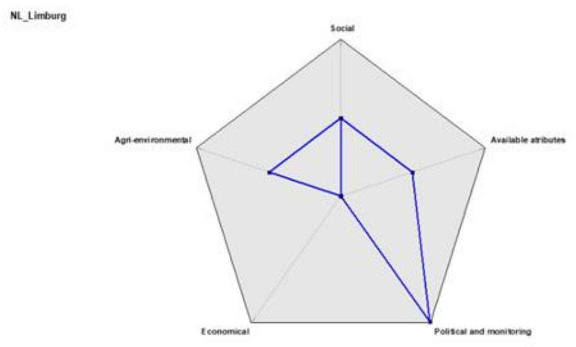

Figure 5: Spider web for the NL_Limburg alternative – level of attributes

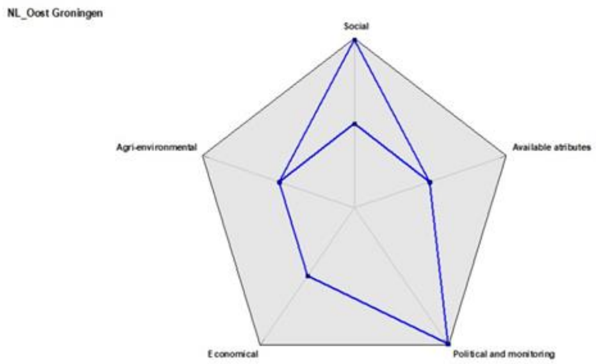

Figure 6: Spider web for the NL_Oost Groningen alternative – level of attributes

Fig. 7 and 8 show a more detailed breakdown of the differences by criteria.

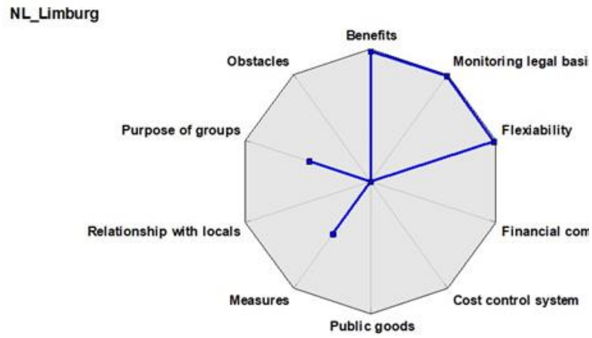

Figure 7: Spider web for the NL_Limburg alternative – level of criteria

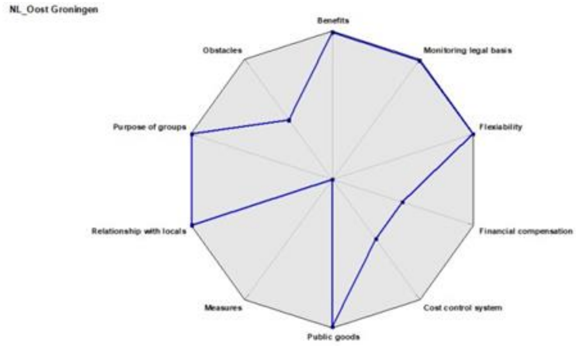

Figure 8: Spider web for the NL_Oost Groningen alternative – level of criteria

If we take a closer look at the economic factor in both cases, we see that the NL_Limburg case has both criteria very poorly assessed. Namely, the SWOT analysis showed that there are practically no systems of collective cost reduction for farmers due to their inclusion in the cooperative form of farming in this case. In contrast, the NL_Oost Groningen case has an organized group purchase of seedlings and seeds to ensure a better price.

4 DISCUSSIONS

As expected, the test DEX model showed weaknesses, especially in the lack of sensitivity of the model, as it does not detect differences between the collaborative forms in the main goal. We will tackle the sensitivity of the model in two ways. The first way is to increase the number of levels from three to seven in the main objective. The second way is by weighting attributes and criteria using two methods, DELFI and AHP pair wise comparison. This can be done because the DEX method allows the inclusion of other MCDM methods, especially at the level of attribute weighting [3], as part of the DEX method is based on the AHP method [6].

Usually the combination of DEX/AHP is used to better separate between alternatives that receive the same DEX assessment which was a problem showed also in this model. However, alternatives will not be compared by decision makers through the AHP or Delfi methods. The qualitative priority calculation of alternatives will be made only through the final DEX model. The AHP priority calculation will be used only at the stage of assigning different weights to attributes and criteria. Therefore, the best DEX feature: determination of utility function through decision rules will still play its role.

In the final DEX model, we will study nine different forms of collaboration between farmers, some of which are very similar in terms of characteristics and environments, and some significantly different. The final DEX model itself will be based on individual decision-making approach, i.e., it will be repeated only once, and the input data will not change. However, because of uncertainty of importance of parameters that are included in the final DEX model, it is extremely important that we include group decision making approach in the stage of deciding of which parameters will be included/excluded in the model. This will be done through DELFI method. After that, an AHP pair wise comparison weighting method of the attributes and criteria will be done through the DELFI process, so at the end, the consensus of weights will be made. The results of consensus for weights of parameters will be put in the final DEX model. At the last step, the adjustment of "if-then" rules will be made.

For the end, it should be noted that there is lack of knowledge about the factors that affect the potential of different forms of cooperation between farmers in coordinated agri-environmental measures, as collective agreements and other forms of cooperation between farmers are relatively new forms of activity (the oldest was established in 2016 [5]) and experts do not yet have any comparable data to decide on. This model is thus the first MCDM model to try to address the issue presented.

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STRATEGIES FOR STRUCTURAL CHANGES IN AGRICULTURAL HOLDINGS AS A FARM TOURISM MODEL DEVELOPMENT

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Abstract: Diversification of agricultural activities into tourist farms is one of the ways of entrepreneurial activity of agricultural holdings and at the same time a way to increase profits of the agricultural activity. Under certain conditions, the transition is possible mainly on potential agricultural holdings. The system dynamics approach was used to analyze the situation, where a simulation model for planning transition strategies to tourist farms was developed. Several proposals for strategic measures were made by analyzing different simulation scenarios.

Keywords: increase profits, farm tourism, system dynamics, pandemic

1 INTRODUCTION

The Slovenian landscape is characterized by topographic variability, which means that almost 90% of the area lies at an altitude of over 300 m, but due to the topographic fragmentation of the territory, the natural conditions for agriculture are not the most favorable. Among other things, Slovenian agriculture is characterized by a relatively high age structure, as at the last census of agriculture it was established that the average age of the owner of a farming holding is 57 years. Only a good 15% of farm managers represent the so-called "young population" under the age of 45. Therefore, we are talking about two important indicators that in some way prevent Slovenia from developing agricultural activity in the way it is developed in the most developed European countries (e.g. it is more difficult to introduce digitization processes in the production process). However, income diversification and structural changes in agriculture are a constant and one of the key areas of the development and agrarian economy [5], also in Slovenia. Slovenian agricultural holdings find it difficult to survive only with income from the agricultural activity itself (just under a fifth), so they also make a living from other sources on or off the farm. We are talking about the possibilities of developing complementary activities, establishing direct sales of agricultural products on the farms themselves, social services (care for the elderly on farms) or the development of tourism on farms, where the offer is directly related to service activities.

The offers of tourism services on farms have proved to be great positive advantages in the event of the covid-19 epidemic [6], [8], [10], [11]. People are increasingly resorting to finding individual offers of tourist accommodation, safe destinations and opportunities to discover natural attractions, preferring tourism in nature [12], where rural tourism in general allows all of this.

Also in Slovenia, in 2020, there were trends of increased interest in finding offers of tourist accommodation in rural areas. In Slovenia, slightly more than 3 million tourist arrivals (or 51% less than in 2019) and 9.2 million overnight stays (or 42% less than in 2019) were recorded in tourist accommodation establishments in 2020 due to the consequences of the covid-19 epidemic. In 2020, about 250,000 tourist overnight stays were created in tourist farms with accommodation, which was about as many as in 2019, except that the numerical ratio between overnight stays of domestic and foreign tourists was reversed. In 2019, foreign tourists generated 79% of all overnight stays on tourist farms, and in 2020 only 25 % [9]. Thus, farm tourism is the only tourism industry in Slovenia that has not suffered from the negative effects of the covid-19 pandemic in terms of the number of overnight stays.

The development of tourism on farms is therefore one of the possibilities for entrepreneurial activity of agricultural holdings and at the same time an example of diversification of non-agricultural activities on farms. With this paper we want to show a model of systemic dynamics of transitions of agricultural holdings to tourist farms, which illustrates the behavior of the real system while testing the effects of alternative decisions over time. The document is divided into three parts. First, we present the methodology of system dynamics, then we present the model of transition of agricultural holdings with an emphasis on the main identified parameters, and the article concludes with a presentation of scenarios.

2 METHODOLOGY

The idea of modeling systems through system dynamics is based on the assumption that all real systems can be described by a system of equations representing interconnected states and flows at different levels, with states depending on previous inflow and outflow states in time [4]. Since even seemingly simple systems often contain complex nonlinearities, we also found in the development of our model, which studies the transitions of agricultural holdings to tourist farms, that this special (time) constant problem is a nonlinear system.

The basic principle of the state can be defined by the variations of the dynamics in the following equation:

$$L(k+1) = L(k) + \Delta t\,(Rin(k) - Rout(k)); \quad k=0, 1, 2, 3, \ldots, n$$

where L means - Level, k - discrete time, Δt - time step, Rin - inflow, Rout - outflow, we also know that the state L (K + 1) does not change if Rin (k) = Rout (k), increases if Rin (k)> Rout (k) and decreases if Rin (k) <Rout (k).

Thus, simulation in system dynamics is a method of numerical integration. When modeling the diversification of non-agricultural activities on a farm, the situation on the one hand represents the number of potential farms that have chances and opportunities to diversify their primary activity, and on the other hand the number of tourist farms. The flow between them is a transition.

Based on the CLD model [13], we further developed the system dynamics model, which is shown in Figure 1.

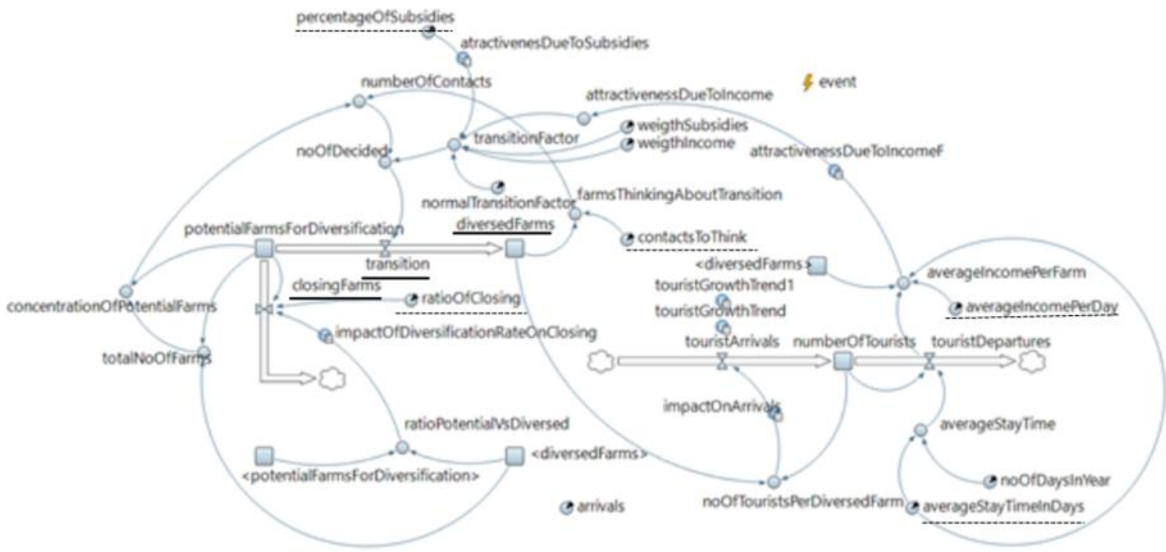

Figure 1: System dynamics model

The developed model was validated in accordance with the equations for Theil statistics [7] and at the same time obtained results that indicate an acceptable correlation or good match between real and simulated values. Among other things, value r^2 (coefficient of determination) at validation was 0.96.

3 LEVER INDICATORS, CHANGING PARAMETERS AND SIMULATIONS

Before generating the scenarios and performing the simulation runs, we defined the leverage indicators that determine our model. For this, we assumed the variable “diversedFarms” and the currents “closingFarms” and “transition”. The parameters “ratioOfClosing”, “contactToThink”, “averageStayTimeInDays”, “averageIncomePerDay” and “percentOfSubsidies” were used to define scenario values in addition to the initial values, which differed in 11 different ways.

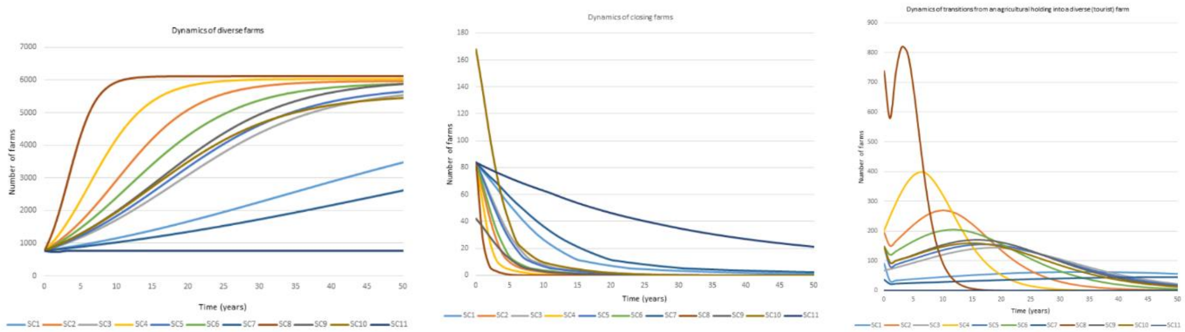

*Figure 2: S*imulation results

Figure 2 shows the dynamics of transitions of potential agricultural holdings for tourism activity into tourist farms in the territory of the state of Slovenia. By changing the above parameters, we provided the system with a comprehensive range of responses. The presented dynamics thus offer us information on different ways of transition of agricultural holdings to tourist farms. The methodological approach to system dynamics provides additional information and guidance for agricultural policy makers. During the performed simulations, we improved the understanding of the influence of individual variables. At the same time, the model allows us to explain why we came to certain results. Because simulations allow us to adjust variables over time, many different scenarios can be tested in advance. These are concrete tools to examine the results that can help in the actual planning of agricultural policies in the real world.

Important parameters influencing the transition of agricultural holdings to tourist farms are the parameters of promotion and subsidies. In the "contact to think" parameter, we can look for parallels with the promotion of tourism activities on farms. Its influence was changed in simulation runs 7 and 8. A similar effect as that of the promotion system can also be seen in the use and application of subsidies. The higher the subsidies (run 2), the faster and more pronounced the transition of potential farms to tourist farms. The opposite - run 1, when subsidies are very low, the transition is slow and low. However, there is a transition, indicating that the system is not entirely dependent on subsidies alone. The meanings of farm subsidies are multilayered [1], [2], [3].

4 CONCLUSIONS

After the simulation runs, the following findings can be identified:

1) In addition to promotion and subsidies, the model was significantly influenced by two other factors - the length of stay of tourists in Slovenia and the income that tourists leave on the farm. These two variables, together with high growth and further development of activities, affect the fact that tourism can also have negative consequences.
2) To get an even more detailed insight into the problem of abandonment of agricultural holdings on the one hand and the possibility of income diversification by introducing activities such as tourism on the farm, the developed model could be upgraded with alternative methods, such as econometric model or agent-based model. At the same time, a multi-criteria scenario analysis is also possible.

The developed model of system dynamics provides additional information support to various tourism and agricultural policy makers.

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Session 1:

Econometric Models and Statistics

DETERMINANTS OF ECONOMIC DEVELOPMENT: AN APPLICATION OF LIMITED DEPENDENT VARIABLE MODELS

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Abstract: The aim of this paper is to estimate the determinants of economic development measured by Human Development Index and by newly introduced Planetary Pressures-adjusted Human Development Index. The models were estimated by limited dependent variables approaches using data for 2019 for both indices. According to the results we could not confirm that the Planetary Pressures-adjusted Human Development Index is more environmentally focused since the estimated signs of some of the odds ratios for environmental variables do not meet the expectations.

Keywords: economic development, HDI, PHDI, Logit, Probit

1 INTRODUCTION

Every economy faces different social, economic, and environmental problems. These vary from country to country and have different levels of complexity. This, in turn, is reflected in the difficulty of achieving the various global goals that have been set for the long term and are nowadays increasingly focused on the sustainable aspect as the most appropriate path for global development. It is important to consider that these problems have an important connection with the level of a country's development and vice versa.

We can mention that a lot of international organizations and individual researchers had developed various methods for measuring human development. The most commonly used is the Human Development Index (HDI) developed by United Nations and it is often found as a basis for research by various authors. Grimm et al. [5] made an empirical evaluation of 32 countries in which they used the three indices of the HDI and the HDI itself as the quintiles of the income allocation. The results showed a powerful general negative correlation between the inequality in human development and the level of human development. Lee, Lin, and Fang [12] used the optimal weights for the indices of components of the HDI for a multiple objective data envelopment analysis model to evaluate the relative performance of the several countries given human development. The HDI also gained the attention of researchers in the studies about sustainable development. In their study, Kvon and others [11] found that countries with higher levels of human development produce more CO_2 emissions per capita and have overall bigger environmental issues. Yumashev et al. [18] used a sample of 28 OECD countries and explored the impact of the quality and quantity of energy consumption on the HDI. Their results showed that besides common macroeconomic indicators also the environmentally oriented indicators have a large influence on HDI.

Sustainable development is therefore considered to be one of the more recent patterns of economic development. In this context, various organizations have also developed specific indices that measure countries' achievements in living standards and health or show how big is country's environmental impact. It is worth noting here that not all the most developed countries have positive results of the mentioned indices. High-income countries tend to have a high life expectancy and well-assessed prosperity, while their economies have a major negative impact on the environment [1].

In this paper, we want to assess the effect of selected factors on the economic development of high and very high developed countries using limited dependent variables methods for two dependent variables (HDI and PHDI). We are mainly interested in whether environmentally oriented factors have the greatest impact on PHDI. That could mean that countries must work on their environmental problems to improve their development.

2 TRADITIONAL AND PLANETARY PRESSURES-ADJUSTED HUMAN DEVELOPMENT INDEX

The Human Development Index was created, by the United Nations Development Program (UNDP), to emphasize that the highest benchmark for assessing a country's development should be people and their capabilities, not just economic growth [7]. The most frequently used indicator of the comparative status of socio-economic development ranks each country on a scale from 0 (lowest human development) to 1 (highest human development) based on three goals of development: a long and healthy life, knowledge, and a decent standard of living.

The HDI is calculated in two steps, first creating three indices for each area, then combining the results of each index to calculate the overall human development index. The indicator is essentially the geometric mean of the three indices. For each index, the corresponding minimum and maximum values for the indicator are determined, after which the index for each area is calculated as a ratio, which is given as a percentage of the distance between the minimum and maximum value achieved by the country [16]. The area of health or "long and healthy life" is calculated by an index of life expectancy at birth [14]. The field of education or "knowledge" is calculated by a combination of average years of schooling of adults and expected years of schooling for compulsory school children entering education [16]. The measurement of expected years of schooling includes residents aged 5 to 24, and the measurement of average years of schooling includes residents aged 25 and over. The indicators are first calculated according to the original equation for each of them, then the arithmetic mean is calculated from the obtained results. This allows a complete substitution between average and expected years of schooling. The area of income or "standard of living" is calculated using GNI per capita, adjusted for purchasing power, to reflect the cost of living and to assume a reduction in the marginal utility of income [14].

In its latest Human Development Report, UNDP presented a probationary index i. e. Planetary Pressures-adjusted Human Development Index (PHDI). It is an index that adjusts the original HDI for pressures that are caused by people on the planet. These pressures have increased enormously in the last 100 years and consequently, human development has slowed down. With new index they want to layout a probability to meet high values of HDI and simultaneously low emissions and better resource use.

PHDI, just as HDI, also ranks the countries from 0 to 1, where 0 means higher planetary pressures and 1 lower pressures. Besides all the basic components: health, education, and income, the PHDI also includes two environmentally-oriented components – carbon dioxide emissions and material footprint. The latter is described as a worldwide allocation of the extraction of used raw materials to the final demand of the economy. The material footprint is a sum of the footprint for metal and nonmetal ores, fossil fuels, and biomass. The indicator shows the mean material use for the final demand and is expressed in tonnes per capita. CO_2 emissions involve emissions produced by peoples' activities from the use of oil, gas, and coal.

All together arising from industrial processes, combustion, gas flaring, and cement manufacture. The indicator is also expressed in tonnes per capita.

The PHDI is calculated in three steps. Firstly, the values of planetary pressure indicators are normalized just like those of the fundamental indicators and so the indices are created. For both indicators, the minimum was set at 0. The maximum for carbon dioxide emissions is 69,85 tonnes and for material footprint is 152,58. So a bigger adjustment to the HDI means the index value of these is smaller, as the observed values of indicators are higher and closer to the maximum. This also means the pressures on the environment are larger. Then follows the second step where the adjustment factor is calculated. This factor is the arithmetic average of the two indices, so it offers an ideal substitution of those. In the last step, the adjustment factor and the HDI are multiplied, and the result is the PHDI [15].

3 DATA AND METHODOLOGY

The data and definitions for life expectancy, mean years of schooling, expected years of schooling, pupil-teacher ratio, material footprint, and GDP were extracted from UNDP's Data Center [7]. Some of them are already defined in the previous chapter. World Bank's Open Data provided the data and indicators explanation for renewable energy consumption and alternative and nuclear energy [17]. The data and explanation from Our World in Data's Charts was for CO_2 emissions [2]. For the indicator Greenhouse gas emissions, we found the data and definition on World Resources Institute's Climate Watch [3].

Pupil-teacher ratio (PTR) shows the mean number of pupils per teacher. The indicator covers primary education and is measured in percentage. GDP measures the total value of end-use output produced by the economy, both by residents and non-residents. The indicator is measured per capita in dollars at 2017 prices adjusted for purchasing power parity. The indicator renewable energy consumption (RE) is presenting the consumption of solar, wind, hydro and tidal power, ambient heat captured by heat pumps, biofuels, geothermal energy, and the use of renewable part of the waste. It is measured as a percentage of total final energy consumption. Alternative energy (ANE) is the energy that is created without the negative externalities and besides nuclear energy, it also comprises the energy from solar or geothermal power. Nuclear energy is the heat produced in nuclear power plants and is a result of the fission or fusion of nuclear fuel inside the reactor. The indicator is presented in the percentage share of total energy consumption. Greenhouse gas emissions (GHG) include six gases of the Kyoto basket: carbon dioxide, methane, nitrous oxide, and the so-called F-gases (hydrofluorocarbons and perfluorocarbons) and sulphur hexafluoride. The indicator shows gases generated in all sectors and is measured in metric tonnes of carbon dioxide equivalent per capita. Material Footprint per capita (MF) describes the average material use for domestic final demand and is expressed in tonnes.

We will check the following hypotheses. H1: Selected explanatory variables have statistically significant effect on both HDI and PHDI. H2: Environmentally oriented factors contribute more to the economic development measured by PHDI than to the economic development measured by HDI.

In order to estimate determinants of economic development, we applied limited dependent variable models, which are described into detail in Greene [4], Johnston & DiNardo [9] and Maddala [13]. The following methods were utilized: logit, probit and extreme value. The dependent variable (economic development) is measured by HDI and by PHDI, for which both indices refer to year 2019. Due to limited availability of data for medium and low developed countries, we focused on very high and high developed countries. The resulting database consists of 85 countries for HDI and 68 countries for PHDI. For all three types of models, HDI and PHDI were marked as 1 for highly developed countries and by 0 for high developed countries. The coefficient covariance in all models was estimated by Huber-White method providing the standard errors of estimated coefficients are robust to potential misspecification of the underlying probability distribution of the dependent variable [6].

4 RESULTS AND DISCUSSION

Table 1 displays results for the models when HDI represents the dependent variable. The estimated odds ratios in logit, probit and extreme value models are statistically significant for mean years of schooling (ED1), expected years of schooling (ED2), pupil-teacher ratio (PTR), gross domestic product (GDP), share of alternative and nuclear energy usage (ANE) and for CO_2 emissions per capita (CO2). Most of the variables have the expected sign. For example, the results for the logit model show that when ED1, ED2 and GDP increase, the log of odds in favour of very high development increases. Similar effect of the two variables, ED2 and GDP, was estimated in the research by Kubat et al.[10]. This result should encourage countries with high HDI values to focus on these factors in order to improve their development rank. While an increased PTR, ANE and CO2 decreases the log of odds in favour of very high development. It is interesting to note that all environmental independent variables had proven to negatively affect the log of odds, while material footprint (MF) is also statistically insignificant. The odds ratios in other two binary models (probit and extreme value) show very similar results.

Table 1: Results of limited dependent variable models' estimation for HDI

Independent variable	***Logit***	***Probit***	***Extreme Value***
Constant	-36.25288*** (6.457396)	-22.70032*** (3.267229)	-23.78121*** (4.314884)
ED1	2.349912*** (0.380358)	1.478189*** (0.249862)	1.286240*** (0.231597)
ED2	0.832465** (0.361195)	0.548788*** (0.166067)	0.644301** (0.301368)
PTR	-1.366946*** (0.254520)	-0.813998*** (0.175057)	-0.663899*** (0.202221)
GDP	0.001522*** (0.000127)	0.000871*** (5.71E-05)	0.000871*** (7.26E-05)
ANE	-0.200140*** (0.055637)	-0.126221*** (0.033517)	-0.082443* (0.048971)
CO2	-0.742767*** (0.076615)	-0.422382*** (0.030055)	-0.411379*** (0.039403)
MF	-0.123461 (0.078056)	-0.065648 (0.041831)	-0.075871 (0.054218)
McFadden R^2	0.995684	0.997570	0.994351
LR statistic	108.6372*** [0.000000]	108.8431*** [0.000000]	108.4918*** [0.000000]
Andrews statistic	17.0585* [0.0731]	6.5129 [0.7705]	18.5383** [0.0465]

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level, * statistically significant at 10% significance level. Standard errors in parenthesis. LR and Andrews Chi-square statistics are presented with statistical significance in the parenthesis.

Results of the estimated set of models when using PHDI as dependent variable are revealed in Table 2. Also, in this case almost all variables are statistically significant. Since PHDI is based on environmental factors, a wide variety of environment related independent variables are employed. In logit, probit and extreme value models all of them are also statistically significant.

In the logit model only ED2 has statistically insignificant coefficient, while in the probit model all estimated coefficients are statistically significant. In the extreme value model, the coefficient for ED2 is statistically insignificant. The education related coefficients and GDP have expected positive sign, providing proof of positive effect on the odds ratio in all three estimated models. Among the environmental variables only ANE, CO2 emissions and material footprint have a straightforward signs in all models. While other two environmental variables (RE and GHG) are statistically significant, but their signs do not meet our expectations since the PHDI should take into account the environmental factors and adjust the HDI level to countries' environmental effect by negative influence of pollution and positive consequences of renewable energy usage. Nevertheless, it can be argued that properly targeted environmental factors contribute positively to the development level as also Yumashev and others [18] stated.

Table 2: Results of limited dependent variable models' estimation for PHDI

Independent variable	***Logit***	***Probit***	***Extreme Value***
Constant	-53.64932*** (6.560548)	-31.63301*** (3.512458)	-29.07313*** (5.028426)
ED1	1.358397*** (0.419179)	0.789290*** (0.207221)	0.794526*** (0.242070)
ED2	0.646433 (0.424438)	0.420369** (0.200286)	0.449519 (0.342661)
GDP	0.000947*** (0.000151)	0.000539*** (7.70E-05)	0.000457*** (8.89E-05)
RE	-0.354307*** (0.087409)	-0.197576*** (0.046100)	-0.163717** (0.065976)
GHG	2.692753*** (0.551145)	1.507847*** (0.276320)	1.256952*** (0.389660)
ANE	0.874151*** (0.143097)	0.502284*** (0.072456)	0.429187*** (0.086577)
CO2	-4.034107*** (0.825811)	-2.230748*** (0.416887)	-1.869504*** (0.602399)
MF	-0.906598*** (0.128777)	-0.534986*** (0.063792)	-0.471919*** (0.094052)
McFadden R^2	0.989271	0.992319	0.976594
LR statistic	56.18066*** [0.000000]	56.35376*** [0.000000]	55.46071*** [0.000000]
Andrews statistic	32.4732*** [0.0003]	14.8643 [0.1371]	6.0419 [0.8117]

Notes: ***statistically significant at 1% significance level, ** statistically significant at 5% significance level, * statistically significant at 10% significance level. Standard errors in parenthesis. LR and Andrews Chi-square statistics are presented with statistical significance in the parenthesis.

5 CONCLUSION

The paper presented results of limited dependent variable models in case of estimating determinants of economic development measured first by HDI and second by newly introduced PHDI. The results of the three estimated models in each case confirmed the fact that the PHDI is more concentrated on environmental variables although not all included environmental variables have the expected signs. In addition, not all explanatory variables are statistically significant. Thus, we can only partially confirm both hypothesis (H1 and H2). Taking into account, the level of HDI and PHDI, countries could improve their performance by concentrating on education factors, GDP and environmental variables such as limiting CO_2 emissions and their material footprints, and encouraging alternative energy usage. The latter is especially important for improving the PHDI level of development. Our research is limited to three types of limited dependent variable models, while it could be extended with results of tobit approach or/and other types of empirical analysis such as two or three stage least squares method. Due to lack of data for less developed countries, we focused on two groups of most developed countries. Further research might include other development factors in general and it could also enhance the environmental point of view by including other environmental data.

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EDUCATIONAL INEQUALITIES ACROSS THE EU REGIONS: MIXED GWR APPROACH

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Abstract: Following the target of the Europe 2020 strategy to achieve at least 40 % of 30-34-year-olds completing tertiary education as well as a new EU cohesion policy for 2021-2027, this paper deals with the analysis of educational inequalities across 219 NUTS 2 regions of the EU during the period 2015-2019. We assume that an uneven distribution of tertiary educational attainment level across the EU regions is the spatial heterogeneity problem. The exploratory spatial analysis is therefore followed by Mixed Geographically Weighted Regression (MGWR) approach to capture the local impacts of the population density and the GDP per inhabitant on the tertiary educational attainment level. To capture the different impact of the GDP variable in the post-socialist regions, a dummy variable in an interaction with the GDP variable was used as a global variable. The results confirming the huge regional disparities proved that the MGWR approach describes the data set better than the Ordinary Least Squares model. Furthermore, the MGWR estimates enabled to assess the impact of analysed tertiary educational attainment determinants in individual regions as well as to capture the additional positive impact of GDP in post-socialist regions.

Keywords: educational attainment, Mixed Geographically Weighted Regression, NUTS 2 regions.

1 INTRODUCTION

The balanced regional development and the reduction of inequalities across the European Union (EU) regions have been at the spotlight of the EU policies for decades. It is obvious that the future of the EU and its regions significantly depends on the capacity to learn and to innovate. Despite previously implemented EU policy measures and the commitments of the EU Member States to promote equality in education, major geographic disparities still persist across the EU Member States as well as within the EU Member States and regions. According to a new EU cohesion policy for 2021-2027 [10] as well as a previous strategy [2], the EU also focused on objectives – targets related to the educational attainment. A target on educational attainment tackles various problems related to the educational opportunities and outcomes. The level of education seems to be a very crucial issue because it helps employability, and subsequently helps to reduce poverty. In addition, higher education levels provide a greater capacity for research and development as well as innovation across all sectors of the economy. For this reason, one of the educational targets is set as at least 40% of the younger generation should have a tertiary degree. The new EU cohesion policy still keeps on investing in all regions, on the basis of three categories, namely less-developed; transition and more-developed regions. However, a more tailored approach to regional development is applied to better reflect the reality on the ground.

The issues of educational inequalities across the EU regions are also empirically researched. For instance, Rodríguez-Pose and Tselios [4] dealt with the European educational inequality distributions to detect patterns of global and local spatial autocorrelation. Their exploratory analysis of the European educational distribution illustrated the systematic differences between urban and rural areas and between North and

South regions. Schlicht et al. [5] presented an empirical evaluation of the influence of national education policies on educational inequality in the EU Member States. The study showed that education policy affects educational inequality very differently, an outcome that was most visible when comparing West European and post-communist countries. Finally, we can mention a study of Burger [1]. He examined the extent to which education systems in Europe are socially segregated and whether social segregation in the school system affects achievement gaps between students of different social origin.

A brief discussion above related to the issue of the regional educational disparities suggests that geographic understandings are indeed required features of the European educational analysis. In this paper, we assume an uneven distribution of education attainment level (tertiary education) across the EU regions, that is the spatial heterogeneity problem. The main aim of the paper is a consideration of this spatial effect in European education problem following a Mixed Geographically Weighted Regression (MGWR) approach. This paper is intended to answer the research questions such as the question of spatial differentiation of the model parameters, the global nature of some parameters will be also the point of examination.

The rest of the paper is organized as follows: sections 2 deals with theoretical backgrounds of the study. Data and empirical results are presented and interpreted in section 3. The paper closes with concluding remarks.

2 BRIEF METHODOLOGICAL BACKGROUNDS

The MGWR model seems to be a suitable tool for examining the hypothesis of spatial heterogeneity. This model is a combination of a linear regression model and geographically weighted regression (GWR) model. Therefore, MGWR model could produce parameter estimations that have global characters, and other parameters are local in accordance with the location of an observation. First, let us pay a brief attention to the GWR model.

The basic model for a site (observation/location) $\mathbf{s}_i$ $(i = 1, 2, ..., N)$ in a two-dimensional space (each site is defined by coordinates, the longitude and latitude of observation *i*) is defined as follows (see e.g., [6]):

$$y(\mathbf{s}_i) = \sum_{k=1}^{K} x_k(\mathbf{s}_i)\beta_k(\mathbf{s}_i) + u(\mathbf{s}_i), \qquad u(\mathbf{s}_i) \sim i.i.d.N(0, \sigma^2), \tag{1}$$

where $y(\mathbf{s}_i)$ is a dependent variable, $x_k(\mathbf{s}_i)$ denotes a *k*-th explanatory variable, $u(\mathbf{s}_i)$ represents an error term, and σ^2 is an error variance. The first row of the explanatory variable is considered as a model intercept, i.e., $x_1(\mathbf{s}_i) = 1$. The goal of GWR is to obtain local linear regression estimates $\boldsymbol{\beta}(\mathbf{s}_i)$ for each site. The parameters of the GWR model are estimated by the weighted least squares approach and the estimation of the parameters in each site - location *i* is given by (see, e.g., [3], [6]):

$$\boldsymbol{\beta}(\mathbf{s}_i) = \left(\mathbf{X}^{\mathrm{T}}\mathbf{W}_i\mathbf{X}\right)^{-1}\mathbf{X}^{\mathrm{T}}\mathbf{W}_i\mathbf{y}\,, \tag{2}$$

where $\mathbf{y}$ is a vector of dependent variable and $\mathbf{X}$ is a matrix of covariates. From formula (2), it is clear that *N* dimensional weighting matrices $\mathbf{W}_i$ must be constructed. The matrix $\mathbf{W}_i$ is constructed such that $\mathbf{W}_i = K(\mathbf{d}_i, h)$, where $K(\;)$ is a spatial kernel function (e.g., Gaussian, Exponential or Bisquare kernel), $\mathbf{d}_i$ is a distance vector between the central point and all neighbours, and *h* is a bandwidth or decay parameter (see, e.g., [3]).

The GWR model defined by formula (2) seems to be not sufficient for socioeconomic variables that have global effects, and it also appears inadequate for local categorical variables. Such a GWR, with spatially varying and fixed parameters, is called the mixed GWR (MGWR). This model can be formulated as follows (see, e.g., [6]):

$$y(\mathbf{s}_i) = \sum_{k=1}^{K} x_k(\mathbf{s}_i)\beta_k(\mathbf{s}_i) + \sum_{l=1}^{L} z_l(\mathbf{s}_i)\alpha_l(\mathbf{s}_i) + u(\mathbf{s}_i), \qquad u(\mathbf{s}_i) \sim i.i.d.N(0,\sigma^2) \tag{3}$$

where $z_l(\mathbf{s}_i)$ denotes a l-th explanatory variable whose parameter α_l is a constant across the space. All remaining terms in model (3) were defined above. Some procedures are proposed to estimate MGWR model, for instance, a back-fitting algorithm can be implemented. For more details, related to the issues of the MGWR estimation (see, e.g., [6]).

3 DATA AND EMPIRICAL RESULTS

The empirical part of the paper uses the data retrieved from the Eurostat database available at [7]. The main focus was given on the tertiary educational attainment across 219 NUTS 2 regions[1] of the EU for the period 2015-2019, defined as the percentage of the population aged 30-34 who have successfully completed tertiary studies. The preliminary exploratory spatial data analysis of regional tertiary educational attainment is followed by the MGWR approach. The tertiary educational attainment in 2019 is supposed to depend on the population density expressed as inhabitants per square kilometre in 2019 and the GDP at current market prices in Euro per inhabitant in 2019. To capture the different impact of the GDP variable in the post-socialist regions, a dummy 0/1 variable in interaction with the GDP variable was used. [2] The spatial analysis was carried out in software GeoDa and the MGWR was estimated in the GWR4 software environment. The shape file for the European regions with regard to NUTS 2016 classification was downloaded from the web page of Eurostat [8].

Figure 1 illustrates the box plots for the tertiary educational attainment in 2015, 2017 and 2019 to capture the development in time. Both, the median and mean values had a growing trend indicating an improvement in the proportion of the highly educated population. On the other hand, the interquartile range representing the middle 50 % of the data had the rising tendency as well as the standard deviation. The huge disparities between the proportion of tertiary educated population aged 30-34 are also clear from comparison of minimum and maximum values indicating the differences of approximately 55 percentage points. Furthermore, the boxplot points to some upper outliers (Warszawski Stołeczny and Sostinės regionas in 2015 and 2017) and no lower outliers.

The natural breaks map in Figure 2 (left) enabled to visualise the unequal distribution of the tertiary educational attainment in 2019 over a space with the sharp differences across considered regions. The highest proportions of tertiary educated population aged 30-34 were revealed in 20 regions corresponding to 15 regions with capital cities of individual countries (Madrid, Dublin, Paris, Brussels, Luxembourg, Amsterdam, Copenhagen, Stockholm, Helsinki, Prague, Bratislava, Warsaw, Budapest, Bucharest, Vilnius) as well as to further highly developed regions located in Belgium (Vlaams-Brabant and Brabant Wallon), Spain (País Vasco), Netherlands (Utrecht) and France (Midi-Pyrénées). On the other hand, the smallest proportions of the tertiary educated population were found in majority of Romanian,

[1] From the reduced data set of 260 NUTS 2 regions received after exclusion of the isolated regions further 41 UK regions were dropped due to unavailability of the GDP data.

[2] In the MGWR the data were considered in the form of natural logarithms. The variables were denoted as follows: *TED* - tertiary educational attainment, *DEN* - population density, *GDP* – GDP per inhabitant, *DUM. GDP* – dummy variable in interaction with GDP per inhabitant.

Bulgarian, Italian, Hungarian, Czech regions as well as in some German, Dutch, Portuguese and French regions. Moran's scatterplot based on the queen contiguity concept of spatial weights capturing both, the global and the local measures (Figure 2 right) clearly documented the positive spatial autocorrelation[3], i.e., that the geographical location does matter in the assessment of the regional tertiary educational attainment. Furthermore, the huge regional differences and statistically significant positive spatial autocorrelation were detected for both other variables under the consideration, namely the GDP in Euro per inhabitant and the population density.[4]

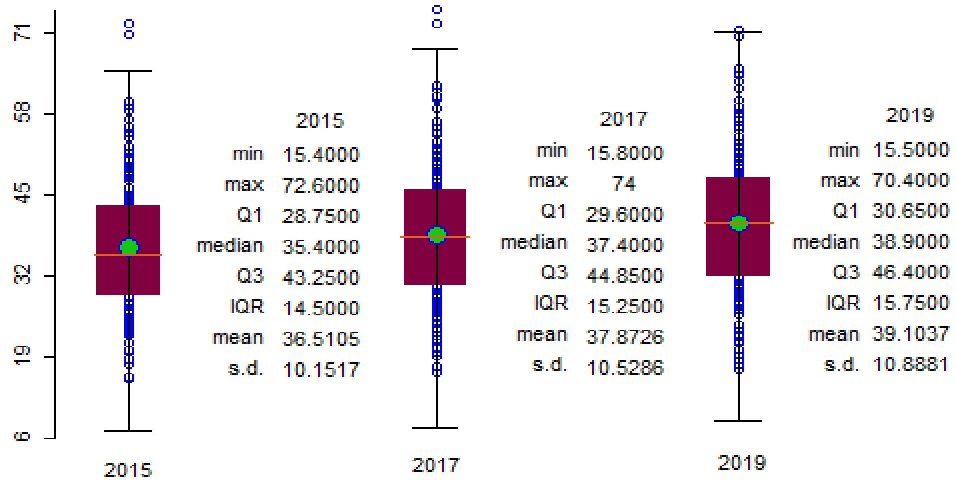

Figure 1: Box plots of tertiary educational attainment in 2015, 2017 and 2019
Source: authors' calculations in GeoDa

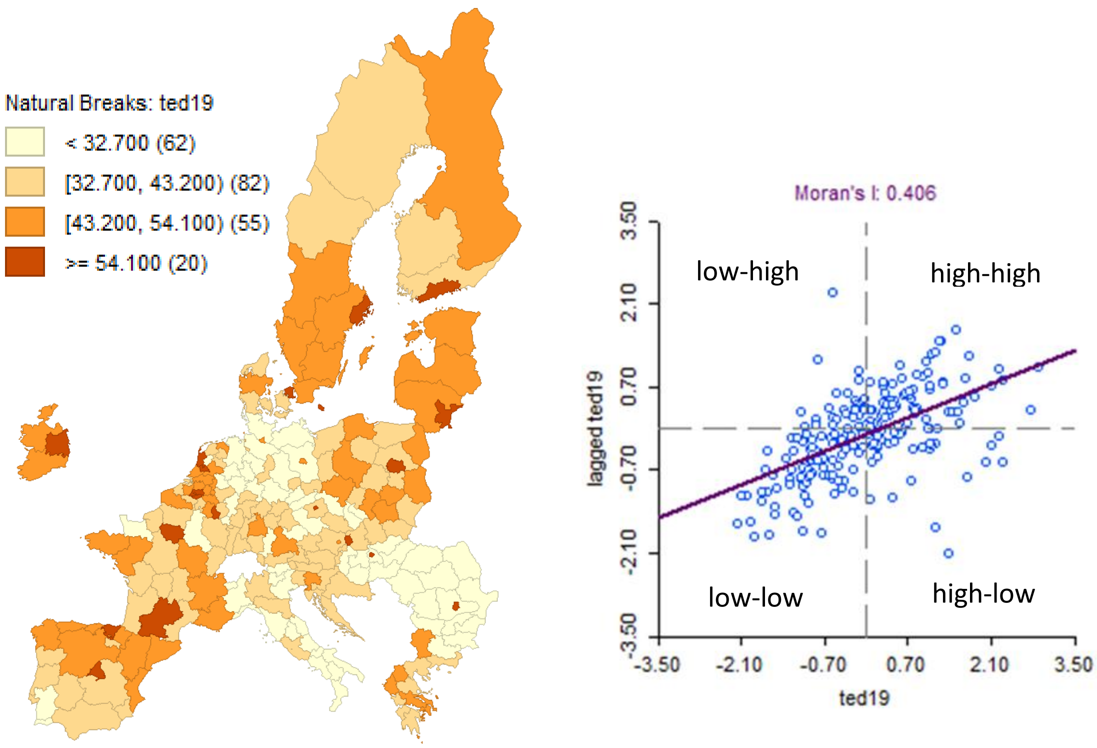

Figure 2: Natural breaks map (left) and Moran's *I* scatterplot (right) of tertiary educational attainment in 2019 (ted19), *Source:* authors' calculations in GeoDa

[3] The statistical significance was confirmed by the randomization approach based on 999 permutations.
[4] Due to insufficient space, the results are available from the authors upon request.

As the next step, it follows an econometric analysis based on estimation of an Ordinary Least Squares (OLS) regression and of the MGWR capturing the relationship among the tertiary educational attainment (dependent variable) and population density, GDP per inhabitant and GDP per inhabitant in post-socialist regions (explanatory variables). The estimates of individual OLS parameters are in Table 1 (column: OLS model). Since the intercept β_1 and parameter β_2 were not statistically significant, parameters β_3 and α_1 capturing the impact of GDP variable and of GDP in post-socialist regions, respectively, were statistically significant at the 1 percent significance level. As supposed, the positive impact of both variables (*DEN* and *GDP*) was confirmed. The dummy variable in an interaction with the GDP confirmed that the increase of GDP in post-socialist regions brought additional positive impact on tertiary educational attainment.

Table 1: Estimation results of OLS regression and of MGWR

Model	**OLS model**	**MGWR**				
		Minimum	Lower Quartile	Median	Upper Quartile	Maximum
β_1(intercept)	0.0646	-5.4296	-2.1042	-0.8126	-0.0686	3.5398
$\beta_2(\ln DEN)$	0.0042	-0.2061	0.0032	0.0269	0.0467	0.1778
$\beta_3(\ln GDP)$	0.3424***	-0.0513	0.3394	0.4164	0.5315	0.9995
$\alpha_1(DUM.\ln GDP)$	0.0222***			0.0368		
AICc	26.2405			-80.5519		
Adjusted R^2	0.2475			0.5926		

Notes: Symbol *** indicates the statistical significance of estimated parameters at 1% level of significance (OLS model). Carrying out of statistical significance tests for the MGWR fit is beyond the scope of this paper.
Source: authors' calculations in GeoDa and GWR4

To capture the spatial non-stationarity across analysed regions, the local MGWR model (3) was estimated using the adaptive bi-square kernel with bandwidth size of 48 nearest neighbours. We supposed, that while the variables population density and GDP had the locally varying impact (with the geographically varying, i.e., local parameters), the dummy variable in an interaction with the GDP was the global variable (with the fixed, i.e., global parameter). The estimation results of MGWR are in Table 1 (column: MGWR) and confirmed the geographically varying impact of analysed explanatory variables (i.e. even the changing signs of estimated parameters across analysed regions). The impact of the population density on the tertiary educational attainment was mainly positive across the analysed regions (however, negative impact was revealed for all Bulgarian and Greek regions and for several Romanian and Italian regions). Almost overall positive effect was proved for the second explanatory variable, the GDP per inhabitant (the only two regions with the negative impact were detected in Poland). The highest positive impact of GDP was confirmed for the Bulgarian, Romanian and Greek regions.[5] Additional positive impact of GDP in post-socialist regions was confirmed, as expected. Comparing the estimation results of the OLS model and those of the MGWR model considering the values of *adjusted* R^2

[5] Due to insufficient space, the results are available from the authors upon request.

0.2475 and 0.5926, respectively (Table 1), demonstrates significant improvement in the model performance. The *AICc* values of 26.2405 and -80.5519 for the OLS and MGWR fit, respectively (see Table 1) confirmed the statistically significant improvement in the MGWR model fit as well (verified by the GWR ANOVA test with the test statistic value of F=5.7272).

5 CONCLUSION

This paper focused on educational inequalities across 219 NUTS 2 EU regions based on MGWR approach. In order to accelerate the economic growth, the level of education seems to play a crucial role. Moreover, one of the educational targets of the EU is set that at least 40% of the younger generation should have a tertiary degree. Our results proved that the location does matter in assessment of regional tertiary educational attainment level. We assumed that tertiary educational attainment in 2019 depends on the population density and the GDP in Euro per inhabitant. In addition, to capture the different impact of the GDP variable in the post-socialist regions, a dummy variable in an interaction with the GDP variable was added to our econometric models. We found out that the OLS model is not sufficient when spatial heterogeneity is present, for this reason the MGWR approach seems to be more appropriate. This is because, the MGWR approach enables to capture the different impacts of explanatory variables in individual locations. Furthermore, based on the global dummy variable for post-socialist regions, some disparities between these two groups of regions were detected.

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APPROACHES TO DATA TRANSFORMATIONS AND THEIR IMPACT ON THE SKEWNESS STATISTIC FOR SERIOUSLY SKEWED DISTRIBUTIONS: SELECTED CRYPTOCURRENCIES' DATA EXPLORED

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Abstract: The normality of distribution presents the underlying assumption of many statistical methods. In some cases, the observed data do not always follow a symmetric bell-shaped distribution or approximately normal distribution. Therefore, data transformation is a commonly used approach to deal with skewed data distributions. This paper analyses the three most often used data transformations: square root transformation, log transformation, and inverse transformation, and their impact on seriously skewed distributions. The proposed data transformations applied to several cryptocurrencies resulted in different statistically significant outcomes, which might be useful for quantitative analysis of data and prognostic modelling.

Keywords: cryptocurrencies, data transformation, hypothesis testing, normal distribution, seriously skewed distribution, significance level

JEL classification: C1, C2

1 INTRODUCTION

Various statistical tests require that the features of data follow a normal distribution. The statistical tests such as t-test, F-test, chi-square test, or statistical techniques applied in statistical process control, assume that data fit the normal distribution. The normal distribution, also known as *Gaussian distribution*, forms symmetric or bell-shaped distribution. The assumption of a normal distribution does not exist in asymmetric data since the skewness seriously impacts the tail of the distribution. Consequently, the calculated p-value results will become incorrectly significant [12]. Such misinterpretation will lead to Type I or Type II error, depending on the structure of observed data and non-normality. Zimmerman argues that non-parametric tests, which do not explicitly require the assumption of normality, do not provide protection against the assumption of normality and homogeneity of variance [15].

The causes for the non-normality of data distribution could be mistakes in data entry or missing data values, but also outliers or the structure of data. There are several possible solutions to deal with non-normal data. One of the options is to objectively prove that assumption of normality is violent. The approaches to solve this issue can range from simple analysis like calculated skew or kurtosis, visual techniques like probability-probability (P-P) plot to applied interferential tests like Kolmogorov-Smirnov test, Wilcoxson test, or Lilliefors test [13]. In the context of normality, it is important to emphasize the central limit theorem. Some authors, such as Olivier and Norberg, state that "the common misconception in statistics that data must be sampled from a normal distribution for significance tests based on a normal assumption to be appropriate" [12]. When data is not sampled from a normal distribution, the sample mean, according to central limit theorem, will be approximately normally distributed for an enough large sample. Olivier and Norberg emphasize that in many papers presumed size of a sample is 30, but they also state that “magic” sample size does not exist [12].

Non-parametric tests, such as the Mann-Whitney test or Kruskal-Wallis test, are also a possible solution for the non-normal distributions. Transformation methods such as log transformation, square root transformation, or inverse transformation could be also possible approaches to non-normal distributions. These methods are often used to improve the assumption of normality. However, they have some shortcomings, which will be discussed in the second section of this paper. In the third section there will be presented the above-mentioned methods for data transformation. In the fourth section of the paper the results of applied data transformation methods will be presented and compared.

2 PREVIOUS RESEARCH

One of the most used methods of data transformation is log transformation. This method is commonly used in psychological and biomedical research to transform skewed data. Feng et al. [7, 9] presented the impossibility of this method to approximately conform to the assumption of distribution normality and to stabilize the variance. The authors highlighted circumstances where log transformation cannot facilitate variability of original data and meet the approximate normality. They also described circumstances that can lead to more variable and more skewed data and recommended new analytical methods such as generalized estimating equations.

The paper by Feng et al. [7] caused different reactions. Bland et al. commented on the problem presented in [7], stating that the paper was not supported by real data and the authors have ignored the context, in which log transformation was applied [2]. Alexander and Anaya-Izquierdo emphasized that the paper [7] is focused on the shifted geometric mean, which presents an important part of log transformation. The authors argued that log transformation does not always deal with outlying observations, since it changes the distribution’s *tailweight* [1]. In [7], Feng et al. were also focused on the skewness of distribution covariates in regression analysis. Nieboer et al. stated that Feng et al. highlighted the (mis)use of the log transformation on the skewed covariate in regression and concluded that if the distributions of covariate are skewed, the transformation should consider the shape of the relationship between the covariate and the outcome [11]. Feng et al. responded to the comments on their paper and emphasized that log transformation is a very useful tool in practice for a long time, but it has certain limitations, as given in [8].

In [13], Osborne presented the possible approaches to data transformation and its impact on the original distributions. He emphasized that the researchers should be aware that data transformation could convert the original structure of data, such as measurement scale, and complicate the data interpretation or form the curvilinear relationship. Therefore, data transformations should anchor the variable with the optimal effect. Rescaling of actual measurement could lead to variability, which may be more homogenous, and the theoretical distribution of the sample mean may be consistent with normal distribution. The optimal effect of data transformation could be also achieved with the Box-Cox method, as shown by Curran-Everett [5].

3 DATA AND RESEARCH METHODS

Data transformation uses mathematical methods to alter the value of the variables. This is one of the possible approaches to prove the assumption of distribution normality or to stabilize the data variance. The commonly used methods of data transformation are square root transformation, log transformation, and inverse transformation. Since there are two types of skewed distributions, positive and negative skewness, the above-mentioned methods of transformation are useful for positively skewed distributions since they are compressing the right side of the distribution [13].

Square root transformation cannot be applied to negative numbers. If observed data contains negative numbers, the constant must be added to move the minimum value of the distribution above 0.00. The square root for the numbers above 1.00 is always smaller than for numbers between 0.00 and 1.00. For example, the square root of number 9 is 3, but the square root of number 0.30 is 0.55. The square root method applied to the continuous variables will treat some of the numbers differently. Log transformation, according to Osborne, as given in [13], is a class of transformation that considers the power (exponent) of a base number that is raised in order to achieve the original number. The logarithm for negative numbers or numbers smaller than 1.00 is undefined; for the numbers, which variable contain values smaller than 1.00, a constant must be added. The inverse transformation computes the inverse form of number or 1/x. The essential feature of this method is that it makes very small numbers very large and vice versa. The transformation of data affects the reversing of the score order [13].

For the design of this research, the cryptocurrencies were chosen according to Chan et al., as given in [3], where statistical features of seven most popular cryptocurrencies were analysed. Our study also includes seven largest cryptocurrencies according to their market domination on January 10, 2021. The short-run analysis of volume trading was performed. In this study, a short period is defined as the period of one year [6]. The data from January 1, to December 31, 2017, were used in the analysis. This period was chosen for analysis since in 2017 the high oscillations of cryptocurrencies prices were evident, particularly of Bitcoin [14]. The daily volumes of cryptocurrency trading were retrieved from the *CoinMarketCap* [4], the leading source of cryptocurrency information. The trading volume, according to the *CoinMarketCap,* is calculated as the total spot trading volume reported by all exchanges over the last 24 hours for specific cryptoassets. Subsequently, the trading volume in U.S. Dollar for chosen cryptocurrencies was analysed. Since the value of trading volume was higher than the billion U.S. Dollar, the value of the trading volume was adjusted to a million U.S. Dollar, for the calculations and graphical presentations.

4 EMPIRICAL RESULTS

The explorative analysis of all observed cryptocurrencies has shown high skewness. The positive (right) skewness has values ranging from 2.053 to 6.385. The coefficients of variation are considerably high for all seven cryptocurrencies, which resulted in deviations from the mean. The kurtosis has positive values in interval from 5.452 to 46.977, so consequently, a lot of data is situated in the tail of the distribution. In Table 1, the main descriptive features of all seven cryptocurrencies are presented, sorted by market domination.

Table 1: Explorative analysis of trading volume in 2017 (in million U.S. Dollar)

Cryptocurrency	***k***	***Mean***	***Median***	***Standard deviation***	***Skewness***	***Kurtosis***	***Var.coef. (in %)***
Bitcoin	365	2,382.868	1,183.000	3,786.474	2.927	8.755	158.904
Ethereum	365	743.279	529.000	856.240	2.053	5.452	115.197
Tether	365	294.931	93.000	611.952	3.557	14.520	207.489
Ripple	365	285.649	88.000	840.679	6.385	46.977	294.304
Litecoin	365	333.208	159.000	601.376	5.418	44.933	180.480
Bitcoin Cash	162	1,042.111	430.000	1,495.457	3.744	20.136	143.502
Cardano	92	69.991	8.698	126.658	3.022	10.054	180.962

In order to explore the impact of data transformation on the skewed distributions, the above-mentioned data transformation methods were applied to all observed cryptocurrencies. Figure 1 shows the results of the data transformation of Ripple, the cryptocurrency with the highest skewness and coefficient of variation in the observed period.

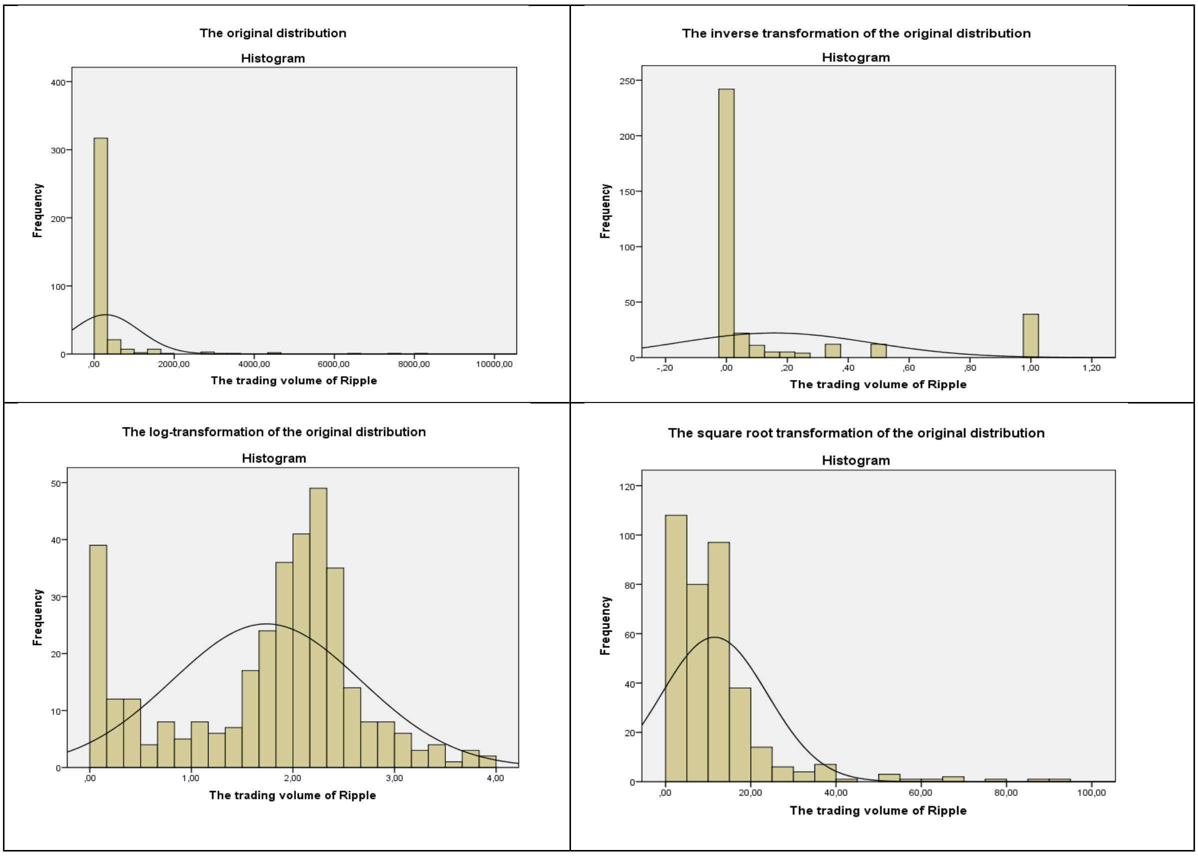

Figure 1. The impact of data transformation on the original data distribution

For the Ripple, the log transformation and the square root transformation methods had the strongest impact on the original distribution, and the right tail of the original distribution was reduced. But for a deeper understanding of the impact of data transformation, it is necessary to analyse the skewness of all observed cryptocurrencies after the conducted methods of transformation. Table 2 shows a comparison of the original values of skewness with the value of skewness after conducted data transformation, and at the first glance, it seems that data transformation has an impact on the original distributions.

Table 2: Overview of skewness for original and transformed distribution of observed cryptocurrencies

Cryptocurrency	***Skewness Original distribution***	***Skewness Inverse transformation***	***Skewness Log transformation***	***Skewness Square root transformation***
Bitcoin	2.927	2.139	0.045	1.682
Ethereum	2.053	2.749	-0.739	0.591
Tether	3.557	3.178	-0.293	1.994
Ripple	6.385	2.065	-0.503	3.080
Litecoin	5.418	1.988	-0.549	1.723
Bitcoin Cash	3.744	4.694	-1.738	1.359
Cardano	3.022	0.962	0.460	1.590

For a deeper understanding of the impact of data transformation on skewness, it is also necessary to analyse are differences between skewness of original distribution and transformed distributions statistically significant. For this purpose, the research hypothesis will be tested, and H_0 is defined: “For very skewed distributions common data transformations do not have a statistically significant impact on the skewness statistic as compared to the original distribution's skewness at reasonable significance levels” and the alternative, H_1 is the following: “For very skewed distributions common data transformations have a statistically significant impact on the skewness statistic as compared to the original distribution's skewness at reasonable significance levels”. The obtained results are shown in Table 3.

Table 3: Hypothesis matrix

α	***Skewness - inverse transformation***	***Skewness - logarithmic transformation***	***Skewness - square root transformation***
0.05	Not reject H_0	Adopt H_1	Adopt H_1
0.01	Not reject H_0	Adopt H_1	Adopt H_1

The testing of the hypothesis at 5% significance, but also at 1% significance, has shown that logarithmic transformation and square root transformation have a statistically significant impact on the skewness of original distribution for all observed cryptocurrencies. The skewness for the most log transformation of original data is negative and consequently, the mean is smaller than the median. Furthermore, there was also analysed the normality of transformed distribution using the Kolmogorov-Smirnov test, as shown in Table 4.

Table 4: Kolmogorov-Smirnov test of the normality

Cryptocurrency	***p value***			
	Original distribution	***Inverse transformation of the distribution***	***Log transformation of the distribution***	***Square root transformation of the distribution***
Bitcoin	0.000	0.000	0.000	0.000
Ethereum	0.000	0.000	0.000	0.000
Tether	0.000	0.000	0.000	0.000
Ripple	0.000	0.000	0.000	0.000
Litecoin	0.000	0.000	0.000	0.000
Bitcoin Cash	0.000	0.000	0.000	0.000
Cardano	0.000	0.000	0.000	0.000

It can be concluded that the conducted methods of data transformation have an impact on the skewness of the original distribution, but the assumption of normality or approximate normality was not met.

5 CONCLUSIONS

The conducted data transformations of seven cryptocurrencies for short-term analysis in 2017, were based on three commonly used methods: inverse transformation, log transformation, and square root transformation. The results have shown that log transformation and square root transformation have a statistically significant impact on the original distribution for the observed data. Further research was focused on the assumption of normality or approximate normality for transformed data. By conducting the Kolmogorov-Smirnov test of normality, the assumption of normality was not met. These results indicate that it is necessary to consider the statistical characteristics of the original distribution. If the standard deviation is proportional to the mean, the distribution will be positively skewed and logarithmic transformation is the appropriate method. The square root transformation is the ideal method for the analyses where the variance is proportional to the mean. The inverse transformation could be conducted only if the standard deviation is proportional to the mean of squared values [10]. Although the data transformation methods had an impact on the skewness of original data distribution, the assumption of normality or approximate normality was not met. So, in the future research methods with optimal effects of data transformation could be used, such as the Box-Cox method.

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STRATEGY EUROPA 2020 AND ECONOMIC DEVELOPMENT FROM A NATIONAL POINT OF VIEW

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Abstract: The strategy Europa 2020 has been issued as an act under the assumption that it would undoubtedly contribute to the economic development of each EU Member State. In the focus of this paper is case study of Croatia as a state that fully meets the requirements of the Europa 2020 in the field of education without having the expected positive effects on socio-economic development. The authors offer an explanation of this unexpected situation by looking at it in the wider socio-demographic environment.

Keywords: Case study of Croatia, education, emigration, Europa 2020, statistical analysis

1 INTRODUCTION

Europa 2020 has been launched in 2010 as a strategy for growth, development and creation of the new employment opportunities in the EU. The strategy represents a long-term growth plan based on five main goals that should have been met by 2020. Their purpose is to address the economic, social and environmental weaknesses of Europe. The EU has therefore made great efforts to create the conditions for a more competitive economy based on knowledge investment, a low-carbon economy, high employment, productivity and social cohesion. The Europe 2020 strategy seeks to foster growth that is smart, sustainable and inclusive.

The five main objectives of the Europe 2020 Strategy serve as a guide for growth policies at national and EU level. The goals are represented in the areas of employment, innovation, education, poverty, climate and energy [3].

The first employment target assumes that 75% of people aged 20 to 64 should be employed.

The second goal is related to research and development in which 3% of EU GDP should be invested.

The third aim related to climate change and energy calls for a reduction in greenhouse gas emissions by 20% below 1990 levels, an increase in the share of energy from renewable sources to 20% and an increase in energy efficiency by 20%.

The fourth target requires that prematurely school leaving has to be less than 10%. In addition, at least 40% of people aged 30 to 34 need to complete their higher education.

The fifth objective requires reducing the number of people living in poverty and / or social isolation or at risk of such a life by at least 20 million people.

2 ACHIEVEMENT OF THE STRATEGY EUROPA 2020 OBJECTIVES ON THE EDUCATION FIELD AND BENEFITS OF IT THAT CROATIA SHOULD HAVE

Croatia has fully fulfilled both fundamental goals of the Strategy Europe 2020 in the field of education. Figure 1. shows the share of population with completed tertiary education by EU countries in 2009 and 2017. This allows us to look at Croatia's attainments in achieving the goals of the Strategy Europe 2020 as well as a comparative analysis with other EU member states.

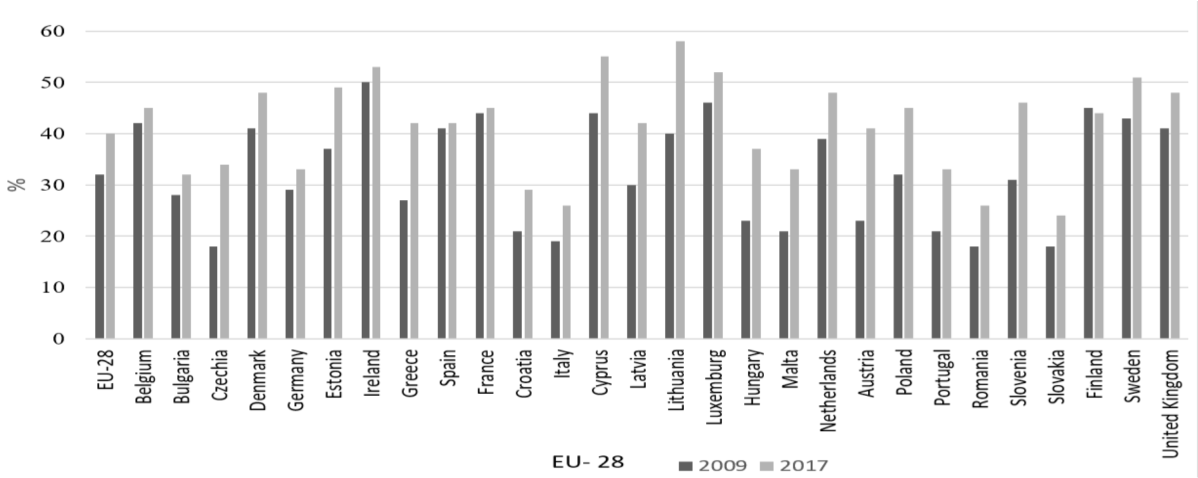

Figure 1: The share of population with completed tertiary education in the EU

So, here we can only briefly list the views of selected theorists on the benefits that Croatia, achieving the goals of the Strategy Europe 2020, should realize. As early as 1966, Nelson and Phelps pointed out a high positive correlation between investment in education and the rate of GDP growth [7]. People with tertiary education should have a better chance of employment [9]. A higher level of education encourages responsible democratic behaviour of citizens [2].

The return from education is manifested in the form of salary [11]. According to OECD research in 2017 on average in all EU countries, wages increased by 7.4% with an additional year of education. Education influences better social care, more active participation in social life, greater life satisfaction of the individual, creation of national identity and integration, and greater criticism of politics [1]. Unfortunately, none of the previously mentioned positives has happened in Croatia. [10].

Official statistics have not yet comprehensively looked at all the consequences of the major Covid-19 pandemic. Therefore, the next section will present the fundamental socio-demographic trends prior to the pandemic which has certainly worsened them many times over.

3 FUNDAMENTAL EMIGRATION FEATURES OF THE CROATIAN POPULATION AFTER JOINING THE EUROPEAN UNION

According to the census 2011 Croatia had 4 284 889 inhabitants. Moreover, according Eurostat data base for 1 January 2013 year, Croatian population was among the oldest population in the world with the average age over the one in the EU. The oldest average age in the EU had German with 45.3 years, whereas in Croatia it is just 11 month less old. [6].

The legislation of the internal EU market includes the free movement not only of capital and goods but also of people and services. The opening of the European labour market to Croats, as a consequence of joining the European Union in July 2013, has led to a massive emigration. This has not been the first emigration wave from Croatia, since around 2.3 million people have emigrated from the present territory of Croatia in the last about a hundred years [7].

Emigration from Croatia as a specific and extremely negative factor of the numerical dynamics of the population has occurred already in the second half of the 19th century. After that a couple of strong immigration currents has been happening. The last major emigration wave began during the global economic crisis in 2008, and has intensified with Croatia's joining the European Union in 2013. This has been the most unfavourable emigration wave in Croatian history because it was happening under the circumstances of the accelerated process of population aging, decreased fertility, negative natural change rate, having left some areas totally depopulated [10].

According to the databases of the Croatian Bureau of Statistics, the most popular countries for Croatian migration in the European Union are Germany, Austria and Ireland. According to the same source, the number of emigrants to Sweden has increased eightfold in the last five years.

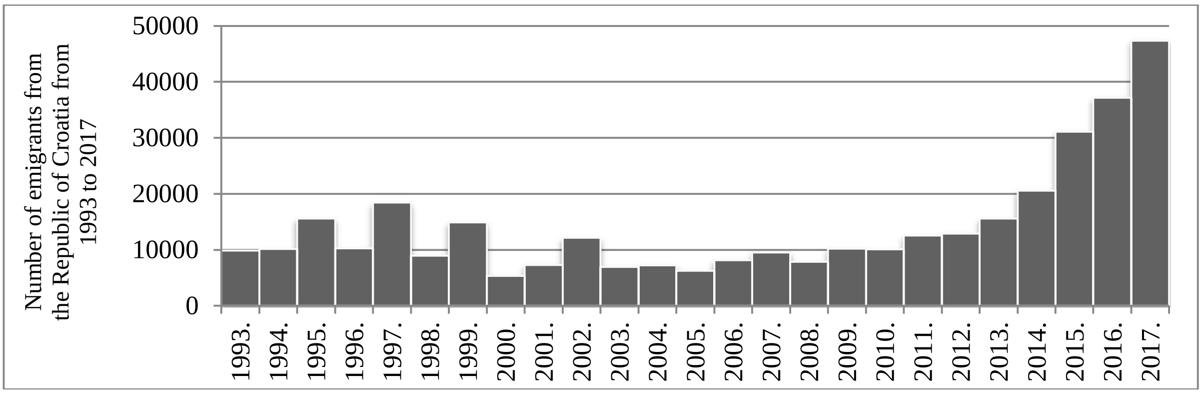

Figure 2: Number of emigrants from the Republic of Croatia from 1993 to 2017

According to the latest databases of the Croatian Bureau of Statistics, the total of 47 352 Croats have moved abroad. This is almost 30% more than during the previous year and six times more than ten years earlier in 2008, the year of the global economic crisis. Moreover, after joining the European Union, the Croatian net migration rate continued its negative trend. While in 2013 it was -4 884, in 2017 it reached the number of -31 802 persons.

Croatian Employers' Association in the mid-2018 published the results of the survey on Croatian emigrants. The survey was carried out from March 15 to May 15 in the same year on a total of 661 respondents using Computer-assisted web interviewing. According to the survey results, men and women are almost equally represented in the emigration. 82% of the respondents moved out with partners and 72% with the whole family.

A little less than half of the respondents have a high school education, while even 50% of them have a university degree. It is interesting to note that just little over 40% of the respondents were employed by a fixed-term contract. Total 73.5% of the respondents had been employed before leaving Croatia. However, the wages of 64% of them had been below-average.

According to the number of respondents who have emigrated between 2013 and 2018, more than half of them moved out in 2016 and 2017. The most common destinations for their settlement were countries: Germany (29, 6%) followed by Ireland (20,8%), Belgium (10,9%) and Sweden (10,3%). Analysing data on the age structure of emigrants the negative effects of such a large number of Croatian emigrants from their own homeland take on the characteristics of a real demographic disaster. Figure 3. shows emigrants from the Republic of Croatia in 2017 according to their age.

It goes without saying that the emigration of such a large number of young people cases the extremely negative consequences on natural depopulation, demographic trends and an increased share of the older population which changes the entire socio-economic picture of the nation. Almost 20% of emigrants in 2017 are between 0-19 years old, which is slightly more than 1% of the total population of the Republic of Croatia in that age group.

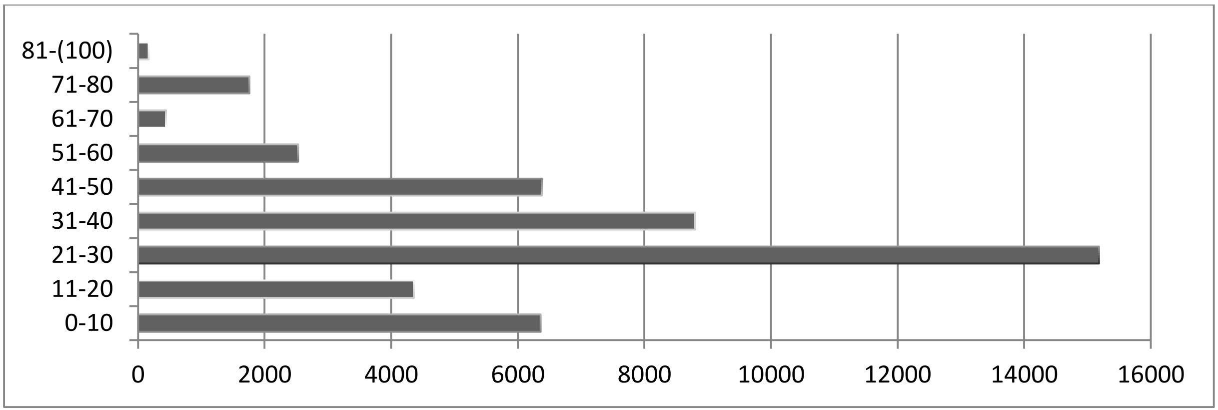

Figure 3: Emigrated from the Republic of Croatia in 2017 by age

The most popular final destination of Croatian emigrants in 2017 year was Germany in which emigrated 61% of the total number of emigrants from the Croatia that year or 29 053 persons. Germany is followed by Austria and Ireland, both with 6% of the total immigrated Croatian citizens. Namely, 2 706 persons from Croatia found their new home in Austria and 2 676 in Ireland. Figure 4. shows the structure of Croatian citizens who have emigrated in 2017 year according their countries of immigration.

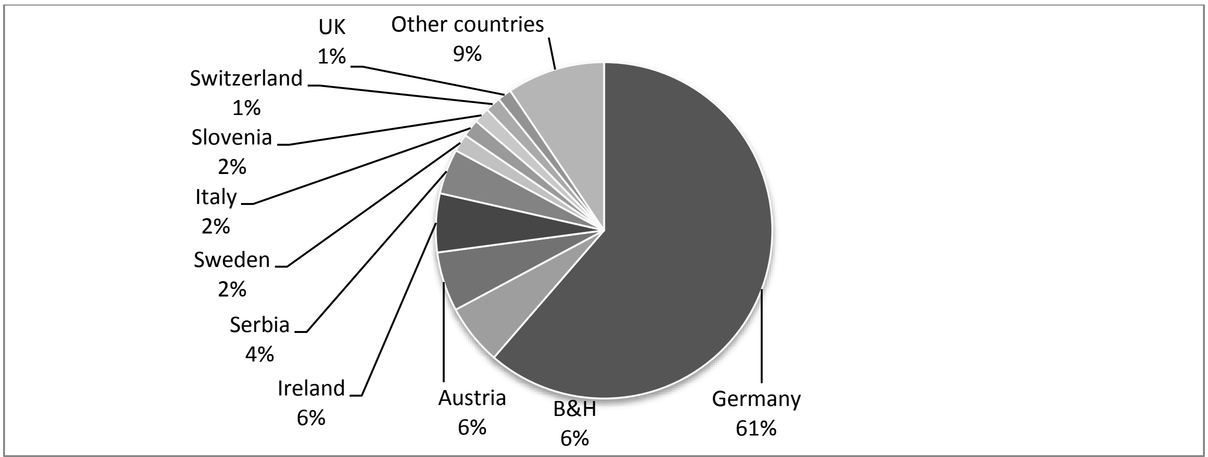

Figure 4: Structure of emigrants from Croatia in 2017 according the countries of immigration

According to the German Federal Bureau of Statistics since Croatia's joining the European Union about 230 000 Croatian citizens immigrated to Germany, which is over 5% of the total Croatian population. At the same time, according to the databases of the Croatian Bureau of Statistics the number of immigrated Croatian citizens in Germany in 2016 amounted to 20343 which is the double less than the number of newly Croatian immigrants officially registered in Germany in the same year. Based on data for Germany, Austria and Ireland, as the three countries with the highest percentage of Croatian immigrants, it can be estimated that, on average, there are 70% more emigrated Croatian citizens than official Croatian Bureau of Statistics data show. The question is why so many Croatian emigrants remain unregistered in Croatian official statistics. Two facts give us the answer. The first is that there is an obligation under the law to apply for eviction to the relevant ministry service. However, no one has been punished for the misdemeanour because he did not sign out. Another reason is that the sign out process in Croatia is relatively much more complicated than in other European Union countries. Based on what has been presented, it can be estimated that since Croatia's joining the European Union, more than 8% of the Croatian population have emigrated, mainly to developed European countries.

According the results of the survey carried out by Croatian Employers' Association in 2018 among the Croatian emigrants, the reasons for leaving Croatia were: disorganized and poorly governed state, incompetent politicians and political parties without vision, nepotism, corruption and crime, lack of perspectives for the family, lack of change in the country, etc. Moreover, 42% of respondents are not planning to return to live in Croatia, while 20.8% of them plans to return after their retirement. On the other hand the respondents cited as the „pull“ factors the following: the country is developing, a better perspective for me and my family, the clear orderliness of the system (legal protection), the job that is offered to me (company and salary), the security of the country and the environment, the recommendation of friends, etc. It can be concluded that the main reason for migration is the failure to meet basic human needs according to Maslow's hierarchy of needs.

The great problem of Croatian external migration is the departure of young highly educated experts, scientists and intellectuals from the country or so-called „brain drain”. According to the Trade unions' databases, only in 2016 as many as 525 doctors left Croatia while in the last five years around 10 000 IT experts did the same. Non-compliance of the Croatian education system and labour market needs and the lack of practical experience lead young people in an extremely unfavourable position at the Croatian labour market. As the consequence, in the last quarter of 2018 in Croatia the unemployment rate in the age group up to 25 years was 22.7% which is at the top of the European countries averages. What it means can be explained in the following quotation: „Highly educated professionals, scientists, intellectuals and artists are the holders of economic and social development of each country, so they are called human capital. Its importance has only been socially recognized in recent times as the most important segment of the intellectual capital conception” [5].Unfortunately, although Croatia has invested and is investing the great efforts and financial resources into the education and professional development of these human resources, it has not been doing anything to retain them in Croatia. Among the "pull" factors for the emigration that forms the so-called "brain drain" dominate professional aspirations and expectations such as finding better conditions for scientific work and creativity, career advancement and various forms of recognition for achievements.

Highly educated young people leave Croatia together with their obligation to repay the funds invested in their upbringing and education. Moreover, they were educated from financial resources that Croatia did not have but borrowed from abroad and it has an obligation to repay debts and interests on a long time range. On the other hand, more developed countries that have invested nothing in these highly educated young people use all the benefits of their work free of charge. Through their work in more developed EU countries highly educated young people have unintentionally been contributing to the growing socio-economic development gap between less and more developed parts of the contemporary EU.

4 CONCLUSION

This paper deals with national point of view on Strategy Europa 2020 and it's contribute to the economic development of each EU member. In the focus is the case study of Croatia which has fully achieved the objectives of the Strategy Europe 2020 in the field of education without having the expected positive effects on socio-economic development. The authors offer an explanation of this unexpected situation by looking at it in the wider socio-demographic environment. The answer to this basic research question is justified on statistical analysis. The aim of this paper is to present, as accurately as possible, what has happened in Croatia in the past decade through statistical methodology and available databases of official state and international institutions. This comprehensive statistical analysis of the structure and trends of the education sector in the Republic of Croatia respects the official indicators and all principles agreed upon by the International Standard Classification of Education (ISCED) adopted at the UNESCO General Convention in November 2011. The paper also presents the comparative statistical analysis of the achievement of the individual targets of the Europa 2020 as well as official indicators according to ISCED for all EU Member States in the research period. On the other hand, this study also offers a statistical analysis of demographic trends with an emphasis on the structure of residents who have emigrated from Croatia in the respective period. Some researches also confirm that the same socio-economic circumstances have occurred in other less developed EU countries. Their achievements of the targets of the Europa 2020 are neither statistically significant nor positive correlated with economic development. The major initiators of the Europa 2020 were led by the assurance of economic strategists and the attitudes of relevant economic theories that the achievement of these goals in the education sector would lead to positive economic development trends. However, the real socio-economic situation in less developed countries testifies to the outflow of highly educated young population into the more developed EU countries in accordance with the European free labour market. Croatia and other less developed EU countries have been left with the debt of highly educated young people. Through their work in more developed EU countries they have unintentionally been contributing to the growing socio-economic development gap between less and more developed parts of the contemporary EU. Moreover, after Brexit, the more developed EU Member States are in favour of a significant reduction of European cohesion funds which can and should depreciate the growing economic development gap in contemporary EU. All the more so as the Covid-19 pandemic has made that disparity worse many times over.

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GENDER WAGE INEQUALITY IN THE LABOR MARKET OF A POST-SOCIALIST ECONOMY

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Abstract: In this paper, the gender wage inequalities are analyzed during intensive structural reforms and ownership transformation in Serbia in the early 2000s. The gender wage inequalities are examined along the wage distribution using the panel data from the survey on living standards measurement. The two-step estimator for panel data quantile regressions is applied as an identification strategy of the estimated coefficients. The preliminary results indicate a discriminatory pattern in the determination of women's wages, especially for younger and less educated women. This further implies the existence of sticky floor effects in the bottom quantiles of the wage distribution.

Keywords: gender wage gap, panel data, Serbia, two-step estimator for quantile regression, transition economy.

1 INTRODUCTION

The extent of gender inequalities in the labor market depends on numerous economic and social factors. Workforce and job characteristics and institutional settings and social norms are among the main explanatory factors when gender wage inequalities are studied across the globe [2, 10, 13, 15, 19]. This paper aims to provide an assessment of changes in the structure and magnitude of gender wage differences in the Serbian labor market over the period 2002-2003. Unlike other post-socialist countries [1, 6, 7, 8, 12, 14, 16, 17, 21], gender wage differences in Serbia were not analyzed systematically over time. So, there is a deficit of studies in Serbia that would show the scope of gender wage differences during intensive structural reforms and ownership transformation. The recent studies for Serbia cover the post-crisis period [3].

The main research hypothesis is to statistically confirm the existence of a significant male-female wage divergence over the period 2002-2003. The empirical strategy is based on studing the pay gap at different segments of the wage distributions.

Bearing in mind the implications for public policies, there are several reasons why studying gender wage inequality is important. The opening of the economy in the early 2000s, stimulated by the liberalization of prices, exchange rate, and foreign trade, initiated significant changes in the economic system. Adoption of the new legislative framework, first of all in the area of labor relations, gave more freedom to employers in determining workers' wages so that greater emphasis is placed on identification of the potential effects of discrimination in order to keep track of the extent to which Serbian labor market is consistent with EU practice. All countries that recently applied for the EU membership took this as an opportunity to upgrade their nations' economic prosperity [11].

The contribution of this paper is at least twofold. Firstly, the paper shows how the gender wage inequality evolved and provides continuity in studying this practice in the labor market of a transitional economy, and secondly, the paper contributes to the literature by examining how the potential impact of discrimination may affect the determination of women's wages.

The structure of the paper is as follows. The second section derives theoretical concepts and explains the data and methods used to estimate gender wage differences in Serbia. The third section presents the main results and provides a discussion of key findings, while the last section concludes the paper.

2 ECONOMETRIC METHODOLOGY

Using [9] results, [4] adopted the two-step estimator for panel data quantile regression. The method transforms the panel data estimator so that the fixed effects (α_i) are eliminated. In the first step, the conditional mean of y_{it} is expressed through the estimate of the unknown parameter β, which is estimated using the within group fixed effects estimator. $\hat{\alpha}_i$ is now calculated as $\hat{\alpha}_i \equiv y_{it} - x_{it}^{'}\hat{\beta}$.

In the second step follows that $\hat{y}_{it} \equiv y_{it} - \hat{\alpha}_i$, i.e. $\hat{\alpha}_i$ is used for correcting values of the dependent variable y_{it}. Then, estimation of unknown parameters $\beta(\theta_j)$ is based on the quantile regression approach which does not include α_i. To proceed with the exercise, the three conditional quantile regressions are estimated simultaneously at the 0.1, 0.5 and 0.9 quantile, where $\theta_j \in (0,1)$

$$\begin{aligned}
[\hat{\beta}(\theta_{0.1})] &\equiv \min_{\beta} \textstyle\sum_{j=1}^{q} \sum_{i=1}^{N} \sum_{t=1}^{T} \phi_{\theta_{0.1}}(\hat{y}_{it} - x_{it}'\beta(\theta_{0.1})), \\
[\hat{\beta}(\theta_{0.5})] &\equiv \min_{\beta} \textstyle\sum_{j=1}^{q} \sum_{i=1}^{N} \sum_{t=1}^{T} \phi_{\theta_{0.5}}(\hat{y}_{it} - x_{it}'\beta(\theta_{0.5})), \qquad (1)\\
[\hat{\beta}(\theta_{0.9})] &\equiv \min_{\beta} \textstyle\sum_{j=1}^{q} \sum_{i=1}^{N} \sum_{t=1}^{T} \phi_{\theta_{0.9}}(\hat{y}_{it} - x_{it}'\beta(\theta_{0.9})).
\end{aligned}$$

The q denotes quantiles, while $\phi_{\theta_j}(.)$ is the loss function. In the empirical model y is the log of real hourly net wages separately estimated for male and female samples. The set of explanatory variables x includes age, tenure, type of employment contract, controls for economic sector, ownership structure, size of firms, and time fixed effects defined as a specific dummy variable that takes on the value of 1 for the year 2003 and 0 otherwise.

The data come from the Living standards measurement survey. The 2003 survey was conducted on a subsample of respondents who participated in the 2002 research survey. Based on a repeated survey, the panel sample for the period 2002-2003 was formed.

3 ESTIMATION RESULTS AND DISCUSSION

This section provides the interpretation of the results of estimation of quantile regressions of wages conducted separately for male and female samples. The same set of explanatory variables is included in both male and female wage equations.

Table 1 presents the estimates of the male wage equation obtained by the two-step estimator for quantile regression with fixed effects. In the first step, individual fixed effects are estimated using the standard within group approach. The estimated fixed effects are then used for correcting the actual values of male wages. Corrected values of the dependent variable are further used for the analysis of quantile regressions.

Instead of the years of experience, a tenure variable is included in quantile regressions of male (female) wages. The years of schooling, which is a good proxy for the market value of wage earners, is not included in the male (female) wage equation because the survey only provides data about "the highest completed level of education".

Age does not have a statistically significant effect on male wages, whereas tenure forms a concave relationship with male wages. The cumulative effect of tenure increases along with the wage distribution; in the 0.1 quantile it is the lowest (25.5%), while in the 0.9 quantile it takes the greatest value (43.0%). However, the effect of experience is concave along with the entire wage distribution and decreases as work experience increases. The employment contract statistically significantly determines male wages in the 0.1 quantile. The estimate of the variable employment for an indefinite period amounted to 17.0% in the 0.1 quantile. Employment in the private sector generates a higher premium than the public sector, although the positive effects diminishes in the 0.9 quantile, which comprises the highest wages in both sectors. Ownership structure and size of firms are statistically significantly associated with male wages in the median quantile regression, implying that job characteristics have a greater effect on wages than the personal characteristics of employed men.

Table 1: Fixed effects quantile regression estimates, male wage equation, 2002-2003

Variables	**$Q_{0.10}$**		**$Q_{0.50}$**		**$Q_{0.90}$**	
	Estimate	**Std. err.**	**Estimate**	**Std. err.**	**Estimate**	**Std. err.**
Age ÷ 10	0.01	0.13	0.03	0.05	0.09	0.09
Age² ÷100	0.01	0.01	0.01	0.01	0.01	0.01
Tenure ÷ 10	0.26***	0.09	0.35***	0.02	0.42***	0.07
Tenure² ÷ 100	-0.001	0.001	-0.003***	0.001	-0.006***	0.002
Ownership						
Public	0.11	0.13	0.10***	0.03	0.14	0.09
Private	0.18	0.14	0.16***	0.03	0.16	0.10
Other (ref.)						
Employment contract						
Infinite	0.17**	0.07	0.02	0.03	-0.18**	0.09
Fixed term (ref.)						
Constant	2.85***	0.30	3.21***	0.11	3.53***	0.21
NT	1518		1518		1518	
Pseudo R²	0.25		0.38		0.25	

Source: Author based on LSMS 2002, 2003. (***), (**) and (*) denote statistical significance at the 1%, 5% and 10% level, respectively. Bootstrapped standard errors are provided. Control variables for economic sector, size of firms, as well as time fixed effects are also included in quantile regressions.

Fixed effects quantile regression estimates for the female wage equation are provided in table 2. The estimates of linear and squared terms of age are statistically significant across all the estimated quantiles, and they are greater in the bottom quantiles of the female wage distribution. The cumulative effects of tenure are not evenly distributed across the female wage distribution. The magnitude of the effects is smaller in the bottom quantiles. The estimates are statistically significant at the 1% level. These findings confirm the assumption of a possible discriminatory determination of women's wages, especially young women and women of low levels of education. Similar results were found for Macedonia, considering the long transitional path and long-term inactivity of women. [18] confirmed that the gender wage inequality due to discrimination could not be confirmed for the higher educated women in the Macedonian labor market. [3] also confirmed that women in the Serbian labor market are more likely to become inactive than men. On the contrary, the higher educated women show a strong incentive to stay in the labor market and be employed.

Women employed in the public sector in Serbia earn a greater premium in the bottom half of the wage distribution than those with employment in the private sector. The wage premium turns positive and statistically significant in the upper quantiles. The estimates in the 0.1 and 0.9 quantile are respectively 0.17 and 0.29, indicating that the public sector provides more than a quarter higher wages for the employees, while persons of similar educational backgrounds earn less in the private sector. This finding indicates that the private sector could not reward the higher educated employees better at the beginning of transitional reforms.

Table 2: Fixed effects quantile regression estimates, female wage equation, 2002-2003

Variables	$Q_{0.10}$		$Q_{0.50}$		$Q_{0.90}$	
	Estimate	**Std. err.**	**Estimate**	**Std. err.**	**Estimate**	**Std. err.**
Age ÷ 10	0.57***	0,23	0.51***	0.08	0.42**	0.19
Age² ÷100	-0.11***	0,03	-0.10***	0.01	-0.10***	0.02
Tenure ÷ 10	-1.15***	0.15	-1.07***	0.04	-1.05***	0.12
Tenure² ÷ 100	0.01**	0.01	0.01***	0.00	0.01***	0.00
Ownership						
Public	0.17	0.16	0.21***	0.03	0.29***	0.10
Private	0.05	0.15	0.18***	0.04	0.25***	0.11
Other (ref.)						
Employment contract						
Infinite	-0.12	0.08	-0.12***	0.03	-0.30**	0.12
Fixed term (ref.)						
Constant	4.31***	0.48	4.67***	0.16	5.38***	0.47
NT	1040		1040		1040	
Pseudo R²	0.63		0.75		0.61	

Source: Author based on LSMS 2002, 2003. (***), (**) and (*) denote statistical significance at the 1%, 5% and 10% level, respectively. Bootstrapped standard errors are provided. Control variables for economic sector, size of firms, as well as time fixed effects are also included in quantile regressions.

At the same time, men employed in the public sector do not earn a statistically significant wage premium compared with men in other sectors. On the contrary, men employed in the business services sector benefit more, especially those whose earnings range from the median to the upper quantiles of the wage distribution. It is interesting to notice that an employment contract for an indefinite period does not affect the movement of women's wages in the lower quantiles; however, the effect is negative in the upper quantiles. In contrast to the estimates of the public and private sector in the men wage equation, which are statistically significant in the lower quantiles (especially in the 0.25 quantile, not reported in tables 1 and 2), estimates of the public sector are greater in the first two quantile regressions of women's wages and statistically significant following the median and upper quantile regressions. The presented results indicate the effect of a sticky floor in determining women's wages in Serbia.

4 CONCLUSION

In this paper, the gender wage inequalities are analyzed during intensive structural reforms and ownership transformation in Serbia in the early 2000s. The gender wage inequalities are examined along the wage distribution using the panel data from the Living standards measurement survey. The two-step estimator for panel data quantile regressions, adopted by [4], is applied to identify the estimated coefficients.

The preliminary results indicate a discriminatory pattern in the determination of women's wages, especially for younger and less educated women. This further implies the existence of sticky floor effects in the bottom quantiles of the wage distribution.

Policy implications based on the empirical analysis of gender wage inequalities can be summarized in the following: the results presented in this paper and the recent assessment of the raw gender wage gap indicate the persistence of this practice in the Serbian labor market. According to the official statistics, Serbia's raw gender wage gap amounted to 8.8% in 2018 [20].

Adopting the new Labor law in 2014 gave employers more freedom to determine workers' wages so that greater emphasis should be placed on identifying the potential effects of discrimination to keep track of the extent to which the Serbian labor market is consistent with

EU practice. At the EU level, gender (in)equalities are monitored regularly, with a special thematic section dedicated to the domain of work [5].

Fixed effects quantile regression estimates, identified in this paper, allow interpretation and monitoring of the impact of explanatory variables at different segments of the distribution of the dependent variable but cannot be used in the decomposition of the total gender wage gap.

The total gender wage gap, decomposed at different segments of the wage distribution, may also be used for testing the statistical significance of the sticky floor and glass ceiling effect. These effects denote underpayment of women at the tails of the wage distribution, which is not a result of women's lower productivity compared with male counterparts and can be attributed in part to the impact of discrimination.

Future research should be based on the methods that will allow the decomposition of gender wage differences so that the discriminatory part of wage determination can be statistically isolated.

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TIPPING POINTS IN THE CROATIAN POLITICAL SENTIMENT: WHEN, WHY, AND DOES THE ECONOMY HAVE ANYTHING TO DO WITH IT?

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Extended Abstract: Building upon two Croatian political opinion polls, namely Cro Demoskop and Crobarometar, we assess the time dynamics of political sentiment, and test for structural breaks using the Bai and Perron procedure. This type of econometric test, allowing for endogenously determined multiple structural breaks, has insofar not been implemented in political sentiment studies, so our paper provides a pioneer effect of that sort. We extract a wide scope of political sentiment variables from the political opinion polls: the approval rates for two major Croatian political parties (HDZ and SDP), government approval rates, and government grade. Finally, we assess two measures of sentiment related to the approval of general direction of the country. Furthermore, we follow two different strategies to unveil the major socio-economic and political forces behind the established structural breaks. To begin with, we form a database of media articles from major Croatian newspapers and perform content analysis of news in the period when the breaks are found. We extract media articles from the web archives of six leading Croatian news portals: Večernji list, Jutarnji list, index.hr, 24 sata, Poslovni dnevnik, and Dnevnik.hr. Approval rates of HDZ and SDP are under a great influence of intrinsic processes related to high party officials. Second, political sentiment seems not to react to minor changes in the economic outlook, only to major turbulences such as the global financial crisis. Additionally, we discriminate between up and down breaks, depending on whether the sentiment indicator of interest is larger or smaller in the regime following the break than in the one prior to the break. In the following step, we examine a wide set of potential determinants of up and down breaks. We examine industrial production as an indicator of aggregate economic activity, the Harmonized Index of Consumer Prices, real wages, and the Labor Force Survey unemployment rate. To account for the potential effect of corruption, we construct a variable of media-based corruption perception. Second, we construct a specific media-based measure of ideological polarization from the media database using predefined keywords. We impose the breaks established for political sentiment on each of the assessed macroeconomic and institutional factors, and calculate their average values in the periods before and after each break. We utilize the Wilcoxon signed-rank test. None of the examined variables are significantly different before and after up breaks, while real wages and inflation are significantly smaller after down breaks in comparison to the period before them. Therefore, citizens find the politicians accountable for the decrease of their living standard. Our results clearly indicate that political sentiment only reacts to negative changes in inflation and real wages, pointing to loss aversion. Further on, we aim to find the significant determinants of political sentiment via a threshold regression model in a multivariate setting. Unemployment is endogenously determined as the threshold variable in all model specifications. This fact conditions the finding that Croatians obviously adjust their political sentiment in accordance with the recorded unemployment levels. As the model switches to higher unemployment regimes, the effect of unemployment becomes negative and significant. Croatian political landscape is highly polarized, divided over ideological issues and socio-cultural norms, so voters in typical economic circumstances do not evaluate incumbents based on their economic performance. On the other hand, high unemployment figures, such as those recorded in the global financial crisis and the subsequent European sovereign debt crisis, are a significant trigger for considerably worsening citizens' political sentiment.

Keywords: political sentiment, structural breaks, government approval rate, political opinion poll, economic voting

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Session 2:

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HOUSEHOLD COSTS FOR PERSONAL PROTECTIVE MEASURES FOR DENGUE DISEASE

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Abstract: Dengue is a vector-borne disease considered one of the major concerns in public health. Measures can be used to reduce the impact of the mosquito around the houses. In this paper, the main focus is mosquito bites prevention through the use of personal protective measures (PPM), such as skin repellent and bed nets. It is proposed a system with six ordinary differential equations, modeling the interaction human-mosquito. At the same time, a functional, related to the household costs with these measures, is added. The aim is the studying optimal control analysis to understand the best way of applying these measures. It is concluded that the application of skin repellent and treated bed nets have an impact on the reduction of infected people and at the same time contributes to the flattening of dengue cases, which could lead to better health cares for each patient.

Keywords: dengue, personal protection, household costs, optimal control, skin repellent, bed net

1 INTRODUCTION

Dengue affects tropical and subtropical areas, but this disease continues to proliferate in other parts of the world. Rapid unplanned urbanization, changing land-use patterns, and increased international travel and trade bring humans into more frequent contact with vectors, while climate and other environmental changes fuel their spread worldwide [19].

According to World Health Organization [20], over 700000 deaths are caused by vector-borne disease annually, and 17% of the global burden of communicable disease is due to vector-borne diseases.

The costs of a disease can be split into two main folds. Downstream, they are related to the treatment, where the cost can be divided into direct (hospitalization, outpatient, drugs) and indirect (loss of productivity, tourism impact, loss of school days). Upstream, the costs are focused on prevention. All the efforts go to mosquito reduction or, at least, the reduction of mosquito bites. They can be developed by health authorities, through the insecticide or larvicide application, education campaigns to promote preventive behaviors; or by each individual that is in an affected area by applying self-protective measures (such as skin repellent, repellent treated cloths, bed nets for sleeping or bed nets for windows and doors) [7, 13, 17].

In this paper, the focus goes to PPM, especially skin repellent and treated bed nets. The use of repellents is one of the actions accepted as part of integrated mosquito-borne disease control programs. Currently, a variety of repellents are marketed, mainly containing synthetic pyrethroids and DEET as an active ingredient [18]. Insecticide-treated bed nets are effective in preventing nocturnally transmitted vector-borne diseases. A recent study [9] refers that insecticide-treated window curtains can reduce dengue vector densities for low levels and potentially reduce dengue transmission [1].

The highlight of this study is the use of the optimal control approach to determine the best strategy of using these measures with maximum protection and, at the same time, minimum cost.

The organization of the paper is as follows. Section 2 presents the mathematical model that describes the interaction between humans and mosquitoes, as well as the functional used to model the application of the PPM. The main numerical results obtained are exposed in Section 3, and the main conclusions are carried out in Section 4.

2 MATHEMATICAL MODEL

The mathematical model is based on the research paper [2], with the adaptation of the functional for two control measures, as well as the related differential equations. In the previous paper, the choice of protection is made a priori and the study focused on the time application; in this work, the main idea is to simulate a consumer's choice, understanding the best combination of personal protective measures and when to apply.

There are considered six state variables, where the first four are related to humans (s susceptible, p protected, i infected, and r recovered), and the remaining are concerned with mosquitoes (s_m susceptible, and i_m infected). Additionally, there are two control variables related to the willingness to use PPM, namely u_1 skin repellent, and u_2 treated bed net. Even with excellent advertising campaigns, it seems to be impossible persuading everybody to apply PPM, and consequently, the controls were bounded between 0 and $umax = 0.7$. This value, 0.7, means that a maximum of 70% of people are considered to use PPM, which appears to be credible.

After the normalization of the state variables, the epidemiological model is defined by:

$$\begin{cases} \frac{ds(t)}{dt} = \mu_h - \left(6B\beta_{mh}i_m(t) + u_1(t) + u_2(t) + \mu_h\right)s(t) + ((1-\rho_1) + (1-\rho_2))p(t) \\ \frac{dp(t)}{dt} = \left(u_1(t) + u_2(t)\right)s(t) - \left((1-\rho) + (1-\rho_2) + \mu_h\right)p(t) \\ \frac{di(t)}{dt} = 6B\beta_{mh}i_m(t)s(t) - \left(\eta_h + \mu_h\right)i(t) \\ \frac{dr(t)}{dt} = \eta_h i(t) - \mu_h r(t) \end{cases} \tag{1}$$

and

$$\begin{cases} \frac{ds_m(t)}{dt} &= \mu_m - \left(B\beta_{hm}i(t) + \mu_m\right)s_m(t) \\ \frac{di_m(t)}{dt} &= B\beta_{hm}i(t)s_m(t) - \mu_m i_m(t) \end{cases} \tag{2}$$

This set of equations is subject to the initial equations ([15]):

$$s(0) = \frac{11191}{N_h}, p(0) = 0, i(0) = \frac{9}{N_h}, r(0) = 0, s_m(0) = \frac{66200}{N_m}, i_m(0) = \frac{1000}{N_m}. \tag{3}$$

To minimize at the same time, the cumulative number of infected persons and the costs related to the application of control measures, it is proposed the following objective functional:

$$J(u(\cdot)) = r(T) + \int_0^T (\gamma_1 u_1^2(t) + \gamma_2 u_2^2(t))dt \tag{4}$$

where γ_1 and γ_2 are positive constants that represent the cost of taking PPM per day and person, related to skin repellent and bed net, respectively. Each PPM has two factors associated: measure cost for a whole year and durability of the protection per day.

At the same time, it is relevant that this functional also has a payoff term: the number of humans recovered by disease at the final time, $r(T)$. In this research, the final time was considered one year, meaning $T = 365$.

As expected, these systems depict the interactions of the disease between humans to mosquitoes and vice-versa. Parameters of the model are presented in Table 1.

Table 1: Parameters of the epidemiological model

Parameter	Description	Range	Used values	Source
N_h	Human population		112000	[15]
$\frac{1}{\mu_h}$	Average lifespan of humans (in days)		79×365	[8]
B	Average number of bites on an unprotected person (per day)		$\frac{1}{3}$	[14, 15]
β_{mh}	Transmission probability from I_m (per bite)	$[0.25, 0.33]$	0.25	[4]
$\frac{1}{\eta_h}$	Average infection period on humans (per day)	$[4, 15]$	7	[3]
$\frac{1}{\mu_m}$	Average lifespan of adult mosquitoes (in days)	$[8, 45]$	15	[5, 6, 11]
N_m	Mosquito population		$6 \times N_h$	[16]
β_{hm}	Transmission probability from I_h (per bite)	$[0.25, 0.33]$	0.25	[4]
ρ_1	Insect repellent protection (per day)		$\frac{1}{6}$	
γ_1	Insect repellent cost (per person and day)		$\frac{10 \times 12}{365 \times 11200}$	
ρ_2	Bed net protection (per day)		$\frac{1}{3}$	
γ_2	Bed net cost (per person and day)		$\frac{20}{365 \times 11200}$	

The following section shows several simulations to understand the trade-off between costs with PPM and the number of infected persons.

3 NUMERICAL RESULTS

The Pontryagin's Maximum Principle [12] was used to solve the optimal control problem, whose objective function is (4) subject to the constraints (1), (2) and (3). Numerically, the problem was solved in MATLAB, version R2017b, under de ODE45 routine, and evaluated using a forward-backward fourth-order Runge–Kutta method with a variable time step for efficient computation (see [10] for more details).

To perceive the impact on dengue cases five strategies were tested. The first one was done without any control ($u_1 = u_2 = 0$). The second and third scenarios consider only a single control. Finally, the last two strategies were drawn using combined controls: one applying both controls allowing them to reach the optimal control strategy, and the other using the implementation of the maximum control ($u_1 = u_2 = 0.7$). Figures 1 and 2 represent the first four strategies previously defined; the last one has similar behavior of the combined optimal control scenario. The main conclusion is that these measures, alone or combined, have effects on a dengue outbreak.

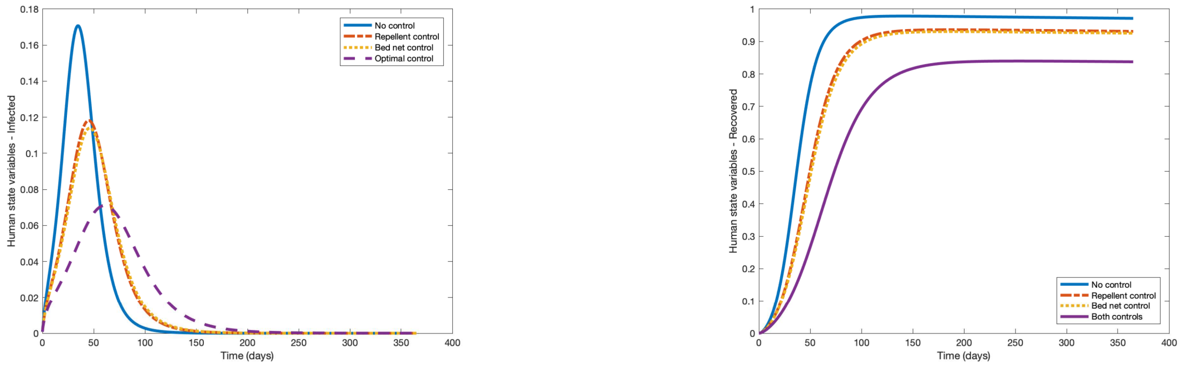

Figure 1: State variables, infected (i) and recovered (r), for the multiple strategies

Through the graphics of the infected (Figure 1, left) is possible to observe the impact of PPM on the peak of the disease. With PPM, it is possible to decrease the number of infected individuals and at the same time flatten the curve, allowing each person have better health care. At the same time, the total number of infected individuals (and then recovered) is approximately 20% lower when the combined strategy is applied (Figure 1, right).

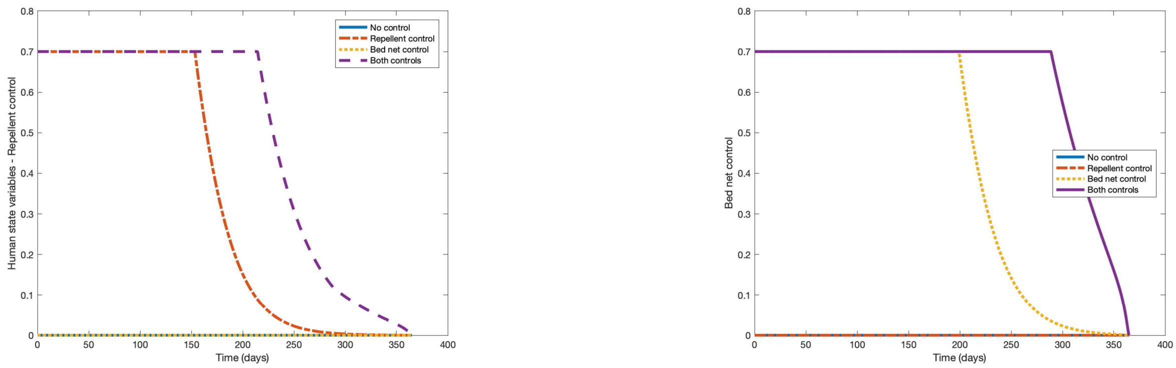

Figure 2: Control variables, u_1 and u_2, for the multiple strategies

Despite every single control have a similar impact on the disease, due to their costs, the application of them has distinct behavior, as Figure 2 exposed. The skin repellent has its optimal application in the 170 days approximately, where the treated bed net should be used longer, more than 200 days. As expected, the strategy of adopting combined controls is recommended to extend in time because it has a significant impact on the number of dengue cases.

However, the cost of using these PPM is different, as Table 2 presents. Not using any control leads to a higher number of infected persons (10878), the peak of the infection is short (35 days). This could be harmful to the preparation of human and logistical resources in an outbreak scenario.

Due to its short duration of any can/bottle of skin repellent, this PPM is very expensive when compared to the use of a bed net. Because of this feature, in the optimal control solution, the application of this measure is shorter when compared with the second control that is 5 times less expensive.

The analysis of the epidemic's end is a meaningful resource, due to the forecasting possibility of the end of the outbreak. The use of the combined strategy of both controls leads to a widening of the outbreak's end. However, when the quality of health service is considered, the spread of the patients per the time could be seen as an advantage.

Another relevant feature of this table is the cost associated with optimal control and maximum control strategies: although having similar behavior in terms of infected and recovered curves, the application of the controls at their maximum leads to an increase of 37% of costs.

Table 2: Summary of the simulations

Strategy	Peak of infected persons	Peak's day	Epidemic's end (day)	r(T)	Cost
No control	1912	35	120	10878	0
Only Repellent	863	58	202	9571	42.3
Only Bed net	710	63	223	9083	8.9
Optimal control	510	72	260	8177	71.5
Maximum control	510	72	261	8176	98

4 CONCLUSIONS

The main conclusion is that the use of controls produces very different results in the spread of the disease. Without the application of any control, the peak of infected people is much higher and earlier, which does not allow health authorities to adapt measures in a timely manner. In this situation, although there are no PPM costs, in the case of an outbreak there will be other types of disadvantages such as hospitalization or absenteeism costs.

Combining the application of the 2 PPM controls, results in a smaller, later and more flattened peak. In the event of an outbreak, congestion in health units (health professionals, beds, medicines) is avoided. When both controls are applied, the repellent should start to be discontinued before the 250th day and the bed net later, after the 300th day. This guideline makes sense, since it is intended to minimize the number of recovered in the final instant but simultaneously the costs. Also, when the controls are applied alone, the repellent should start to be reduced earlier when compared to the bed net. As the repellent is more expensive than the bed net it makes sense to stop applying it sooner.

The strategies of optimal control and maximum control yielded very similar results in terms of the peak of infected, peak's day, epidemic's day and $r(T)$ but significantly different in terms of costs. This relevant guideline denotes that it is not necessary to use the controls at their maximum value (most expensive solution) because no better results are obtained.

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INCREMENTING HEURISTIC FOR NON-DOMINATED DESIGNS OF EMERGENCY MEDICAL SYSTEM

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Abstract: This paper deals with an incrementing heuristic for special class of location problems based on the weighted *p*-median problem formulation. This class includes also the problem of Emergency Medical System optimization. The new approach introduced in this paper complies with two specific aspects of studied integer programming problems. The first of them consists in generalized disutility, which allows the operations researchers to model stochastic behavior of real systems by more service centers providing the urgent medical care to the same clients. The second important point of view takes into account the contradictory system design requirements, which lead to the usage of a bi-objective problem formulation. Since it is not possible to optimize two conflicting criteria simultaneously, suggested approach was developed to approximate the exact Pareto front of non-dominated feasible solutions of the *p*-location problems. Theoretical explanation is accompanied here with a computational study on real instances obtained from the road network of selected regions of Slovakia.

Keywords: Emergency Medical System, generalized disutility, contradictory objectives, optimal service center deployment, incrementing heuristic

1 INTRODUCTION

Emergency Medical Service (EMS) is a specific and very interesting system from many points of view. While doctors, paramedics and other medical staff focus on the provided service aimed at urgent pre-hospital healthcare, the top management of emergency agencies concentrates on the efficiency connected with financial, technical or personal aspects. Furthermore, operations researchers and software engineers study the EMS system from the viewpoint of mathematical modelling and optimization by means of integer programming [1, 2, 3, 4, 5, 12]. In this paper, we deal with a heuristic technique developed to search for a suitable system design.

When an EMS system is to be optimized, i.e. newly formed or redesigned, then the optimal structure of EMS stations is searched for. Obviously, the service centers deployment plays a key role in service accessibility for clients. Therefore, several demands are usually made not only by the service providers, but also by the served population. If the quality criterion of the design takes a simple form, then there are several exact and heuristic methods available even for the generalized objective function [6, 8, 9, 11]. On the other hand, the problem becomes much more complex and difficult, if there are two or more different objectives to be optimized. Furthermore, such requirements can be contradictory. This fact makes the decision-making process even harder [6, 7, 9].

The presented formalization of the EMS system design problem reflects two points of view at the quality of system design. The first objective measures the system design quality by average response time, what is generally denoted as the system criterion. The second objective incorporates element of fairness into the system design. These two objectives are conflicting, i.e. an improvement of one of them brings worsening of the other.

As far as the solving methods for the bi-objective problems are concerned, the research reported in this paper focuses on an incrementing heuristic approach, the aim of which consists in approximation of the exact Pareto front of non-dominated feasible solutions. The Pareto front of solutions represents a set of different solutions that is provided to managers responsible for the decision-making for setting up the final service centers deployment [6, 9].

2 BI-OBJECTIVE EMERGENCY MEDICAL SYSTEM DESIGN PROBLEM

The further presented approach considers the EMS system design as a choice of p locations out of m possible service centers so that a given objective is minimal. Thus, the set of all feasible solutions of the problem often denoted as the p-location problem can be described by (1).

$$\left\{P \subseteq \{1, ..., m\} : |P| = p\right\} \tag{1}$$

The associated optimization problem can be formulated by (2).

$$\min\left\{Obj\left(P\right) : P \subseteq \{1, ..., m\}, |P| = p\right\} \tag{2}$$

Complexity of the problem depends on accuracy, with which the objective function Obj describes the relations in the real emergency medical service systems. In this paper, we assume that the modelled system yields emergency service to all inhabitants of a serviced region and these inhabitants live in n communities, where the j-th community comprises b_j inhabitants. Demands for service at the location j emerge randomly and their frequency is proportional to the community population.

The response time for a demand at the community j is computed as an expected traversing time from an assigned service center to the location j. As the nearest service center may be occupied by an earlier occurred demand, the probabilities q_1, …, q_r ae introduced to describe situations that the nearest service center is the closest available one or that the second nearest center is the closest available one and so on up to the r-th situation [8, 10, 11]. If t_{ij} denotes the traversing time from a possible service center location i to a community location j and if the result of the operator $\min_k\{t_{ij}: i \in P\}$ returns the k-th minimal value of t_{ij} for $i \in P$, then the average response time is proportional to the value of the expression (3) for the set P of chosen service center locations.

$$Obj^S\left(P\right) = \sum_{j=1}^{n}\sum_{k=1}^{r} b_j q_k \min_k\left\{t_{ij} : i \in P\right\} \tag{3}$$

The fair objective can be formulated in many ways. In this paper, we model fairness of the design by the number of inhabitants, which are located outside the radius T from the nearest service center. The fairness objective $Obj^F(P)$ is defined by (4).

$$Obj^F\left(P\right) = \sum_{j=1}^{n} b_j \max\left\{0, sign\left(\min\left\{t_{ij} : i \in P\right\} - T\right)\right\} \tag{4}$$

This way, each EMS system design P is evaluated by a pair $[Obj^S(P), Obj^F(P)]$ of the objective function values and the remainder of this paper will be devoted to a search of a suitable compromise of these two objectives.

3 NON-DOMINATED SOLUTIONS OF EMERGENCY SYSTEM DESIGNS

Cardinality of the set of feasible solutions (1) is enormous for most of real problem instances. Nevertheless, the set can be presented by a relatively small subset of so-called non-dominated solutions, which cannot be improved in one objective unless the other objective is worsened. More exactly, a solution from (1) is called non-dominated solution if every other solution R

from (1) for which $[Obj^S(P), Obj^F(P)] \neq [Obj^S(R), Obj^F(R)]$ satisfies the following clause $Obj^S(P) < Obj^S(R)$ or $Obj^F(P) < Obj^F(R)$. The set of all non-dominated solutions is called Pareto front or Pareto set. As the process of the complete Pareto front constitution is very demanding as concerns necessary computational time [6, 7, 9], we concentrate our effort on heuristic search of a good approximation of the Pareto front for the bi-criterial problem defined by (1), (3) and (4).

Restriction on approximate sets of non-dominated solutions evokes the necessity to measure the accuracy of the obtained approximation with respect to the Pareto front. As each member of the approximate set must be either a member of the Pareto set or it must be dominated by some member of the Pareto set, we will measure the accuracy by the difference of areas under curves determined by the Pareto front and approximate set as shown in Figure 1 and Figure 2.

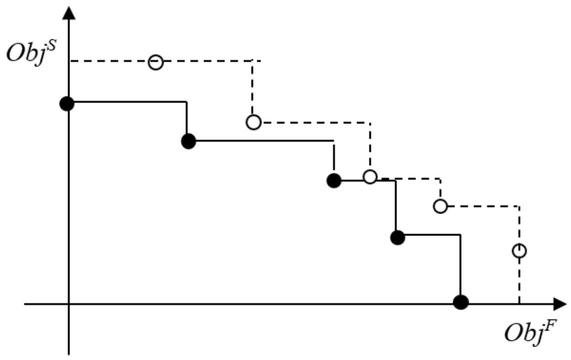

Figure 1: The black circled correspond to the Pareto front members and the empty circles denote the members of the approximation

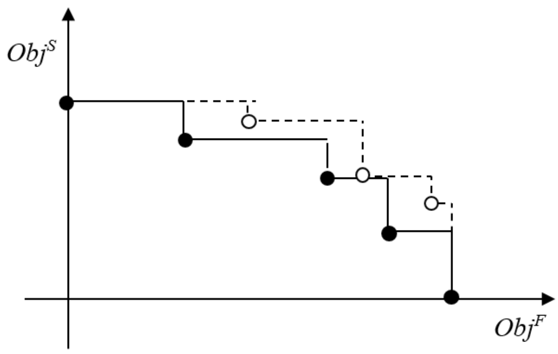

Figure 2: The black circled correspond to the Pareto front members and the empty circles denote the members of the approximation

As the individual instances may differ in domains of objective functions, the original values can be normalized by maximal values of Obj^S and Obj^F of the elements of a union of the Pareto front and its approximation.

4 SWAP HEURISTICS FOR NON-DOMINATED SET OF EMERGENCY SYSTEM DESIGNS

To suggest the process of constituting an approximation of the Pareto front, we made use of experience obtained during preliminary research performed with the swap algorithm. The previous numerical experiments proved that even the simple heuristic is able to achieve near-to-optimal solution, when applied to the *p*-location problem.

The basic operation used in the further described algorithm is the operation *Exch*(P, i, j) defined for a set P of chosen center locations and for a pair of locations i and j, where $i \in P$ and $j \notin P$. The operator performs according to *Exch*(P, i, j) = $(P - \{i\}) \cup \{j\}$.

The operation *Compl*(P) produces complement of the set P with respect to the universe of all possible service center locations $\{1, \ldots, m\}$. Input of the suggested algorithm is represented by some starting solution P and a real parameter $\lambda \in [0, 1]$. The most important input-output structure *NDSS* is the set of non-dominated solutions.

The basic algorithm performing according to the best-admissible strategy is described by the following steps.

Algorithm *BestAdmissible*(P, λ, *NDSS*)

1. {Initialization}
   Set $O^* = \lambda * Obj^S(P) + (1 - \lambda) * Obj^F(P)$, $O^{**} = O^*$, $C = Compl(P)$.
1. For each $i \in P$ and $j \in C$ perform step 2 and then continue with step 3.
2. Perform *Manage*(*NDSS*, *Exch*(P, i, j)).
   If $O^* \geq \lambda * Obj^S(Exch(P, i, j)) + (1 - \lambda) * Obj^F(Exch(P, i, j))$, then
   set $O^* = \lambda * Obj^S(Exch(P, i, j)) + (1 - \lambda) * Obj^F(Exch(P, i, j))$, $i^* = i$, $j^* = j$.
3. If $O^* < O^{**}$, then update $P = Exch(P, i^*, j^*)$, $C = Compl(P)$ and go to step 1. Otherwise terminate and return P and *NDSS*.

The procedure *Manage*() mentioned in step 2 updates the current set of non-dominated solutions by the imported solution. The updating means that the imported solution is refused if it is dominated by a member of the current set or it is included into this set and the current solutions, which are dominated by the newly imported solution, are excluded.

As the algorithm *BestAdmissible*(P, λ, *NDSS*) yields only a small set of non-dominated solutions, when applied to one concrete value of λ, we embedded it into a hyper-algorithm, which changes the value of λ to obtain a larger set of non-dominated solutions. The hyper-algorithm performs according to the following scheme with the input solution P.

0. Initialize *NDSS* with the solution P.
1. For λ from 0 to 1 with the step Δ perform *BestAdmissible*(P, λ, *NDSS*).
2. Return *NDSS*.

5 CASE STUDY

Each new algorithm designed to solve optimization problems must be subjected to numerical experiments aimed at verifying the properties of proposed method. It is no different now.

The used algorithms were codded in the programming language Java making use of the NetBeans IDE 8.2 environment and the experiments were run on a PC equipped with the Intel® Core™ i7 4790 CPU@ 3.60 GHz processor and 8 GB of RAM.

The benchmarks used in this computational study were taken from our previous research reported in [6, 9] due to the fact that the exact Pareto fronts for these problem instances are available. This advantage allows us to evaluate the quality of suggested algorithm from the point of result accuracy. As a source of input data for the experiments we used the road network of selected self-governing regions of Slovakia, in which the emergency medical service system is operated by private agencies. Out of all regions, we report the results only for Bratislava (BA), Nitra (NR), Trenčín (TN), Trnava (TT) and Žilina (ZA). The abbreviations in the brackets after each region name are used to reference the benchmark in the tables containing the achieved results. It should be noted that all the inhabited network nodes serve as a set of candidates for service center locating as well as served communities. The number of system users sharing the location j is denoted by b_j. As the objective function (3) admits providing the service from more service centers and it takes into account the distance to the expected nearest available center, the parameter r was set to 3. The associated coefficients q_k for k=1 … r were set in percentage in the following way: q_1 = 77.063, q_2 = 16.476 and q_3 = 100 - q_1 - q_2. These values were obtained from a simulation model of existing EMS system in Slovakia [10].

The exact Pareto fronts were obtained from [6, 9] and their characteristics are reported in Table 1. The problem sizes are defined by the cardinality m of the service center candidates set and by the number p of centers to be located. The column denoted by *NoS* contains the number of solutions in the Pareto front and the denotation *CT* is used to report the computational time in seconds, within which the exact Pareto front was obtained. Finally, let the symbol Obj_{max} denote the objective function value (4) of the most right member. Analogically, the column Obj_{min} reports the value of the most left member. To compare the exact and approximate Pareto fronts better, in the column *Area* we report the percentage penetration of the graph areas formed by the members of the exact and heuristic Pareto fronts as depicted in Figure 1 and Figure 2.

Table 1: Basic characteristics of the used benchmarks and the results of the exact Pareto fronts

Region	m	p	**Exact Pareto front**			
			NoS	*CT*	Obj_{max}	Obj_{min}
BA	87	14	29	102.84	280	0
NR	350	27	105	25264.40	976	557
TN	276	21	96	5824.93	567	223
TT	249	18	64	4428.66	921	450
ZA	315	29	97	10778.00	728	254

The following Table 2 contains the results of suggested algorithm described in Section 4. This table takes the same structure as the table above.

Table 2: Results of suggested algorithm for Pareto front approximation

Region	m	p	**Approximate Pareto front**				
			NoS	*CT*	Obj_{max}	Obj_{min}	*Area*
BA	87	14	19	0.11	280	20	15.95
NR	350	27	73	2.07	1024	630	49.67
TN	276	21	48	0.96	567	235	78.26
TT	249	18	42	0.82	880	476	69.56
ZA	315	29	49	1.92	691	255	75.11

The results reported in Table 1 and Table 2 show that obtaining the exact Pareto front of non-dominated feasible solutions is a very time-demanding process. Thus, suggested algorithm for Pareto front approximation brings a significant save of computational time. As far as the quality of the approximation is concerned, we have achieved very satisfactory results.

6 CONCLUSIONS

This paper was focused on EMS system designing. If the associated model is supposed to optimize two conflicting objectives, then a Pareto front of non-dominated solutions seems to be a sufficient output of any solving approach. Since obtaining the exact Pareto front requires a lot of time, the emphasis was put on a heuristic approach, which performs in order faster than the previously developed methods. Based on the results we can conclude that we have constructed a useful tool for fast solving a location problem with contradictory quality criteria.

Future research in this field may be focused on further strategies of parameter lambda adjustment and on usage of uniformly deployed set of solutions as starting solutions.

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FUNCTIONAL AREAS IN HIGHER EDUCATION: A CASE STUDY FOR SLOVENIA

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Abstract: This paper offers an approach to the analysis of functional areas (FAs) of higher education. Functional areas are formed by grouping basic spatial units (BSUs) on the analysed territory. BSUs connected to the central BSU are included in a FA of higher education. Central BSUs are defined by the location of higher education institutions. BSUs in the hinterland are included in FA if a minimum of the relative number of students in the BSU goes to the central BSU to study. In the case study for Slovenia, we looked at different criteria for municipalities to be included in the functional area.

Keywords: functional areas, higher education, Slovenia.

1 INTRODUCTION

Spatial studies provide important information on economic, social and environmental development as a basis for decision-making. When discussing spatial development, it is crucial to have meaningful information about the actual conditions of the place or region that are functionally connected [1, 7, 11]. The concept of functional systems in space derives from the idea of functional areas as complex, open, dynamic and non-linear systems that function on the basis of functional interactions between larger and smaller basic spatial units (BSUs) [5, 6, 22]. A functional area (FA) is a dynamic system to be distinguished from administratively defined areas such as administratively and/or statistically defined regions and provinces. It is precisely because of these dynamic characteristics that functional areas are important in the analysis of economic, social and environmental development as a basis for important development-related decisions [26]. The concepts of functional areas and functional regions are thus intended for the analysis of spatial development, the expansion of economic activities, the analysis and resolution of social and spatial disparity, labour market disparity and as development support at all spatial levels [4, 6].

Functionally connected parts of space are thus behaviourally based activity areas/regions, and although they too can be defined by outside observers, they are also active parts of everyday life in the empirical world. The idea of functional area/region captures the concept of a territory characterised by spatially connected human activities that link different parts of the territory. This means that our focus shifts from the space of places to the space of interactions.

In the literature, there are many studies on functional urban areas and functional (urban) regions. According to [3] and [6], a functional region (FR) is a part of an analysed territory defined with a generalised pattern of flows and interactions in space; it is a system of strongly connected larger and/or smaller basic spatial units; thus, a functional urban region (FUR) is a FR around an urban centre; and a functional urban area (FUA) is a functionally connected area between an urban centre and its catchment area. FRs and FURs cover the analysed area homogeneously and do not overlap, so they have less adaptive formations than FUAs, which may overlap and do not always cover the whole analysed area. However, they are all modelled with quantitative criteria [2].

FUAs (also FURs) are modelled around urban centres, which can be selected by agreement or on the basis of quantitative criteria (population density, number of permanent residents in an urban centre area, percentage of residents both living and working in an urban centre area, percentage of an urban centre's population working in another urban centre of the same FUA, etc.). FUA (and FUR) centres are most often defined in terms of high density areas that form the core of an urban area. When urban centres are defined, FUAs are delineated with an aggregation of basic spatial units (BSUs) from which a certain percentage of flows go to the centres. Most often, BSUs are census and other statistical units, postal districts, settlements, municipalities, communities and other regions. According to OECD [20, 21], ESPON [9] and Eurostat [10], FUAs consist of BSUs from which at least 15% of the working-age population commutes to work in urban centres.

Within the OECD-EU and ESPON initiatives, there is a wealth of research analyses that examine the socio-economic characteristics of small and large cities. These take into account the dynamics that take place over time and seek to develop strategies and policies to improve urban areas of all sizes. Slovenia is a part of both ESPON and OECD and has therefore been the subject of analysis and definition of different strategies to classify and define FUAs, FRs and FURs. Within ESPON, six FUAs were defined for Slovenia [8]. However, considering the importance of medium and small urban areas, additional criteria were added and another five FUAs were defined [22, 23]. As a result, Slovenia has fifteen FUAs (see Fig. 1), which correspond to the gravitational areas of urban centres defined in the Spatial Development Strategy of the Republic of Slovenia [6, 14].

Figure 1: Fifteen functional urban areas in Slovenia (source: [14]: 22)

Compared to previous research, where FAs were studied on the basis of labour commuting flows, in this paper we analyse FAs in higher education. A case study was conducted for Slovenia, where the system of higher education was divided into public and private higher education institutions. Tertiary education in Slovenia includes short-cycle higher vocational education and higher education. Short-cycle higher vocational education is defined by law, namely by the Act on Higher Vocational Education [13]. It is offered by both public and private higher vocational schools. Higher education in Slovenia is regulated by law, namely by the Higher Education Act [12]. Higher education is organised both by public and private universities and by other higher education institutions, namely faculties, art academies and higher vocational schools [18].

2 METHODOLOGY

2.1 Data

In Slovenia, higher education is part of the Ministry of Education, Science and Sport (MESS) and is regulated by the Higher Education Act [12]. To define the FAs of higher education in Slovenia, we used the public record of all registered higher education institutions [16] and the record of study programmes in Slovenia [15]. The list of higher education institutions (HEIs) consists of all names of institutions, study programmes and study locations. The dataset does not provide structured and filtered information on how institutions are distributed across the country.

Aggregate data on student flows between origin municipality (the municipality with the permanent address), destination municipality (the municipality where the study is conducted) and flow volume (number of students from the origin municipality studying in the destination municipality) were provided by [17].

Together, HEI records and statistical data on inter-municipal flows of students in Slovenia in the academic year 2019/2020 were used to calculate FAs of higher education.

2.2 Method

In order to analyse and determine the FAs of the HEIs, the data had to be organised and structured into table of flows of students and municipalities of study. For spatial analysis, we define the geolocation of the institutions by addresses given in the evidence [16]. We controlled it using data from the evidence of study programmes in Slovenia [15].

In 2019/2020, there were 25 municipal centres in which HEIs were located. To determine the FAs of these centres, the data were analysed with different thresholds to determine the appropriate criterion for the flows. Following the recommendations for the criterion of commuting to work, which is 15% [6, 9, 10, 20, 21] and generates one of the most frequent flows in space [19], we tested thresholds smaller than 15%, namely 1%, 2.5%, 5% and 7.5%. The fact is that the frequency of student flows is much lower than the frequency of commuter flows to work. For example, for 7.5%, this means that the municipality of origin was included in FA around the destination municipality (a) if at least 7.5% of the students with permanent residence in the municipality of origin study in the destination municipality and (b) if the municipality of origin is located at FA.

3 RESULTS

We have not found a clear purpose in the literature for the spatial distribution of HEIs in Slovenia. There are twelve statistical regions in Slovenia. HEIs are seemingly evenly distributed across the country and cover most of the regions. Although there is no specific purpose for the spatial distribution of HEIs, they cover the main regions in a balanced distribution.

In our analysis we tested four different values of the statistical criterion: 1%, 2.5%, 5% and 7.5%. The first two values included most of the specified municipalities in FA for the largest universities in Slovenia and were therefore excluded from further analysis. On the other hand, the threshold of 7.5% excluded most of the smaller flows and was therefore not used to generate

FAs. The threshold of 5% proved to be the most appropriate benchmark due to the inclusion of many smaller municipalities in FAs of higher education.

As expected, most students study in the capital of Slovenia, therefore it has the strongest spatial inflows, which can be seen in Figure 2. Due to its strong attraction, FA of Ljubljana includes all municipalities in Slovenia (see Fig. 3). Besides Ljubljana, which attracted 62.9% of students, Maribor is also an important higher education centre, attracting 18.5% of all students involved in higher education in 2019/2020. All other higher education centres attracted less than 4%, and the last half of the FAs even less than 0.5%; see Tab. 1.

Fig. 3 shows all FAs of higher education in Slovenia for 2019/2020. Of the 212 municipalities in Slovenia, only 11 meet the criteria for creating FA of higher education. The rest either have no students who are part of higher education or the percentage of students studying in the centre is less than 5%.

From Fig. 3 it can be seen that higher education institutions in Ljubljana attract students from the whole territory of Slovenia - this is mainly due to the faculties and academies of the University of Ljubljana. By size of territory, the second largest FA higher education institution is FA of Maribor, which covers the entire eastern half of Slovenia, while a large part of the western half of Slovenia is covered by FA Koper.

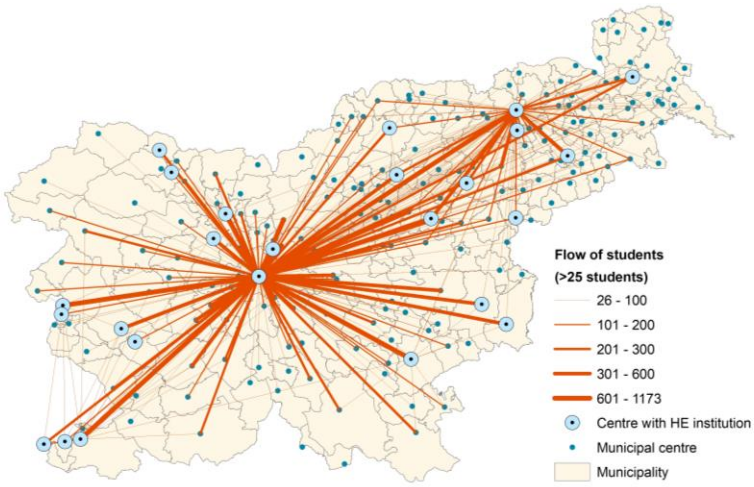

Figure 2: Intermunicipal students' flows in Slovenia in 2019/2020
(note: only flows for more than 25 students are shown)

Table 1: Number of students in municipalities with higher educational institutions

Rank	Municipality	Students	
		number	%
1	Ljubljana	37,930	62.9
2	Maribor	11,168	18.5
3	Koper/Capodistria	2,374	3.9
4	Novo mesto	1,300	2.2
5	Celje	1,191	2.0
6	Kranj	1,113	1.8
7	Nova Gorica	951	1.6
8	Izola/Isola	889	1.5
9	Piran/Pirano	875	1.5
10	Hoče - Slivnica	356	0.59
11	Trzin	337	0.56
12	Jesenice	320	0.53
13	Slovenj Gradec	281	0.47

Rank	Municipality	Students	
		number	%
14	Škofja Loka	281	0.47
15	Murska Sobota	170	0.28
16	Velenje	162	0.27
17	Brežice	147	0.24
18	Krško	98	0.16
19	Slovenske Konjice	96	0.16
20	Ptuj	69	0.11
21	Bled	61	0.10
22	Rogaška Slatina	39	0.06
23	Vipava	34	0.06
24	Ajdovščina	17	0.03
25	Šempeter - Vrtojba	1	0.002

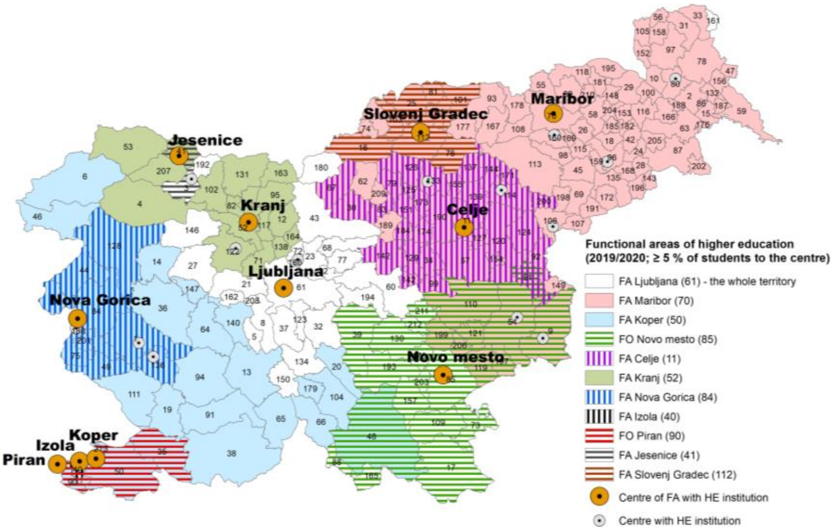

Figure 3: Functional areas in higher education in Slovenia in 2019/2020.

4 DISCUSSION AND CONCLUSION

In this paper we have analysed the functional areas of higher education in Slovenia. The criterion according to which a municipality belongs to a FA - if at least 5% of the students from the municipality study in the FA centre - was found to be appropriate.

The results of the FA modelling are, with a few exceptions, as expected. It is expected that the area size of the FA (Fig. 3) correlates with the number of students studying in the FA centre (Table 1). However, it is surprising that all municipalities in Slovenia are included in FA Ljubljana. However, Ljubljana hosts the largest number of HEIs in Slovenia and also the most study programmes. It is also surprising that most of the eastern part of Slovenia is covered by FA Maribor, so FA Maribor covers most of the eastern part of FA Ljubljana. It also covers the whole area of FA Celje and FA Slovenj Gradec , while only half of FA Novo mesto is covered by FA Maribor. The largest FA in the western part of Slovenia is FA Koper, which covers the entire area of FA Piran, FA Izola, FA Nova Gorica and surprisingly also one municipality in the south-eastern part of Slovenia, in FA Novo mesto, namely the area of the municipality of Kočevje (48). Given the number of HEIs and the fact that the University of Primorska has a wider choice of study programmes and a long tradition, FA Koper has an expected impact on the western part of Slovenia.

As a direction for future work, FAs of higher education could be compared with FAs of upper secondary education, and both could be compared with functional urban areas (FUAs) delineated by labour commuter flows in Slovenia. In addition, functional regions (FRs) of higher education (as well as FRs of upper secondary education) could be analysed and compared with general FRs of Slovenia.

Acknowledgements

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VALIDATION OF THE FAN TYPE SCALE IN CROATIA

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Abstract: The purpose of this paper is to examine the factor structure of the fan type scale in Croatia. The scale was translated into Croatian and administrated to 307 spectators during the Europa league match of a Croatian football club to answer a key research question: What is the underlying factor structure of the fan type scale? Past researches suggest a five and six factor structure (fanatical, devoted, local, dysfunctional, and temporary fans). The findings of the study present a 24-item three-factor fan type scale among which "passionate fan" appears as the most significant factor. The results provided new insights into the validity of the original version of the fan type scale. It is concluded that the Croatian adaptation of the fan type scale is a useful instrument for segmenting the sports market.

Keywords: fan scale, sports market, football fans, Croatia.

1 INTRODUCTION AND THEORETICAL BACKGROUND

The sports industry has become a global and extremely profitable industry. With the transformation of sports into real business, the adoption of business principles is becoming increasingly important. The focal aims of marketing managers are to understand what drives consumers and to focus on the most valuable target audience. Different types of fans are the main target of the global sports industry. Therefore, a classification of sports fans is of great importance and high utility to sports marketers.

Hunt et al. (1999) developed a conceptually-based classification of sports fans. The authors defined a fan as a consumer of organized sports who has some level of attachment with an object related to sports. They stated that a fan's motives and behaviour vary depending upon the type of fan, which they classified as: temporary, local, devoted, fanatical, and dysfunctional (see Table 1). The source of temporary and local fans' motivation is situational, bounded by time or space and thus is more temporary in nature. The temporary fan does not use the "fan" for self-identification and his interest in the sport is time-constrained, which makes him different from all other types of fans. Hunt et al. (1999) also stated that the fanship of a local fan, which is only peripherally used for self-identification, stems from his identification with the geographical area. On the contrary, the source of motivation for other three types of fan is enduring, with no such boundaries, where fans reveal their level of attachment through their sports-related behaviour. While devoted and fanatical fans are included in a positive fan-like behaviour, a dysfunctional fan engages in an anti-social, violent, and deviant behaviour. For the former, being a fan is a (very) important part of self-identification, but for the latter it is vital for self-identification.

Table 1: Fan scale by Hunt et al. (1999)

Fan scale	Motivation	Sport-related behaviour	Level of attachment
Temporary fan	situational	fan for a specific, time-bound event	being a fan not used for self-identification
Local fan	situational	bounded by geographic constraints	only peripherally used for self-identification
Devoted fan	enduring	no boundaries; positive fan-like behaviour	an important part of self-identification
Fanatical fan	enduring	no boundaries; engages more in fan-like behaviour	a very important part of self-identification
Dysfunctional fan	enduring	anti-social, disruptive and deviant behaviour	primary (vital) form of self-identification

Based on Hunt et al.'s (1999) classification, Agas et al. (2012) developed the first empirically based typology of sports fans in Greece. The authors' results confirm the existence of four original fan types, namely: *temporary, devoted, fanatical*, and *dysfunctional* ones. However, the results of the factor analysis show that the local fan type of the Hunt's et al. (1999) classification scheme is not a distinct type. Their empirical research indicates that the local fan dimension is incorporated into the temporary fan dimension and the devoted fan dimension, forming two separate and new types of fans, which they named *temporary local* fan and *devoted local* fan.

Over the last decade, a number of authors (Kosciolek and Nessel, 2019; Fisher, 2019; Kim et al., 2016; etc.) have tried to find a more appropriate way to classify fans using different segmentation criteria like team identification, motivation, satisfaction, social media usage, etc. These studies have provided some new and useful marketing insights, but have remained in the shadow of Hunt et al.'s conceptual work (1999). In this paper, we have tried to test and validate Hunt's et al. (1999) fan scale because a lack of such measurement instruments has been identified in the existing literature, and the results can be extremely useful to sports managers in the market segmentation process.

2 METHODOLOGY AND RESULTS

In this paper, Pallant's (2010) suggestion of the three main steps in conducting factor analysis was followed: assessments of the suitability of the data set, factor extraction and factor rotation, and interpretation. A total of 307 respondents participated in the study and 282 usable responses were received. The ratio of participants to items was a ten to one, which is adequate in most cases. In order to achieve an acceptable response rate, the author participated in the administration of the survey, was on the disposition to participants when they had problems completing the questionnaire, and finally participated in the collection of completed questionnaires. In this way, a very high response rate was achieved. The participants filled in the questionnaire individually and were asked to indicate the extent to which they agreed with each item on a five-point Likert scale.

To approve the factor structure provided by the original version of the fan scale, an explanatory factor analysis was conducted on the original 28 items. Our purpose was to clarify which factor structure explained our data the most. The 28 items of the scale were subjected to principal components analysis (PCA) using SPSS version 23. Prior to performing the PCA, the suitability of the data for factor analysis was assessed. The examination of the correlation matrix confirmed the suitability of the data for conducting the factor analysis due the presence of many coefficients of 0.3 and above. The results of Cronbach's alpha for five components, the same as those proposed by Hunt et al. (1999), were as follows: for the temporary fan $r = 0.594$, for the local fan $r = 0.645$, for the devoted fan $r = 0.949$, for the fanatical fan $r = 0.861$, and for the dysfunctional fan $r = 0.841$. Using SPSS, two important statistical measures were calculated, i.e. Bartlett's test of sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy, which can help us to judge the factorability of data. The Kaiser-Meyer-Olkin measure was 0.926 and the Bartlett's test was significant ($p < 0.5$), which confirmed that the data set is suitable for factor analysis.

In this paper, the principal component analysis was used to explore the underlying factor structure of the scale. Using Kaiser's criterion, the first five components recorded eigenvalues above 1 (11.206, 3.988, 2.128, 1.089, and 1.002). These five components explain 69.33 per cent of the variance. Pallant (2010) said that Kaiser's criterion had been criticised for resulting in the retention of too many factors in some situations. Catell's scree test recommends retaining all factors above the elbow, or break in the plot, as these factors contribute the most to the explanation of the variance in the data set. An inspection of the scree plot (see Figure 1) revealed a clear break after the third component and it was decided to retain only three components for further investigation. Therefore, Tabachnick and Fidell (2007) recommendation that researchers should adopt an exploratory approach, experimenting with different numbers of factors until a satisfactory solution is found, was followed. Additionally, it is obvious from Table 2 that most of the items load quite strongly on the first three components and very few items load on components four and five, further supporting our decision to retain only three factors. As three or more items must load on each component this solution cannot be considered an optimal one. Those facts suggest that a three-factor solution is likely to be more appropriate.

Table 2: Component matrix and Communalities

Item	***Component***					***Item***	***Communalities***	
	1	*2*	*3*	*4*	*5*		*Initial*	*Extraction*
10	.906					1	1.000	.722
9	.897					2	1.000	.220
13	.878					3	1.000	.736
14	.864					4	1.000	.728
12	.855					5	1.000	.567
11	.848					6	1.000	.013
26	.806			.303		7	1.000	.592
8	.795		.332			8	1.000	.768
7	.795					9	1.000	.824
1	.791					10	1.000	.824
3	.773		.314			11	1.000	.714
4	.671		.497			12	1.000	.821
16	.642		.418			13	1.000	.834
15	.635					14	1.000	.800
5	.631		.442			15	1.000	.484
20		.828				16	1.000	.625
21		.793				17	1.000	.626
22		.784				18	1.000	.628
23		.771				19	1.000	.628
28		.604		.380		20	1.000	.689
24		.582				21	1.000	.650
18	.336		.773			22	1.000	.629
19		.368	.754			23	1.000	.627
17	.405	.315	.561			24	1.000	.414
2	.351	413		-.599		25	1.000	.311
27		.311	-.407	.559		26	1.000	.726
25	.337			.497		27	1.000	.281
6					.977	28	1.000	.541

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization

To achieve the optimal solution, the number of factors is limited to three with iteration and Varimax rotation. Using Kaiser's criterion, all three factors recorded eigenvalues above 1 (11.206, 3.988 and 2.128) and this solution of three factors accounted for 61.863 per cent of the total variance. In Table 3, it is possible to see an information about how much of the variance in each item is explained. Pallant (2010) claims that communality values can change dramatically depending on how many factors are retained and suggests that it is often better to interpret the communality values after you have chosen how many factors you should retain. The results indicate that in the three-factor solution four items show low values (e.g. less or around 0.3): I 2 “I like going to my team’s games with body painting displaying my team’s name” (0.220), I 6 “I like being dressed in my team’s colours” (0.013), I 25 “I support the local team of the city I live in” (0.311) and I 27 “When my team loses, my close environment believes that this fact doesn’t affect my mood” (0.281). It points to the fact that items do not fit well with other items in its factor. Since we are interested in improving (refining) the scale, we decided to remove these items from the scale. Removing items with low communality values tends to increase the total variance explained. It can be seen in Table 3 that, after excluding four items from the fan scale, 68.703 per cent of total variance is explained in comparison with 61.863 per cent explained by the three-factor solution with 28 items. Component 1 contributes by 45.77%, component 2 by 16.20%, and component 3 by 6.73%.

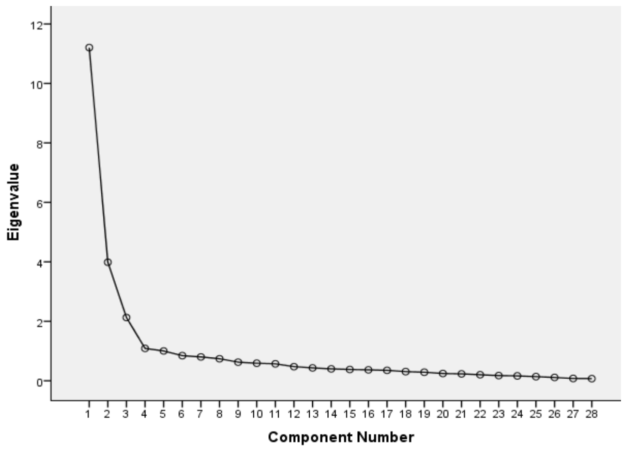

Figure 1: Scree plot of initial analysis

Table 3: Total Variance Explained

Component	***Initial Eigenvalues***			***Rotation Sums of Squared Loadings***		
	Total	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*
1	10.986	45.773	45.773	8.473	35.303	35.303
2	3.888	16.199	61.973	4.389	18.287	53.590
3	1.615	6.730	68.703	3.627	15.112	68.703

To aid in the interpretation of these three components, Varimax rotation was performed. The rotated solution revealed the presence of three components, which show the number of strong loadings and almost all variables loading substantially on only one component. Table 4 presents the factor solution and includes all values of loadings (not just those above 0.3) after Varimax rotation.

Most remaining items loaded on their theoretical scale. The first component is a combination of the items of the two factors of the original fan type scale: the fanatic fan and the devoted fan. Hunt et al. (1999) stated that those two groups are quite similar and characterized the fanatical fan as just a bit more deeply committed than the devoted fan and as the one who engages more in a fan-like behaviour. With an exception of item 4, all remaining items plus item 26, “the fact of changing city and moving away from my team cannot change the strong tie I have with it”, which originally belongs to the local fan scale, are related to this component referred to as the “passionate fan”. The second component represents the “dysfunctional fan” and the items are the same as in the original version of the scale. Hunt et al. (1999) stated that for the dysfunctional fan the fact of being a fan is his/her primary method of self-identification. Additionally, the item 4, “my close environment believes that my attachment to my team follows immediately after my attachment to my family or my religion or my work”, are related to this factor. Hunt et al. (1999) state that fans reveal their level of attachment through their sports-related behaviour and put emphasis on how easy it is to cross the border from extreme but positive fan-like behaviour to the anti-social, disruptive and deviant behaviour. It is obvious how thin the line between fanatical and dysfunctional fans is. The last component consists of almost all the items that originally formed the local fan scale to which item 28, “my close environment believes that I deal with my team only when it participates in sports events” was added, which belongs to the temporary fan scale. According to the results of the factor analysis, the temporary fan dimension of the Hunt et al. (1999) classification does not represent a separate component but is incorporated into the local fan dimension. The local fan in Croatia is bounded by time and geographic constraints and uses being a “fan“ as only a peripheral object for self-identification. In contrast to our empirical research, Agas et al. (2012) results shows that in Greece the local fan dimension does not represent a separate component. They claim that the local fan dimension is incorporated into the temporary fan dimension and the devoted fan dimension brings into surface new fan types labelled as the temporary local fan and the devoted local fan.

Table 4: Component matrix

Item	***Component***		
	1	*2*	*3*
13	**.913**	.092	-.003
10	**.901**	.188	-.018
14	**.891**	.123	-.003
9	**.876**	.266	-.017
26	**.826**	.132	-.014
11	**.824**	.243	.023
12	**.797**	.433	-.041
7	**.762**	.128	.080
1	**.696**	.482	-.039
8	**.680**	.444	-.072
3	**.640**	.456	-.107
15	**.568**	.360	.179
5	**.544**	.432	-.026
18	.214	**.773**	.248
19	.123	**.753**	.346
17	.260	**.703**	.257
4	.422	**.681**	-.132
16	.413	**.609**	.078
23	-.024	-.025	**.820**
20	-.037	.234	**.793**
22	-.029	.131	**.791**
21	-.081	.231	**.770**
28	-.038	-.253	**.652**
24	.195	.213	**.592**

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization

A complete analysis of this three-factor solution was conducted to examine the internal consistency of the factor and factor independence (see Table 5). Alpha coefficients ranged between 0.842 and 0.961, indicating acceptable levels of internal homogeneity and reliability for all three factors. Factor (scales) correlations were significantly and positively intercorrelated ($p < 0.01$) and ranged from 0.472 and 0.730 suggesting no concerns over multicollienarity.

Table 5: Descriptive statistics and intercorrelation matrix for the three-factor solution of the fan scale

Component	*n*	*Mean*	*SD*	*α*	*F1*	*F2*	*F3*
Passionate fan	282	37.65	14.288	0.961	1.00		
Dysfunctional fan	282	12.59	6.024	0.881	0.527*	1.00	
Local fan	282	8.26	3.53	0.842	0.472*	0.730*	1.00
Fan scale	282	58.5	19.728	0.942			

Note: * $p < 0.01$

3 CONCLUSION

According to the results of the factor analysis, the author developed an empirically based typology of football fans in Croatia inspired by the conceptually based Hunt et al.'s (1999) classification. The results of this study indicate that it was not possible to confirm either the original five-factor solution or the Greek six-factor solution. The fan movement is not so developed in Croatia and there is a cultural difference between fans from different countries. Our data suggests that the three-factor solution is preferred: passionate, dysfunctional and local fan among which the passionate fan appears as the most significant factor. The main purpose of this study was practical in nature and this empirically based typology may serve as an essential beginning for segmentation. The findings of this research help marketers develop marketing strategies tailored to each group of fans. It is necessary for marketing managers to create a specific approaches and campaign related to motives and behaviour of each fan type. Sports marketers should take advantage of the connection of local fans with the geographical area and the feelings of passionate fans to help them to become "crazier" about their team. As for dysfunctional fans, their offensive behaviour should be directed into fan-like behaviour as soon as possible using various demarketing techniques. This research was limited to one country, one sport, and only one club. Therefore, future research could be conducted to examine different scales for determining fan typology in different contexts (other countries, different sports or different sports-related subjects).

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MCDM WITH IMPRECISE INFORMATION: ECONOMIC, ECOLOGICAL, SOCIAL AND PARTICIPATORY INSIGHTS ON NATURAL RESOURCE MANAGEMENT SCENARIOS

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Abstract: Due to rapid social, climatic, environmental, and other changes there is a strong need to develop an adapted (optimal) decision making process (scenarios, alternatives) for management of natural resources on a resilient and sustainable basis [10]. We are faced with the MCDM problem in which the scenarios must be determined, evaluated, and ranked according to the goals and preferences of end-users [9]. Incorporating representatives of various groups who benefit or lose from the scenario undertaken is one of the most important goals when measuring social and ecological consequences of implemented scenarios [1]. Nevertheless, their opinion is expressed by verbal comparisons of intangible alternatives and criteria which have then to be converted into numerical values (scale); otherwise, they supply imprecise information or even missing evaluations. Thus, in this paper, an AHP method is extended by the study of different scales compared to the Saaty's Fundamental scale. Further, AHP is combined with Dempster-Shafer (DS) theory of evidence for ranking the selected management scenarios under imprecise information conditions. Finally, a numerical example from the field of natural resource management is considered to illustrate the presented MCDM (AHP, scales, DS theory) approach.

Keywords: natural resources, social issues, management, multi-criteria decision making, analytic hierarchy process, comparison scales, imprecise information, Dempster-Shafer theory

1 INTRODUCTION

Global economic, social and above all environmental and climatic changes increase the requests for new, innovative, resilient, and sustainable decisions which must reach multiple goals set by UN 2030 Agenda [15], numerous worldwide resolutions, action plans, protocols, and directives on economic, social, and environmental development [8]. Based on this paradigm management of natural resources (arable land, forest, water, ….) also calls for a balance of economic, social, and environmental objectives. Further, several stakeholders with conflicting interests are included through participatory planning of development possibilities. Thus, we are considering a problem with multiple, interdependent, uncertain, long term, spatial- and data-extensive parameters, objectives and constraints which are obtained as preference judgements by decision makers/stakeholders. Because of their subjectivity these qualitative or quantitative data usually present imprecise information or in some cases even missing evaluations. Consequently, facing a MCDM problem we are concerned with the ranking of decision alternatives, based on verbal and inadequate stakeholders' preference judgements made on decision scenarios over several criteria and sub-criteria (Figure 1).

Many MCDM methods have been developed to solve this problem. Amongst these methods the Analytic Hierarchy Process (AHP), originally proposed by [11] has been widely used [7]. In AHP the decision maker must make pairwise comparison between scenarios and between criteria. Their opinion is expressed by surveys, based on verbal comparisons of scenarios/criteria and these comparisons have then to be converted into numerical comparison scale which has to fulfill the prescribed limitations. The choice of the scale affects consistency in AHP and, of course, final evaluation of scenarios [5]. Thus, in this paper we elaborate six numerical scales, compare them with the most widely used Saaty's Fundamental scale [12] which is taken as benchmark. Finally, in the results section we categorize the treated scales upon some AHP characteristics.

Further, information about alternatives and objectives may be incomplete because of lack of data, limited information, intangibility of some parameters or limited precision of human assessments [6]. Several approaches have been developed to solve the problem of incomplete information, but most of them are not applicable to a comparison decision matrix in AHP [17]. In this paper, DS-AHP method [6] is proposed for MCDM problem with incomplete information.

The paper is organized as follows: Section 2 is devoted to AHP and scales, Section 3 shortly presents a DS-AHP approach. In section 4 a numerical example to illustrate the methodology is given; concluding remarks are presented Section 5.

2 AHP AND SCALES

In classical AHP a 1-9 ratio scale (Table 1) is used to compare two elements on the same level of hierarchy regarding the element on the next higher level.

Table 1: The fundamental AHP judgements scale with integers 1-9 and their verbal equivalents [12]

Value	Description
1	Criteria *i* and *j* are equally important.
3	Criterion *i* is a little more important than criterion *j*.
5	Criterion *i* is more important than criterion *j*.
7	Criterion *i* is proved to be more important than criterion *j*.
9	Criterion *i* is much more important than criterion *j*.
2, 4, 6, 8	Middle values

The priority vector ***w*** can be derived from comparison matrix *A* using eigenvector method (EV) [11]:

$$Aw = \lambda_{A,max}, \tag{1}$$

where $\lambda_{A,max}$is maximal eigenvalue of the matrix A.

Since matrices are often not consistent, the inconsistency is measured by consistency ratio:

$$CR_A = \frac{CI_A}{RI_n} \tag{2}$$

where $CI_A = \frac{\lambda_{A,max}}{n-1}$ is consistency index and RI_n is random index [12]. A is acceptably consistent if $CR_A < 0.1$.

Let m be the number of decision makers with comparison matrices $A^{(k)} = \left(a_{ij}^{(k)}\right)_{n\times n}$, *k=1,...,m*. We assume that all decision makers are equally important. Our approach for aggregation of individual judgments into group interval judgment is geometric mean of individual judgments which is known geometric mean method (GMM) in classical group AHP [13]:

$$a_{ij}{}^{(GMM)} = \sqrt[m]{\prod_{k=1}^{m} a_{ij}^{(k)}} \tag{3}$$

All geometric means are gathered in an aggregated matrix

$$A^{GMM} = \left(a_{ij}^{(GMM)}\right)_{n\times n} \tag{4}$$

But, in practice, it is not necessary to be limited to Saaty's Fundamental scale, i.e., 1-9 numbers and given verbal equivalents. There have been several other scales proposed [4]. Most of the authors introduced new scale and analyze the scale in the direction of function properties, weight uncertainties and weight dispersion. When studying the scales, we have primarily seen that different scales produce different consistency ratios for comparison matrices and different ranking of alternatives are resulted when using different scales. Let's look at an example: if a survey with verbal description as given in Table 1 results in a comparison matrix A for Fundamental scale 1-9 we get, using formula (2), CR_A=0.062 and using formula (1) $\boldsymbol{w}$ = (0.34, 0.30, 0.08, 0.28). If we use for the same verbal data potential scale $2^{(n-1)/2}$ we get comparison matrix B, CR_B=0.065 and $\boldsymbol{w}$ = (0.29, 0.33, 0.11, 0.27).

$$A = \begin{bmatrix} 1 & 2 & 3 & 1 \\ \frac{1}{2} & 1 & 6 & 1 \\ \frac{1}{3} & \frac{1}{6} & 1 & \frac{1}{3} \\ 1 & 1 & 3 & 1 \end{bmatrix} \qquad B = \begin{bmatrix} 1 & 2^{1/2} & 2 & 1 \\ 0.70 & 1 & 2^{2.5} & 1 \\ \frac{1}{2} & 0.176 & 1 & \frac{1}{2} \\ 1 & 1 & 2 & 1 \end{bmatrix}$$

In our study we observed seven scales (Table 2).

Table 2: The studied scales

	Name of the scale	**Scale function**	**Scale values (max value)**
1	Linear 1-9	$y = x$	1,2,3,4,5,6,7,8,**9**
2	Inverse linear	$y = \frac{9}{10 - x}$	1,1.13,1.29,1.5,1.8,2.25,3,4.5,**9**
3	Balanced	$y = \frac{0.45 + 0.05x}{1 - 0.45 + 0.05x}$	1,1.22,1.5,1.86,2.33,3,4,5.67,**9**
4	Logarithmic	$y=\log_a(x + a - 1);\ a = 2$	1,1.58,2,2.32,2.58,2.81,3,3.17,**3.32**
5	Root square	$y = \sqrt[a]{x};\ \ a = 2$	1,1.41,1.73,2,2.23,2.45,2.65,2.83,**3**
6	Power	$y = x^a;\ \ a = 2$	1,4,9,16,25,36,49,64,**81**
7	Geometric	$y = a^x;\ \ a = 2$	1,2,4,8,16,32,64,128,**256**

The first is Fundamental Saaty's with maximum value 9 (max = 9). Other scales form three categories: inverse linear and balanced form category 1, (max = 9); logarithmic and root square category 2, (max < 9), while power and geometric category 3 (max > 9). At this stage of our research, the results of different scales will be compared to Saaty's fundamental scale.

3 DS-AHP APPROACH

Dempster-Shafer theory ([3], [14], [2]), assigned as DS, is a useful tool for modelling uncertainty and imprecision where the information/data are imperfect. The DS approach first identifies the so-called focal elements from the decision matrix which is incomplete, and then calculates the decision alternative's basic probability assignment (BPA) for each focal element. Finally, according to DS the belief measure of each alternative is computed. Using the ranking method proposed by [16] the preference relations among alternatives are determined by comparing the belief measures.

Let $\theta = \{a_1, \ldots, a_N\}$ be a set of alternatives; BPA is a function m: $2^\theta \rightarrow [0,1]$, where 2^θ is a power set of θ satisfying $m(\phi) = 0$ and $\sum_{A \subseteq \theta} m(A) = 1$. Each subset $A \subseteq \theta$ such that $m(A) > 0$ is called a focal element of m. If for the decision problem with alternatives a_i (i=1,…,N) exist attributes C_j (j=1,…, M), and if $f(a_i,C_j)$ represents the evaluation of a_i under C_j, then for the focal elements defined from decision matrix the following holds: a_i and a_k belong to the same focal element if $a_i \neq a_k$ and $f(a_i,C_j) = f(a_k,C_j)$.

Further, let A_k^j (j=1,…,M and k=1,…,t) be the set of all focal elements that belong to attribute C_j,, and let w_j be the weight of C_j, then the decision maker's preference on A_k^j is:

$$p(A_k^j) = \text{wjf(ai,Cj)} \tag{5}$$

Further, BPA of A_k^j is defined as: $\boldsymbol{m_j(A_k^k)} = \frac{\boldsymbol{p}(A_k^j)}{\sum_k \boldsymbol{p}(A_k^j)}$ (6)

BPA of E (E is intersection of focal elements $A_k^{j_1}$ and $A_l^{j_2}$ under attributes $j_1, j_2 \in (1,\ldots,M)$) is:

$$(m_{C_1} \otimes m_{C_2})(E) = \frac{\sum_E m_{C_1}(A_k^{C_1}) m_{C_2}(A_l^{C_2})}{1 - \sum_{E=\emptyset} m_{C_1}(A_k^{C_1}) m_{C_2}(A_l^{C_2})}$$

if $E \neq \phi$ and $(m_{C_1} \otimes m_{C_2})(E) = 0$ if $E = \phi$ (7)

Belief measure of alternative ai Bel(ai) $= \sum_{a_i \in E} m(E)$ for each i=1,…,N (8)

If $Bel(a_i) > Bel(a_k)$ then a_i is preferred to a_k.

4 NUMERICAL EXAMPLE

For the case study we took the area at the eastern part of Slovenia. The area is covered with preserved old forest, agricultural and urban land and is part of Natura 2000. Further, the area is significant for species diversity, landscape and regional diversity, recreation, hunting, learning trail for education, important for fresh water, air, health features, tradition of sustainable and close-to nature forest management. Three stakeholders/decision makers:- DM1 is environmentalist (representative of the research institution, government and public, as well as NGOs), DM2 is representative of the educational institutions, DM3 is representative of farmers/owners and the local community - were selected as decision makers who helped in defining the future management scenarios and objectives of the area. Different management scenarios/alternatives (a_1, a_2, a_3, a_4, a_5, ….) were defined, dependent on four criteria: economic C_1, ecological C_2, educational C_3, and social C_4 (Figure 1).

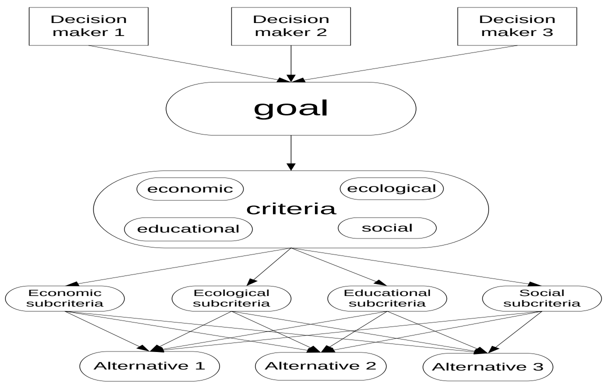

Figure 1: Hierarchical presentation of the case study

Through surveys we obtained the comparisons of criteria expressed verbally. For each scale from Table 2 we calculated three individual crisp comparison matrices for comparing the criteria. All matrices offered complete information. Using (3) and (4) we calculated aggregated comparison matrix for criteria and finally by (1) we calculated the priority vectors **w**. The results are in Table 3. The results show that the scales of category 2 (max < 9) generate lower priorities to criteria with higher rank (rank 1 and 2), obtained by using Fundamental Saaty's scale, and of course, vice versa higher priorities to criteria with lower rank (rank 3 and 4). The change of rank order is also noticed when using scales of category 2. The scales of category 2 show also the tendency to compress the weight range: for logarithmic scale is 11,6%, i.e., [0.165, 0.281] and for the root square 13.5%, i.e. [0.156, 0.291]. The scales of category 3 (max

> 9) generate higher priorities to criteria with higher rank (rank 1 and 2), obtained by using Fundamental Saaty's scale, and of course, vice versa, lower priorities to criteria with lower rank (rank 3 and 4). The change of rank order is also noticed when using scales of category 3. The scales of category 3 additionally show the tendency to expand the weight range: for power scale is 21.7%, i.e, [0.109, 0.326] and for the geometric 18.1%, i.e. [0.142, 0.323]. The weight range for scales from category 1 (max = 9): Fundamental scale is 14.3%, inverse linear 15.1% and balanced 14.7%. The rank of criteria is the same for all scales from category 1. These findings coincide with the observations of [5] for the case taken from [11], using only one DM, EV (1) for calculating priorities and only one scale from each category.

Table 3: Results for seven different scales for criteria

Scale	C_1		C_2		C_3		C_4	
	Priority	Rank	Priority	Rank	Priority	Rank	Priority	Rank
Linear 1-9	0.294	1	0..274	3	0.287	2	0.145	4
Inverse linear	0.289	1	0.271	3	0.288	2	0.152	4
Balanced	0.295	1	0.272	3	0.285	2	0.148	4
Logarithmic	0.279	2	0.275	3	0.281	1	0.165	4
Root square	0.291	1	0.271	2	0.275	3	0.163	4
Power	0.298	2	0.267	3	0.326	1	0.109	4
Geometric	0.312	2	0.223	3	0.323	1	0.142	4

We also calculated CR using (2) for individual pairwise matrices and aggregated matrices for the selected scales. All matrices were consistent for Fundamental scale. Scales of category 2 in general lowered the CR, in category 3 increased CR but in no case, CR exceeded 0.1. For scales in category 1 the CR was mostly the same as for matrices using Fundamental scale.

The priority weights for four criteria C_1, C_2, C_3 and C_4 assessed by three decision makers who supplied complete information, using Fundamental scale, GMM for aggregation of individual comparison matrices, and EV method are given as $\mathbf{w}$ = (0.294, 0.274, 0.287, 0.145) (line for scale Linear 1-9 in Table 3). Further, the decision makers yielded incomplete information when assessing alternatives (we defined here five alternatives) in dependence of four selected criteria. Their aggregated values were obtained by Delphi method and are gathered in Table 4.

Table 4: Decision matrix for alternatives in dependence of criteria with missing values

Alternative	C_1	C_2	C_3	C_4
a_1	5	1	4	3
a_2	*	5	3	5
a_3	5	*	*	4
a_4	3	5	*	3
a_5	1	6	3	*
Focal elements	$(a_1, a_3), (a_4), (a_5), \Theta$	$(a_1), (a_2, a_4), (a_5), \Theta$	$(a_1, a_2), (a5), \Theta$	$(a_1, a_4), (a_2), (a_3), \Theta$

Using formulas (5), (6), (7) and (8) we calculated the final rank order of the alternatives.

5 CONCLUSIONS

The problem of scales is still worthy of investigation, also in AHP, because the decision makers usually express their preferences verbally. Within a numerical case we looked at six scales and compared them to Fundamental scale regarding the rank order of criteria/alternatives and consistency of comparison matrices. In the future more cases need to be studied to bring up a general proof for scale characteristics, depending also on different aggregation methods, number of criteria and uncertainties. Further, performance measures to test different scales and other consistency measures (not only (2)) should be developed. Finally, the question of changing the verbal terms (in literature only one, given in Table 1, is used) should be investigated.

Regarding the incomplete information in decision matrices, we presented the most elementary version of DS-AHP method. Further extensions about DS-AHP should include incomplete decision matrices with fuzzy and interval values, and aggregation methods when several stakeholders are included in the decision process.

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Session 3:

Finance and Investments

AN EVIDENCE ON RISK AND RETURN OF CRYPTOCURRENCIES

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Abstract: The main issue of the paper is to examine risk of cryptocurrencies in the period of more intensive trading, from the beginning of 2017 up to mid-spring 2021, thus encompassing the Covid-19 crisis period. The three risk measures are employed: standard deviation, Value at Risk and Conditional Value at Risk. There are periods, like the crisis period, when parallel to the high and growing levels of the measured risk, the appropriate return-risk ratio is increasing even with the higher rates, showing that the risk-taking investment in cryptocurrencies was cost-effective.

Keywords: cryptocurrencies, risk, return, crisis.

1 INTRODUCTION

From the very beginning, cryptocurrencies are considered as a "risky business" and for some years, there was no big interest for them from wider population. At the same time, scientific approach was rather scarce. If we look at the data of the most famous cryptocurrency – Bitcoin, low levels of the variables like prices, market capitalization and volumes in comparison to the newer ones, and their negligible movements, were present until 2017 (https://coinmarketcap.com/currencies/bitcoin on April 30, 2021). With the time, because of different reasons like historically low interest rates and very low rates of returns of traditional investments, or searches for a safe heaven, they are becoming more and more popular. In the meantime, the growth of scientific approach in explaining different features of this phenomenon is obvious. Up to now, research show that from possible roles of cryptocurrencies that of investment instrument is predominant, [1], [3], [5], and demonstrate the benefits of cryptocurrencies inclusion in portfolios, [8], [9], [10], [11].

Research regarding influences on the cryptocurrencies prices show that attractiveness or popularity is the variable with the highest influence, [4]. This finding we can employ for the early spring 2021 sharp rise of primarily Bitcoin price, but also of other cryptocurrencies. Baur and Dimpfl, [2], found that in the case of cryptocurrencies, volatility increases by more in response to positive shocks than in response to negative shocks implying an asymmetric effect that is different to that generally observed in stock markets. In the explanation of that appearance, they use the FOMO – Fear of Missing Out concept: uninformed investors' herding and buying due to the fear of missing out rising cryptocurrency valuations, and pump and dump schemes. Researching the impact of peoples' holding intention of bitcoin by their perceived risk and value, Huang [6] finds that the majority of individuals do not have any understanding neither of the values, neither of the risks of Bitcoin.

However, in the world of investments focus should never be only on the rate of return. Side by side to this variable, the volatility of prices or the risk is of a high importance. The goal of this paper is to investigate the accompanying volatility of prices of cryptocurrencies and to put it in relation to the observed returns. Together with the standard deviation and Sharpe ratio, we employ Value at Risk (*VaR*) and Conditional Value at Risk (*CVaR*), which represent the common measures for the purpose, [12], [15]. Since the observed data also include those from the Covid-19 crisis period, we get insight to the rate of return, risk and their ratio during the first strong and deep crisis in the "life of cryptocurrencies".

After the short presentation of the data and methodology, we proceed with the discussion of the obtained results and round out with concluding remarks, including announcement of the further research.

2 DATA AND METHODOLOGY

The started sample consisted of top 25 cryptocurrencies ranked by market capitalization according to https://www.coingecko.com/en/ on April 30, 2021. Proposed period for historical data needed in further calculations is from January 1, 2017 to April 30, 2021. Since, some of the cryptocurrencies in started sample are not traded in the observed period or the key values of their available historical data are close to zero during the long period, final dataset contains nine cryptocurrencies: Bitcoin (BTC), Ethereum (ETH), Ripple (XRP), Tether (USDT), Dogecoin (DOGE), Litecoin (LTC), Stellar (XLM), Monero (XMR) and Neo (NEO). Daily close prices as one of the fundamental features, were collected for each coin, giving the 1580 observe data per coin. Also, observe data consists of daily close prices of Cryptocurrency Index (CRIX). Table 1 gives the overview of descriptive statistics for 9 cryptocurrencies and CRIX along with Jarque – Berra (JB) test for normality. JB tests whether the sample data have the skewness and kurtosis matching a normal distribution.

Table 1 Descriptive statistics for selected cryptocurrencies for Jan 1, 2017 to Apr 30, 2021.

	CRIX	***BTC***	***ETH***	***XRP***	***USDT***	***DOGE***	***LTC***	***XLM***	***XMR***	***NEO***
Min	-281.08%	-43.37%	-56.31%	-54.95%	-28.10%	-50.71%	-47.15%	-43.94%	-51.21%	-50.38%
q1	-1.43%	-1.47%	-2.02%	-2.25%	-0.05%	-2.45%	-2.64%	-2.99%	-2.50%	-3.10%
Me	0.38%	0.28%	0.17%	-0.04%	0.00%	-0.08%	0.00%	-0.09%	0.14%	0.09%
q3	2.33%	2.10%	2.97%	2.24%	0.05%	2.35%	2.75%	2.98%	3.00%	3.18%
Max	274.77%	28.71%	31.21%	88.13%	12.75%	147.91%	51.36%	71.21%	45.81%	80.45%
M	0.34%	0.25%	0.37%	0.34%	0.00%	0.46%	0.25%	0.33%	0.21%	0.41%
Σ	10.85%	4.26%	5.64%	7.56%	1.22%	8.41%	6.07%	7.93%	5.93%	8.05%
α_3	-0.8595	-0.67412	-0.56087	1.781443	-6.40128	4.53748	0.548817	1.851984	-0.03957	1.728214
α_4	546.4067	13.50714	12.29798	25.25885	207.7095	72.81283	13.13743	19.23461	11.35758	23.06061
JB	19427869***	7382,99***	5770,64***	33432,07***	2767848,34***	326075,78***	6840,5***	18242,84***	4595,90***	27262,42***

Source: The author's calculations in MATLAB (*, ** and *** indicate significance at the 0.1, 0.05 and 0.01 levels, respectively)

From Table 1, at 1%, 5% and 10% significance levels, it can be concluded that for all cryptocurrencies the returns are not normally distributed. Half of cryptocurrencies have positively skewed distribution. Another half have somewhat negatively skewed distribution, although the coefficient of skewness is roughly around zero for four of them. Moreover, all cryptocurrencies show positive excess kurtosis indicating leptokurtic distribution, meaning that the tails on this distribution are heavier than that of a normal distribution, indicating a higher degree of risk and higher probability of extreme values.

For measuring the cryptocurrencies risk, we consider traditional risk measures from the literature that are the most popular and widely used. First risk measure, standard deviation is a representative of the Markowitz's classical approach. Considering that cryptocurrencies have non-normal distribution, our second and third choices are Value at Risk (*VaR*) and Conditional Value at Risk (*CVaR*). According to the fundamental Value at Risk definition, it is the maximum expected potential loss on the portfolio over the given time horizon for a given confidence interval under normal market conditions, [7]. The Conditional Value at Risk, introduced by Rockafellar and Uryasev, [14], quantifies the expected losses that occur beyond the *VaR* breakpoint. There are three key elements characteristic for both of these measures: time (period), confidence interval, and specified amount of loss in value or percentage. Mathematical formulations of these three risk measures are given as follows:
Standard deviation:

$$StD(X) = \|X - E(X)\|_2 , \tag{1}$$

Value at Risk:

$$VaR_a(X) = \min\{-z : F_X(z) \geq \alpha\} = -F_X{}^{-1}(\alpha) , \tag{2}$$

Conditional Value at Risk

$$CVaR^-{}_\alpha(X) = E(-X : X \leq F_X^{-1}(\alpha)) , \tag{3}$$

where $E(X)$ stands for the average return of the asset, α represents the confidence level and F_X(z) stands for the cumulative distribution function of the daily returns.

For cryptocurrencies analysis, we also use the Sharpe ratio that measures excess portfolio return over the risk-free rate R_f, relative to its standard deviation:

$$Sharpe\ ratio = \frac{E(R) - R_f}{StD(R)} . \tag{4}$$

3 RESULTS AND DISCUSSION

The calculations are based on the historical data of cryptocurrencies' close price. More precisely, for the period of January 2017 to April 2021, using the rolling window of 180 daily returns with the shift of 30 days, standard deviations, *VaR*, *CVaR* as well as Sharpe ratio are calculated. *VaR* and *CVaR* are calculated for 90% and 95% significant levels. Total number of calculations in observed period is 46 per measure. The results are presented in Figures 1-6.

From the Figures 1-5, it can be seen that for almost all cryptocurrencies (except Tether), standard deviation, *VaR* and *CVaR* achieve very high values in the period July 2017 – July 2018. From August 2018 until December 2020, the values of those measures are considerably lower. During that period, some measures detect risk better than other ones: standard deviation, but also *VaR*, have less oscillation than *CVaR*. In January 2021, the values of these three measures are again increasing, as the reaction on the Covid-19 crisis for which the obvious changes of the relevant indicators have started in April 2020.

Values of the Sharpe ratio, similar to the risk measures, are high in the period July 2017 – May 2018, showing the favourable return-risk relation, despite high levels of risk. In the bigger part of the time interval from June 2018 to April 2020, the values of the ratio are negative, while from the beginning of the crisis, April 2020, its values are increasing. With the few falls, the values of the Sharpe ratio are higher and higher through the whole crisis period, showing that the risk-taking investment in cryptocurrencies during the crisis was cost-effective.

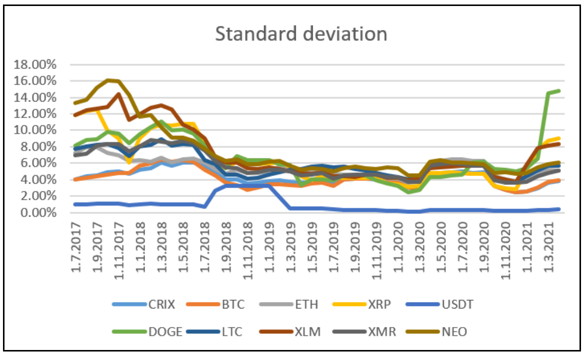

Figure 1 Results for standard deviation

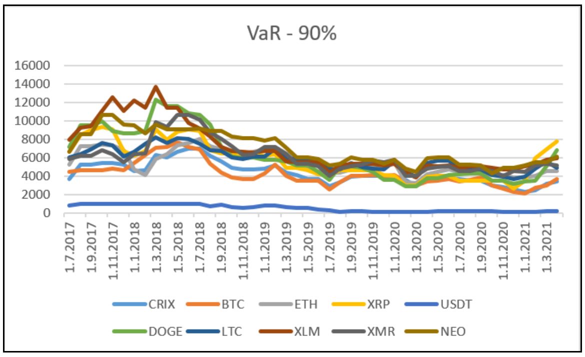

Figure 2 Results for Value at Risk with 90% significant level

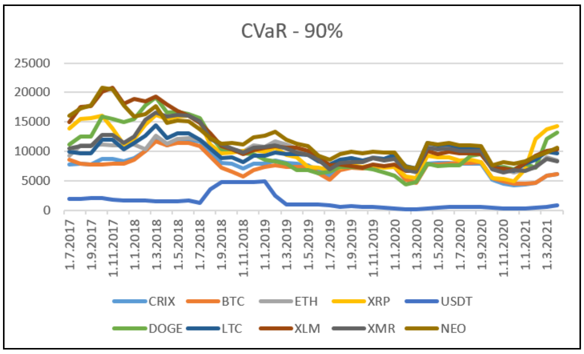

Figure 3 Results for Conditional Value at Risk with 90% significant level

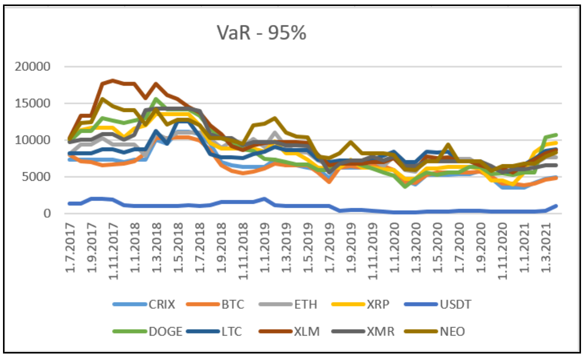

Figure 4 Results for Value at Risk with 95% significant level

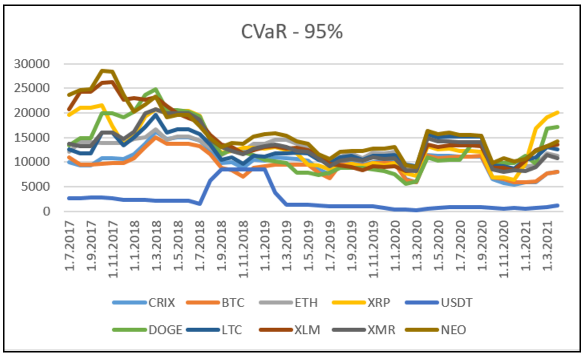

Figure 5 Results for Conditional Value at Risk with 95% significant level

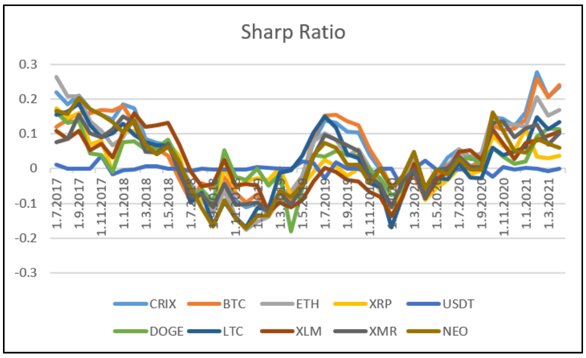

Figure 6 Results for Sharpe ratio

As we mentioned before, one cryptocurrency – Tether, follows different patterns than the others. Tether is of a specific character and sometimes even considered as s controversial digital token, [13], but very popular and stable cryptocurrency, keeping its value on the 1$ level.

From the Figures 1-6, it can be seen that the most famous cryptocurrency – Bitcoin, performs almost the same as the Cryptocurrency Index – CRIX, regarding all measures and variables, showing that the prevailing professionals' opinion and use of Bitcoin as a benchmark in the world of cryptocurrencies is correct, [16]. In addition, due to this feature of Bitcoin, research made on Bitcoin's issues can be generalized to the big extent.

Table 2 shows ranks of the nine cryptocurrencies and the CRIX, regarding the average of 46 values for each of five risk measures and Sharpe ratio performance.

Table 2 Ranking cryptocurrencies considering different measures

	VaR 95%	***CVaR 95%***	Σ	***VaR 90%***	***CVaR 90%***	***E(R)/σ***	***Sum of ranks***
BTC	9	9	9	9	9	9	54
USDT	10	10	10	10	10	1	51
CRIX	8	8	8	8	8	10	50
ETH	6	6	7	7	7	8	41
LTC	7	7	5	5	6	5	35
XMR	3	4	6	4	3	7	27
XRP	5	3	4	6	4	2	24
DOGE	4	5	3	3	5	4	24
NEO	2	1	1	2	1	6	13
XLM	1	2	2	1	2	3	11

Source: The author's calculations in MATLAB (rank 10 indicate the best value and rank 1 the worst value for each of measures)

Looking at the last column of the Table 2 – Sum of ranks, we can see that Bitcoin and Tether are two leading cryptocurrencies, taking into consideration risk, measured by the five risk measures, but also return-risk ratio measured by the Sharpe ratio. Due to its specific character, Tether is known for a low volatility of prices and it was to be expected that Tether would have the lowest levels of the measured risk. When we take into consideration risk together with the return of the cryptocurrency compared to its risk, Bitcoin remains not dethroned.

4 CONCLUDING REMARKS

The research has confirmed the risky character of cryptocurrencies. During the Covid-19 crisis, parallel to the high and growing levels of risk, a higher earning potential is recorded. To have a full picture of the levels of risk and earning potentials, wider analysis is to be made. The future research will be expanded to other investments, traditional as well other alternative investments.

Acknowledgement
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THE ASSESSMENT OF TWIN DIVERGENCE IN CROATIA: THE IMPACT OF TRADE DEFICIT ON THE BUDGET DEFICIT

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Abstract: This paper empirically assesses the twin divergence hypothesis in Croatia by estimating the impact of trade deficit on the budget deficit in Croatia from the first quarter of 2004 to the fourth quarter of 2019 using Johansen's cointegration approach. The trace and maximum eigenvalue tests point to the existence of one cointegrating relation between two deficits. The increase in the trade deficit results in a reduction in the budget deficit, pointing to the important role of indirect tax revenues in the Croatian tax system. In line with the results of empirical research, restructuring of the Croatian tax system is recommended. Taking into consideration the twin divergence as well as the importance of the export competitiveness for the economic growth, lower dependency of revenues on consumption and imports is suggested.

Keywords: twin deficit, indirect taxes, Johansen's cointegration approach, fiscal policy, twin divergence, trade balance.

1 INTRODUCTION

The twin deficit hypothesis assumes a positive relationship between the budget and trade deficit through the exchange rate mechanism, whereby an increase in the budget deficit causes an increase in the trade deficit [3]. If the problem of twin deficit is not addressed, negative consequences may be inevitable for the economy from the aspect of public finance management and economic competitiveness. Since the hypothesis of a twin deficit according to the Keynesian proposition has not been empirically confirmed in the case of Croatia [13, 14], this paper will examine the proposition of one-way causality from trade to budget deficit. Given that the Croatian tax system is dominated by indirect taxes [7,8], the research will examine whether an increase in the trade deficit causes a drop in the budget deficit. Previous relevant research of [1], [17] and [18] emphasizes that an increase in the trade deficit will result in a reduction in the budget deficit, as increased imports will increase indirect taxes revenues.

The theoretical framework and empirical research of the twin deficit will be discussed in more detail in the next chapter, followed by a description of the variables in the model and the analysis of the tax system in Croatia. In the context of empirical analysis, Johansen's cointegration will be applied, which examines the existence of twin divergence in Croatia, i.e. the hypothesis that an increase in the trade deficit results in a reduction of the budget deficit. Also, residual diagnostics will be conducted to examine the model adequacy. In the concluding part, the results of the empirical research will be discussed, as well as recommendations to economic policy makers in Croatia.

2 LITERATURE REVIEW

In the empirical research, four propositions of twin deficit are emphasized: Keynesian, Ricardian equivalence, one-way, and two-way causality. The Keynesian proposition is derived from the Mundell - Fleming model, pointing out the assumption that the budget deficit causes a trade deficit through various transmission mechanisms [4]. In other words, an increase in the budget deficit will result in an increase in domestic interest rates, given the increased borrowing needs, which in a country with a flexible exchange rate regime and capital mobility will result in an increase in capital inflows [2]. Consequently, capital inflows cause the exchange rate to appreciate, which is reflected in a relative increase in imports and cause a current account deficit. Furthermore, the Ricardian equivalence counters the Keynesian proposition by pointing out that an increase in the budget deficit will not affect the exchange rate appreciation and consequently the current account deficit. Namely, rational agents will predict that due to the increase in expenditures, there will be a higher tax burden in the future, which results in a lack of consumption and an increase in imports [4]. In general, the impact of the budget deficit on the current account deficit does not exist given that the low level of public savings, i.e. the budget deficit, according to rational agents, will be financed from increasing tax burden in the future [16]. In the case of one-way causality, the impact of the current account deficit on the budget deficit is observed, whereby slow economic growth will result in unfavourable fiscal developments, given that tax revenues are cyclically sensitive to certain macroeconomic bases [2]. Finally, according to [2] two-way causality intuitively implies that the current account deficit causes a budget deficit and vice versa.

In case of Croatia, [1], [13], [14] and [17] empirically researched the twin deficit hypothesis. According to [13], the results of the VAR model and Johansen's cointegration test indicate the existence of a twin deficit, but in inverse form. In more detail, the budget deficit has a negative effect on the trade deficit in the period from 1995 to 2010. The absence of a positive effect of the budget deficit on trade deficit could be reflected in the Croatian exchange rate regime, given the nominal anchor of the monetary policy by which the CNB stabilises inflationary expectations and, ultimately, inflation itself [15]. According to [14], the Keynesian proposition has not been confirmed in Croatia, given that there is no causality from the budget to the trade deficit, but there is a slight causality from the trade to the budget deficit, indicating the Ricardian equivalence. The research of [1] indicates that the negative impact of the trade deficit on the budget deficit is noticeable, reflecting the important role of the tax system dominated by indirect tax revenues [18]. Also, the research of [17] emphasizes that the twin deficit hypothesis is not valid in countries whose tax system is dominated by indirect taxes given that budget deficits will decrease due to increased imports and consumption.

3 DATA AND RESEARCH METHODOLOGY

In order to construct the variables of the budget and trade deficit, it is necessary to express the budget deficit as the difference between expenditures [9] and revenues [8] of the consolidated general government budget (ESA 2010), and the trade deficit as the difference between imports [10] and exports [11] of goods and services. In other words, positive values represent a deficit, and negative values a surplus, which is in line with Krtalić & Grdović - Gnip (2011). Quarterly data were obtained from the Eurostat database. Also, the budget and trade deficits are expressed as shares in GDP [12].

Since the crisis caused by the coronavirus pandemic in 2020 could affect the results of the research, we use a sample from first quarter 2004 to fourth quarter 2019. Namely, the corona crisis, unlike the previous ones, affected demand and supply in different ways, with countries activating numerous fiscal packages that affected the growth of the expenditure side of the budget, more specifically subsidies in terms of support for employers to preserve jobs.

According to [1], [17] and [18] the structure of tax system mostly explains the twin divergence of the trade and budget deficit in Croatia. The tax system, which is dominated by indirect taxes, records favourable fiscal movements due to an increase in imports and consumption. Furthermore, a significant share of indirect taxes in the total revenues of the consolidated general government is noticeable [7,8]. According to the methodology ESA 2010, taxes on production and imports comprise taxes on products and other taxes on production. Furthermore, value added tax (VAT) is included in taxes on products.

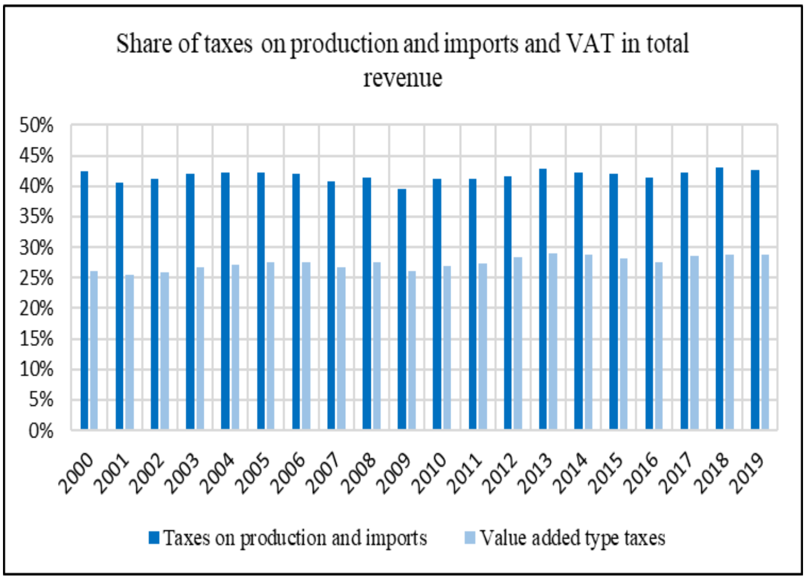

Figure 1: Share of taxes on production and imports and value added type taxes in Croatia [6,7]

According to the Figure 1, indirect taxes revenues [6] represent around 40% of the total general government revenues [8] in the period from 2000 to 2019. In other words, a consumption-oriented tax system is observable in Croatia. Also, it is noticeable that the share of value added tax revenues [7] in the total general government revenues [8] in the period from 2000 to 2019 is around 25%, which is a consequence of high VAT tax rates (25%, 13% and 5%) (Fig. 1). In 2019, in Croatia the share of indirect tax revenues [6] in the total general government revenues [8] amounted to 43%, while the share of value added tax revenues [7] in the total general government revenues [8] amounted to 29%. Consequently, one can say that indirect tax revenue plays a significant role in the tax system. Therefore, in the next chapter, an empirical analysis of the relationship between the trade and budget deficits will be conducted, analysing the movement of the budget deficit as a function of the trade deficit.

4 EMPIRICAL ANALYSIS OF TWIN DIVERGENCE IN CROATIA

Augmented Dickey-Fuller (ADF) unit root test is used to test the stationarity of trade and budget deficit. Both variables are nonstationary in levels, but stationary in first differences, i.e. both variables are integrated of order 1, I(1) at any reasonable significance. Hence, the Johansen procedure is applied in order to test for the existence of cointegration among trade and budget deficit. Authors use lag length equal to in order to avoid the existence of residual autocorrelation and heteroskedasticity because a lower number of lags leads to both mentioned problems. Furthermore, it is required to select a proper model regarding the existence of deterministic components. The lowest values of Akaike and Schwarz information criteria are recorded for Model 4, where the level data and cointegrating equations exhibit linear trends.

After selecting deterministic components of the model, the number of cointegrating relations is assessed using the trace test and maximum eigenvalue test. Both tests are commonly carried out until the first time the null hypothesis cannot be rejected [5]. The results of both tests are presented in Table 1.

Table 1: Results of trace and maximum eigenvalue test

Hypothesized number of cointegrating relations	***Eigenvalue***	***Trace statistic***	***Trace test 0.05 critical value (p-value)***	***Max-Eigen Statistic***	***Max-Eigen test 0.05 Critical value (p-value)***
None *	0.770655	97.22017	25.87211 (0.0000)	94.24173	19.38704 (0.0000)
At most 1	0.045472	2.978439	12.51798 (0.8791)	2.978439	12.51798 (0.8791)

* denotes rejection of the hypothesis at the 0.05 level
Source: Authors' calculation using EViews 9

The estimated cointegrating equation is given by the equation (1), with *t-statistics* in parentheses:

$$BD = -21.40403 + \underset{(7.29580)}{0.235369}\,trend - \underset{(7.67824)}{1.372065}\,TD \qquad (1)$$

The estimated equation points to the log-run significant negative impact of trade deficit (*TD*) on budgetary deficit (*BD*). In other words, an increase in the trade deficit results in a reduction in the budget deficit, which points to a twin divergence. The empirical results of [1] and [17] potentially reflect the role of the tax system given the considerable share of indirect tax revenues in total general government revenue. The residual diagnostic tests of estimated model are conducted. The White test for residual heteroskedasticity test statistic equals 52.19428 with empirical level of significance of 0.5443, thus at any reasonable level of significance the null hypothesis of homoscedasticity of variance is not rejected. The residual serial correlation LM test indicates that at 5% significance level, the null hypothesis of no serial correlation up to lag 3 cannot be rejected, since the empirical levels of significance are higher than 0.05.

The variance decomposition illustrates the percentage of the variance of the prognostic error due to variations in the variable itself against variations in other variables. In empirical research, it is common for the variable itself to explain a large share of the variance of its prognostic error over a short period of time. With increasing time horizon, the share of prognostic error variance explained by the variable itself decreases [5].

Table 2 shows the decomposition of the prognostic error variance of the budgetary deficit *BD*. After the first quarter, the variable itself explains 100% of the variation of its prognostic error. However, after one year (4 quarters) mentioned percentage decreases to 96.64%, while after 12 quarters (3 years) it equals 75.51%. The shock of trade deficit *TD* after one year explains 3.36% of the variation of the prognostic error in budget deficit *BD*, and after three years the mentioned percentage is increased to 24.49%. As already mentioned, a significant percentage in explaining the budget deficit stems from Croatia's tax system, in which the increase in imports will be reflected in an increase in the revenue side of the budget, more specifically in indirect taxes revenues.

Table 2: Variance decomposition of *BD*

Period	***BD***	***TD***
1	100.0000	0.0000
2	99.9348	0.0651
3	98.8811	1.1189
4	96.6415	3.3585
5	92.9673	7.0327
6	88.5267	11.4732
7	84.6392	15.3609
8	81.24572	18.7543
9	78.8083	21.1917
10	77.3845	22.6155
11	76.2773	23.7227
12	75.5145	24.4855

Source: Authors' calculation using EViews 9

5 CONCLUSIONS

This paper is focused on the one-way causality from the trade to the budget deficit in Croatia. The reason for choosing the analysis of twin divergence over twin deficit, stems from the results of large body of empirical research in which the Keynesian proposition of twin deficit was rejected. Since the CNB stabilizes inflation using a nominal monetary policy anchor, it is unlikely that the budget deficit would cause a trade deficit through the exchange rate transmission channel. Additional motivation for the analysis is reflected in empirical research that emphasizes the importance of the tax system in Croatia, which is dominated by indirect tax revenues. In other words, the increase in the trade deficit, i.e. imports, due to the significant share of indirect tax revenues in total tax revenues, could result in a reduction of the budget deficit. The analysis of the budget and trade deficits from the first quarter of 2004 to the 4th quarter of 2019 using Johansen's cointegration approach points to a significant negative impact of the trade deficit on the budget deficit. In other words, an increase in the trade deficit results in a reduction in the budget deficit, reflecting the important role of indirect tax revenues in the Croatian tax system. Given the results of empirical research, economic policy makers in Croatia should focus on the tax system restructuring so that revenues do not depend largely on consumption and imports as well as on fostering the economic growth through the export competitiveness.

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INCOME INEQUALITY AND CURRENT ACCOUNT IMBALANCES IN NEW EU MEMBERS

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Abstract: We show that rising income inequality linked with financial liberalization is responsible for the deterioration of the current account in new EU members. The increase in income inequality is usually associated with an economic policy of financial liberalization designed to maintain the standard of living for those suffering from real income stagnation. However, such a policy is not intended to solve the causes of inequality but generates additional stimulus for aggregate consumption through cheaper borrowing. Financial liberalization leads to increased household domestic debt contributing to a deterioration of the current account. We also show that the rise of dependency ratio as a demographic factor deteriorates the current account due to reduced savings.

Keywords: current account, income inequality, financial liberalization, panel data, Hausman test, feasible generalized least squares

1 INTRODUCTION

In the last three decades, large external debts have emerged in many countries while other countries experienced asset growth. This phenomenon is known as global imbalances and refers to global external imbalances or current account imbalances. A change in net foreign assets is considered a good approximation of the current account imbalances. While some countries report an increase in net foreign assets by increasing the current account surplus, other countries report a decrease in such assets by increasing the current account deficit. Current account deficits in many countries result from lower savings than real investments, indicating global sub-investment in productive capital. The worldwide financial crisis 2007-2009 attributed to the development of substantial global external imbalances. An investigation of the causes of global imbalances shows that growing income inequalities are worsening the current account. However, the link between income inequality and the current account deficit is poorly empirically explored.

Cross-sectional econometric analysis shows that top income shares (and financial liberalization) are associated with large current account deficits. Namely, the poor and middle class (with a smaller share of total income), presumed not to have direct access to international capital markets, borrow funds from the rich. The decline in their consumption is smaller than the decrease in their income. At the same time, the consumption and investments of the rich grow significantly, so the net effect is an increase in domestic consumption and the current account deficit. Financial liberalization helps households to smooth consumption. Thus, loans to households by domestic and foreign investors maintain aggregate demand and result in current account deficits and an increase in household debt. However, in less developed markets, households cannot borrow funds from financial investors, who place surplus abroad, which leads to a current account surplus. The increase in income inequality is usually associated with an economic policy designed to maintain the standard of living for those suffering from stagnation in real income. Unfortunately, such policy is usually not aimed at solving the causes of inequality but enables cheap borrowing followed by financial liberalization. Although financial liberalization generates additional stimulus for aggregate consumption, it reduces capital accumulation and thus aggregate supply (because investors increase preferences towards financial assets rather than real assets), which puts further pressure on the deterioration of the current account.

Many emerging markets have experienced greater income inequality under current account surplus conditions. However, their current account surplus can also be explained by income inequality, but not because of the role of domestic financial markets. Namely, these financial markets do not allow the poor and middle class to respond by borrowing due to lower income.

The growth strategy of new EU member states was trade integration into the EU, where financial integration has been the central pillar. The process of accession of new countries into the EU has been accompanied by the liberalization of their capital accounts followed by extensive capital inflows and outflows. According to an IMF study [11], these countries have been mainly recipients of capital from abroad (mainly from advanced European countries). Foreign banks with established subsidiaries and branches in the new EU member states have transferred foreign capital for extensive use for domestic businesses and households. The natural product of the convergence process is sizeable current account deficits in these countries, accompanied by income inequality. Figure 1 points out a negative cross-country correlation between changes in current accounts and changes in top 10% income shares among selected new EU member countries for the analysed period (1995-2019).

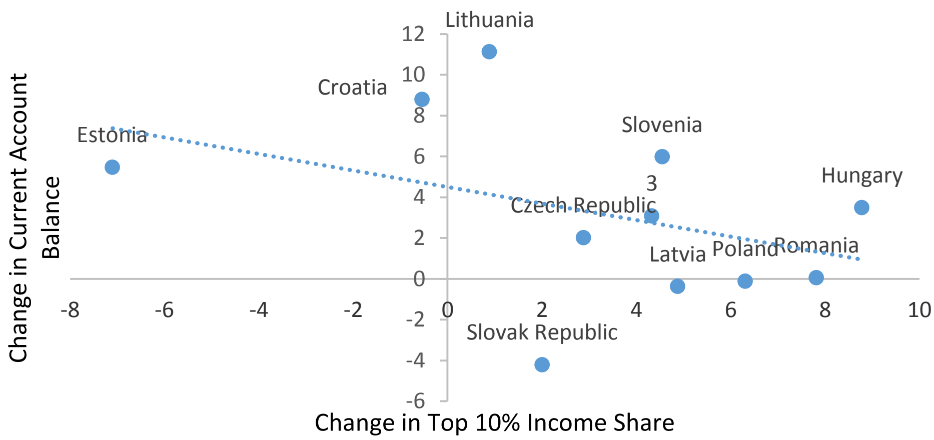

Figure 1: Changes in Current Accounts and Top 10% Income Shares (1995-2019)

When the worldwide financial crisis started in 2007, these countries faced increasing difficulty with borrowing abroad. Under those circumstances and import compression, they had to reduce borrowing, which led them to reduce their current account deficit. At the same time, new member EU states are facing a strong demographic decline, which negatively impacts the current account.

The empirical analysis performed in this paper assesses the relationship between the current account and income inequality. Moreover, the employed panel data analysis accounts for additional factors: population ageing, financial liberalization, relative income and household indebtedness and the impact of the 2007 global financial crisis. As the relationship between income inequality and the current account deficit is poorly empirically explored, this article aims at filling the empirical gap. Furthermore, the paper contributes to a better understanding of the phenomenon of global imbalances, rising inequalities and the relationship between them.

The remainder of the paper is organized as follows. Section 2 gives an overview of the existing research. The dataset, the model employed in the empirical analysis and the estimation results are presented and discussed in section 3. Finally, section 4 concludes.

2 LITERATURE REVIEW

Global external imbalances reflected in current account imbalances and low world real interest rates were the primary source of financial vulnerability in the run-up to the 2007-2009 worldwide financial crisis [2], [4], [15]. It seems that the root causes of the global current account imbalances and the financial crisis coincided.

Searching for causes of current account imbalances, researchers find increased income inequality, especially with the worsening of the current account imbalances [8]. It should be mentioned that the rise in income inequality occurs in countries with a current account surplus (such as China and some other Asian countries).

The empirical literature on income distribution usually deals with changes in income distribution in the long run [1], [12], [13]. Such studies confirm that the most significant change in income distribution is a substantial increase in the top income share.

Some studies elaborate why pronounced income inequality increases the saving rate in surplus economies and decreases the saving rate in deficit economies leading to more significant global current account imbalances [7], [10]. Economic policy measures aimed at reducing income inequality play a vital role in the growth of current account deficits. Namely, such policy measures do not directly affect the causes of inequality but financial liberalization [14]. In other words, through consumer loans, financial liberalization leads to an increase in living standards for the poor and middle-class population, which is often primarily financed through capital inflows. However, real income stagnates. It is the main reason why in deficit countries, consumer inequality remains relatively stable despite the increasing income inequality. Consumption financed by loans reduces national savings. Consequently, as the national savings are lower than domestic demand for real investments, the current account deteriorates.

Therefore, it is not surprising that growing divergence between consumption and income inequality leads to the current account deterioration and makes countries vulnerable to financial crises [9].

In countries with less developed financial markets (China and other Asian countries), there is no consumption deficit like in countries with developed financial markets due to their financial market imperfections [4].

Some researchers primarily show interest in finding the linkage between consumer inequality and current account imbalances. While the tax and transfer policy can influence income distribution, consumption inequality is affected through savings and borrowing policies and various forms of measures for smoothing consumption [3]. Therefore, it is desirable to investigate current account imbalances covering not only income but also consumer inequality. One such research, recently conducted on a sample of OECD countries, finds that consumption inequality is poorly followed by income inequality in deficit countries but well followed in surplus countries [6].

3 DATA AND ECONOMETRIC RESULTS

Panel data analysis of the relationship between current account balances and income inequality is performed for a cross-section of new EU members ($N = 11$) over the period from 1995 to 2019 ($T = 25$). The countries included in the analysis were: Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Romania, Poland, Slovenia and the Slovak Republic. We model the current account balance through the panel specification

$$y_{it} = X_{it}'\beta + \alpha_i + \varepsilon_{it},\ i = 1, \ldots N,\ t = 1, \ldots T \tag{1}$$

where y_{it} is a dependent variable, X_{it} is the matrix of regressors, α_i is the (unobserved) country effect, and ε_{it} is the error (idiosyncratic) term with $E(\varepsilon_{it}) = 0$, and $E(\varepsilon_{it}\varepsilon_{js}) = \sigma_\varepsilon^2$ if $j = i$ and $t = s$ and $E(\varepsilon_{it}\varepsilon_{js}) = 0$ otherwise.

Three regression models with various combinations of regressors were estimated. Highly correlated regressors were used separately in different models to avoid the problem of multi-collinearity. For each model, random-effects (RE) and fixed-effects (FE) regressions were estimated and proper estimators were selected according to the Hausman test. The test suggests that the FE model is superior to the RE model for all model specifications. The models were estimated using feasible generalized least squares (FGLS) with a corrected standard error approach that allows estimation in the presence of heteroscedasticity across panels [5].

In all models, the current account balance expressed as a percentage of GDP was employed as a dependent variable (CA). Explanatory variables, whose selection was based on theoretical background and data availability, were: 1) income share held by highest 10% and 1% of the income distribution representing income inequality (TOP10 and TOP1), 2) household debt as a percentage of GDP representing household indebtedness (HD), 3) net foreign assets as a percentage of GDP representing financial liberalization (NFA), 4) total dependency ratio as a percentage of the working-age population representing a demographic variable (DR), 5) relative income (GDP per capita relative to its EU-15 counterpart) RI, and 6) annual GDP growth rate representing income factor (GR)[1]. The potential impact of the 2007-2009 financial crisis was incorporated through a dummy variable. Data were collected from Eurostat, World Development Indicators, International Financial Statistics and World Bank Database.

Estimation results, presented in Table 1, show that all coefficients have the expected signs and in line with previous theoretical findings and empirical research.

Table 1: Model estimation results for the ratio of the current account balance to GDP

Variable	***Model 1***	***Model 2***	***Model 3***
TOP10 (top 10% income share)	-0.34612511*** (0.0510405)	-0.25098463*** (0.051153)	
TOP1 (top 1% income share)			-0.16564868* (0.0802395)
GDP growth rate (GR)	-0.39218466*** (0.0695523)	-0.44398919*** (0.07202639	
RI (GDP per capita/ GDP per capita in EU-15)	0.09308969*** (0.0157783)	0.0954778*** (0.0162407)	
HD (household debt (% of GDP)			0.1302847*** (0.017963)
DR (total dependency ratio)	0.32399025*** (0.0595716)		
NFA (net foreign assets in % of GDP)			0.0759487*** (0.0173093)

[1] EU-15 is the number of member countries in the European Union before the accession of ten candidate countries in 2004.

Crisis dummy	-0.93414069 (0.6546227)	-2.2453259*** (0.6129975)	-1.3846362** (0.5228118)
Constant	-8.4508925** (2.805321)	4.0950051* (1.5914)	-5.261178*** (0.988734)
Hausman test	0.0001	0.0000	0.0187
Wald chi2 (p-value)	135.81 (0.0000)	95.39 (0.0000)	83.87 (0.0000)
No. of observations	272	272	216

Note: Standard errors are in parentheses, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The results (Table 1) indicate a statistically significant and negative coefficient for different income inequality measures in all models. Rising income inequality results in a deterioration of the current account. Foreign financing presented by net foreign assets as an indicator of financial liberalization policy shows a statistically significant impact on the current account. In addition, the growth of this variable is manifested in higher household indebtedness, which contributes to a deterioration of the current account. The current account is negatively correlated with economic fundamentals. A significant and negative coefficient on GDP growth and the GDP per capita relative to GDP per capita in EU-15 is confirmed in all regression models.

The demographic factor, given by the dependency ratio, shows that the correlation with the current account is negative due to the larger share of the population (young and old), characterized by reduced savings.

4 CONCLUSION

The new EU member states experienced a rise in income equality and deterioration of current accounts balances. Due to the catching-up process, these countries endured financial liberalization and capital inflows, mostly from core EU countries. Through the borrowing process financial liberalization boosts the living standards of the poor and middle-class with stagnating real incomes. In such circumstances, foreign financing has a statistically significant impact on current accounts of the new EU member states, as our results of panel data analysis of determinants of current account balance and the income inequality show. We also find that unfavourable demographic characteristics in the new EU members act as amplifying factor in the deterioration of current accounts balances.

As a guideline for future research, in addition to static panel models that are usually employed in the analysis of the relationship between current account balances and income inequality, a dynamic panel model framework could also be considered. The main limitation of this research refers to data (un)availability. Namely, there are no available data on consumption inequality for the analysed countries. Furthermore, some variables could, arguably, act as a better proxy instead of variables employed in this paper. For instance, consumer credit could be a better proxy for domestic indebtedness or net capital inflow as an indicator of foreign financing but data are not available for the analysed countries.

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ANALYSTS’ RECOMMENDATIONS AS THE PREDICTIONS OF FUTURE STOCK RETURNS AT PRAGUE STOCK EXCHANGE

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Abstract: According to the efficient market hypothesis it is believed that all relevant information is already reflected in the stock market prices, which means that the future stock returns depend solely on the riskiness associated with the particular stock(s). On the other hand, it is a common practice that the analysts, usually brokerage firms or banks, publish their recommendations regarding the particular stocks and their future price development. In this paper, we study the recommendations issued on the bluechip stocks traded at the Prague stock exchange and their predictive power for the one-year period following the issuance of the recommendation. Based on the linear regression model we found that for more than two-thirds of analysts there is a statistically significant linear relationship between the one-year potential return and observed one-year return. However, we found the same relationship only for three stocks from eight analyzed stocks.

Keywords: analysts’ recommendation, prediction, stock returns.

1 INTRODUCTION

According to the semi-strong form of the efficient market hypothesis, see [2], all publicly known information is reflected in the price. In the case of the stock market, the future expected return should solely depend on the riskiness of the particular stock(s). A well-known Capital Asset Pricing Model (henceforth CAPM) is describing the expected return to be dependent on the riskiness measured by the beta coefficient. The beta coefficient in the CAPM model represents the systematic risk. There are also other models, such as Fama-French three (four, five) factor models, which consider also other risk drivers such as the market-to-book ratio, company size, momentum. See [3] for the five-factor model.

On the other hand, it is a common practice that the analysts, usually brokerage firms or banks, publish their recommendations concerning the particular stock and its future price development. Typically, the analysts issue the analysis in which they publish the estimated price of the stock in one-year period, the reasoning for their estimate, and suggested action for investors. The suggested action is usually of buy, sell, or do-nothing type and it is based on the difference between the estimated fair value and the actual market price. Although there is a discussion between the practitioners whether these recommendations are of any use, the general idea is that by applying valuation models and precise estimates of future cash flows the analysts can compute the fair value of the stock while the market price fluctuates around that value. There can be also some changes at the market or in the company, which is yet not reflected by the market but analysts can take note of it.

There exist some studies focused on the analysts’ recommendations in the literature. These studies are dedicated mostly to the price movements after the upgrade or downgrade of the recommendation (the change in the suggested action) [1, 7]. For instance, Womack [10] studies the price drift after the issuance of a recommendation and finds that analysts appear to have market timing and stock picking abilities. Kudryavtsev [5] extends the analysis and explores the stock price dynamic after analysts' recommendation revisions in the dependence on the abnormal return on the day of the recommendation issuance. Most of the empirical studies are, however, focused on the US stock markets.

Kresta [4] and Minasjan [8] focused on the Prague stock market, however, they considered only the analysts' recommendations as the explanatory variable. In the paper, we extend their analysis and model the dependence of the observed one-year stock return on the potential one-year return as forecasted by analysts and the observed one-year market return. Adding the observed market return as the second explanatory variable should allow us to take the riskiness of the stocks into account.

The paper is structured as follows. In the next two sections, we briefly describe the methodology and dataset, which we apply in the paper. In the fourth section, we present the obtained results, which are discussed. In the conclusion section, we briefly summarize the findings.

2 METHODOLOGY

In this paper, we analyze the one-year stock returns r, which can be calculated as follows,

$$r = \frac{p_{365} - p_0}{p_0}, \tag{1}$$

where p_0 is the price at the day of recommendation issuance and p_{365} is the price one calendar year later. We focus solely on capital returns and we do not consider dividends, because the potential returns stated by analysts do not consider them as well.

In our study, we examine whether there is any predictive edge in the analysts' recommendations. We specifically focus on the estimated fair value. Let us assume the following dependence: the future one-year return depends on the relative difference between the market price at the day of recommendation issuance and the fair value estimated by the analyst and truly observed market return in the same period. We can model the relationship by the linear regression model,

$$r = \alpha + \beta \cdot \left(\frac{p_{fv} - p_0}{p_0} \right) + \gamma \cdot r_M + \varepsilon, \tag{2}$$

where r is the observed return in a one-year period (i.e. in 365 calendar days from the publication of the recommendation), α, β and γ are estimated coefficients, r_M is the observed one-year return of the market portfolio, p_{fv} is the fair value estimated by the analyst, p_0 is the price on the day of recommendation issuance and ε represents the error term. We further call the part $\frac{p_{fv} - p_0}{p_0}$ a potential return, because it represents the potential profit estimated by the analysts (i.e. how much the stock is undervalued).

The parameter γ is related to beta in CAPM model and parameter α accounts for risk-free return and other factors as specified in the Fama-French five-factor model [3]. In our analysis, we are interested in the parameter β. If $\beta = 1$, the analysts can perfectly predict the future price evolution (i.e. they can identify the undervalued and overvalued stocks) or the market perfectly follows their recommendations. However, we do not expect this situation to be found.

The more probable situation is that $0 < \beta < 1$. In this situation, we can conclude that the analysts have some predictive power, i.e. the estimated fair value provides some useful information to the investors. However, there can be also the case in which $\beta < 0$. According to this result, we can conclude that the analysts are usually wrong about the future price (i.e.

fair value) or that the price does not approach their fair value in a one-year period, however, surprisingly, even in this situation the analysts provide some useful information to the investors. They only should do the opposite action than suggested by the analysts.

Finally, $\beta = 0$ means that there is no predictive power, i.e. the analysts' recommendations are useless to the investors. To test this, we can formulate the following null hypothesis:

$$H_0 : \beta = 0, \tag{3}$$

with an alternative hypothesis,

$$H_A : \beta \neq 0. \tag{4}$$

In order to decide whether we can reject the null hypothesis, we can apply the so-called t-test, i.e. the calculated t-statistics,

$$t_{calc} = \frac{\beta}{\sigma_\beta}, \tag{5}$$

where σ_β is the standard error of β, is compared to the calculated critical value. Due to the specification of H_A we apply a two-sided test. We base our decision about the acceptance or rejection of the null hypothesis on the p-value, which under the null hypothesis, simply speaking, represents the likelihood of observing the t-statistics at least as extreme as the calculated critical value. If the p-value is less than or equal to the specified significance level, usually 0.05, 0.01, or 0.001, the null hypothesis is rejected; otherwise, the null hypothesis is not rejected.

3 DATASET

For our analyses, we created the dataset of market prices and the dataset of analysts' recommendations. The first dataset consists of market prices from Prague Stock Exchange [9]. The index Eurostoxx 50 is assumed as the market portfolio and the data are obtained from Yahoo [11]. We do not consider the Czech market index PX, because the weight of the analyzed stocks in the index is relatively high (even 20% for one stock), which can influence the results.

The analysis is performed on the dataset of analysts' recommendations with the stated fair value issued from 2006 to 2018 obtained from [6] for stocks Central European Media Enterprises Ltd. (CETV), ČEZ, a.s. (ČEZ), Erste Group Bank AG (ERSTE), Komerční banka, a.s. (KB), O2 Czech Republic a.s. (O2), Paegas Nonwovens, a.s. (PEGAS), Philip Morris ČR a.s. (PM), Vienna Insurance Group (VIG). Input data were modified in the following ways:

- only recommendations with fair value are considered;
- names of analysts and their recommendations were merged in case that their name changed in the analyzed period;
- duplicate recommendations were omitted;
- analysts with less than thirty recommendations were omitted;
- all the fair values were recalculated to CZK according to the exchange rate on the day of issuance.

In total, the dataset consists of 2 951 recommendations from 30 analysts. The number of observations for analyzed stocks and analysts can be seen in Table 1 and Table 2.

4 RESULTS

The results of the linear regression model (2) are summarized in Table 1 and Table 2. In Table 1, the estimated parameters are presented for each analyzed stock. As can be seen from the table, for only two stocks (ERSTE and PEGAS) the alternative hypothesis can be accepted within 0.001 significance level and for one stock (O2) at 0.05 significance level. As can be seen, the value of the beta coefficient for these stocks is around 0.5, which means that in one year after the recommendation issuance the stocks move on average by around 50% of the move predicted by the analysts (potential return). This suggests that analysts can indeed predict the one-year fair value for these stocks.

Table 1: Parameters of the linear regression model for stocks (* p-value <0.05; ** p-value<0.01; *** p-value<0.001)

Stock	*alpha*	*beta*	*gamma*	*#observations*
CETV	-5.12%*	-0.049	0.081	234
ČEZ	1.36%	-0.055	0.243**	*328*
ERSTE	4.34%***	0.389***	0.676***	1 401
KB	5.68%***	0.016	0.649***	*289*
O2	4.54%	0.545*	-0.438*	143
PEGAS	7.75%***	0.601***	0.339***	52
PM	7.65%**	0.114	0.204	48
VIG	-7.59%***	0.086	1.159***	456

Table 2: Parameters of the linear regression model for analysts (* p-value <0.05; ** p-value<0.01; *** p-value<0.001)

Analyst	*alpha*	*beta*	*gamma*	*#observations*
AlphaValue	9.30%***	0.907***	0.367***	263
BNP Paribas	-1.25%	0.751***	0.434***	188
KBW	-0.90%	0.495***	0.615***	187
J&T Banka	-2.41%	-0.139*	0.614***	170
J.P. Morgan	-0.28%	0.038	0.590***	162
Komerční banka	-1.91%	-0.065	0.178	158
HSBC Securities	-3.63%	0.530***	0.263*	143
Patria	2.41%	0.582*	-0.128	131
Goldman Sachs	-8.97%**	0.448***	0.183	127
Erste Group	-3.68%	0.393*	0.181	110
Kepler Cheuvreux	-1.59%	0.046	1.212***	109
KBC	0.40%	0.528***	1.266***	107
Raiffeisen Centrobank AG	-12.03%**	0.808*	0.735***	105
Wood & Company	-6.66%*	0.598***	0.388	94
Societe Generale	-5.11%	0.498**	0.552*	80
Barclays	-9.49%**	0.774**	0.640***	74
Nomura Holdings	-3.48%	0.615**	-0.086	70
Deutsche Bank	-9.19%	0.421*	0.480	69
Natixis Bleichroeder	-10.78%	0.934**	-0.034	69
Credit Suisse	-4.64%	0.456**	0.804***	67
Berenberg	2.38%	0.141*	0.648***	62
Dom Maklerski mBanku SA	-0.42%	0.526***	0.200	59
Commerzbank	2.35%	0.160	0.488*	58
Fio Banka	-1.48%	0.305	0.395**	56
Vtb Capital Sa	3.19%	0.788***	0.318	48
UBS	-1.64%	0.263	0.484**	44
Baader Helvea	-4.15%	-0.071	1.848***	40
Concorde Securities	7.73%	-0.481	0.333	36
Morgan Stanley	-5.00%	0.233	0.250	33
Mediobanca	-12.70%	0.914***	0.869**	32

When we look at the other parameters of the model, we can see that for many stocks the value of gamma is low. Also, for two stocks (CETV and VIG), there is a negative value of alpha. This may suggest that the Czech stock market is underperforming the Eurostoxx 50 index. Here two issues must be mentioned. First, the majority of the bluechip stocks at Prague Stock Market pay high dividends, which are not considered in the analysis, thus the total return is higher than the capital return. Second, in our analysis, the data are not evenly distributed in time but depend on the recommendation issuance days. So, for some stocks, the recommendations can be issued mostly before the stock price decline.

In Table 2 we present the estimates for linear regression model (2) for each analyst, i.e. different stocks are considered together. As can be seen from the results in the table, for more than two-thirds (21 out of 30) of the analysts we can reject the null hypothesis and accept the alternative hypothesis, which means that for these analysts there is a statistically significant dependence of future one-year return on the predicted potential return. Moreover, for some analysts the value of the beta coefficient is close to one, see e.g. AlphaValue, Natixis Bleichroeder, and Mediobanca with betas of 0.9, which means that the potential return is almost completely reflected in the future one-year return.

As there are more stocks mixed, there is no clear interpretation of the gamma coefficient, which can vary in dependence on the stocks the analysts cover and is related to the average of CAPM betas of these stocks. Moreover, the parameter is statistically significant only for 18 out of 30 analysts. The parameter alpha is statistically insignificant for most of the analysts. To summarize, we can say that there are analysts, whose recommendations can help predict the future one-year return. Taking the recommendations of only these analysts we re-estimate the parameters shown in Table 1.

In Table 3, the estimated parameters are presented for each analyzed stock with only the recommendations from the analysts with the statistically significant beta at 0.01 significance level, see Table 2. When eliminating the statistically insignificant analysts, there are no recommendations for stock PEGAS. As can be seen from the table, there is only a minor improvement in the statistical significance of the beta parameter. Now three stocks have statistically significant beta: CETV, ERSTE, and VIG. However, for VIG the value is negative, which would mean that the analysts are statistically wrong in the direction.

Table 3: Parameters of the linear regression model for stocks after the exclusion of statistically insignificant analysts (* p-value <0.05; ** p-value<0.01; *** p-value<0.001)

Stock	***alpha***	***beta***	***gamma***	***#observations***
CETV	-15.23%**	0.470**	0.602*	69
ČEZ	-4.51%*	-0.030	0.168**	187
ERSTE	1.18%	0.531***	0.620***	990
KB	1.39%	-0.015	0.647***	145
O2	-3.02%	-0.286	-0.088	53
PM	-6.17%	0.669	-0.865*	12
VIG	-14.03%***	-0.225**	1.306***	152

5 CONCLUSION

In the paper, we analyzed and modeled the dependence of the observed stocks' one-year return on the potential one-year return as stated by the analysts and the market observed one-year return. We found out that for only less than half of the analyzed stocks we can find the statistically significant dependence. On the other hand, we found out the statistically significant dependence when we analyze all recommendations of particular analysts.

The main drawback of the analysis is the non-even distribution of the data sample in time. We consider all relevant recommendations published by the analysts, which can be clustered in some periods. In further analysis, the recommendations can be grouped and the mean/median fair value each month can be considered. Also, other indexes can be assumed as a market proxy.

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DERIVATIVES MARKETS DEVELOPMENT AND COUNTRY POLITICAL RISK

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Abstract: This paper investigates the impact of country political risk on currency derivatives market turnover for 19 countries. Previous empirical literature has confirmed the role that political risk has on financial institutions and the stock market development, whereas the relationship between currency derivatives and political risk has not been empirically investigated
Therefore, taking into account the heterogeneity of the selected currency derivatives markets and a possible heterogeneity in the relationship between derivatives turnover and political risk, heterogeneous non-causality test in panels are employed. This method successfully deals with both types of heterogeneity. The results have confirmed the heterogeneous causality of political risk on currency derivatives markets. Moreover, political risk has a more significant effect on currency derivatives turnover in countries with a less developed financial system.

Keywords: derivatives, country political risk, financial system development, non-causality test in heterogeneous panel.

1 INTRODUCTION

Many empirical papers [7], [3] found evidence that the level of development of a country's financial system is important for its economic growth. Thus, researchers [9] have focused on the development of financial markets as a part of the financial system. Major conclusions of all these researches are that the development of financial markets facilitates economic growth by providing important services and that financial markets provide services different from those provided by financial institutions. However, most of the existing empirical literature concentrates on stock markets and neglects other segments of financial markets. Therefore, we investigate currencies derivative markets because they provide different services to the economy with the aim of providing a deeper understanding of the sources of development of that specific financial market segment.

The connection between derivative markets and macroeconomic factors have not been investigated sufficiently regardless of their importance for hedging various economic risks. One of the rare research on this topic was conducted by [15]. They confirmed the existence of international bidirectional causality between derivatives markets and economic growth. In addition, they found that trade openness and government spending have a more pronounced effect on derivative markets than economic growth and inflation. Moreover, they found that the connection is stronger between macroeconomic factors and currency derivatives in higher-income countries than in upper-middle-income countries. In addition, [14] investigated currency derivative market turnover of emerging market economies to find why these markets have a small activity compared to the share of their economies in the global GDP or trade. They found that GDP per capita has a negligible effect on currency derivative market while the size of the bond market, the openness of the capital account, the amount of foreign trade and the size of external liabilities have a positive effect. Previous studies have concentrated on the effect that country macroeconomic variables have on currency derivative markets.

This paper goes one step further; it tries to find an empirical evidence about the relationship between currency derivatives market turnover and the country's political risk. Namely, empirical papers [7], [12], [1], [5] found that a country's law system and corruption in the country affect the development of the financial system. In addition, [8] argue that problems related to institutional quality in a country may develop uncertainty and send out misleading signals to the financial markets. Research [4] provides empirical evidence that political instability during political elections in South Koreas increase speculative trading on derivative markets. Finally, [2] investigated 31 countries in the 1984–2016 period and found empirical evidence that countries with increased political instability and serious corruption tend to experience a real exchange rate depreciation. All the aforementioned results provide motivation to explore the influence of political risk on currency derivatives markets more deeply. Namely, the main motivation for using currencies derivatives is hedging currency risk. Higher political risk increases mistrust in the currency and, therefore, motivates economic agents to hedge risk. On the other hand, in countries with a more developed financial system there are more possibilities to hedge risk. Therefore, we suppose that the usage of derivative markets will be determined by the country's political risk and will differ depending on the level of development of the country's financial system.

Rare researches about currency derivate market turnover concentrate only on the effects of macroeconomic indicators. Regardless the fact that the quality of institutions plays a significant role in the development of financial markets, they are not included in modelling currency derivative market development. To fill this gap, this paper provides empirical evidence of the importance of the country's political risk on currency derivatives turnover.

The paper is organized as follows. In Section 2, data and methodology are described. In Section 3, the results are presented and discussed. In Section 4, the conclusions are given.

2 DATA AND METHODOLOGY

This dataset used in the research covers the monthly data from January 1994 to December 2020. For the political stability (PS) indicator, Political risk index from the International Country Risk Guide (ICRG) database is used. Political Risk Index covers the following 12 political and social features of a country: Government Stability, Socioeconomic Conditions, Investment Profile, Internal Conflict, External Conflict, Corruption, Military in Politics, Religious Tensions, Law and Order, Ethnic Tensions, Democratic Accountability, and Bureaucracy Quality. The value of the index can vary from 100 (Very Low Risk) to 0 (Very High Risk) points.

Derivative market data were collected from the Bank for International Settlements (BIS) - Derivative statistics. Our data set comprises data of turnover for all currencies derivatives (DER) from the BIS database that are traded on exchange markets all over the world. Currency derivative turnover is connected with a country that issues a currency. We included all the countries from the database except the Euro area countries because the political risk data for the whole region is not available. The data set consists of 19 countries, which are heterogeneous in their economic and financial development and social and political systems. Table 1 presents the countries according to the Financial Development Index, which summarises the development of financial institutions and financial markets in terms of their depth, access, and efficiency [13]. The country with the most developed financial system is Switzerland (0.98) and the country with the least developed financial system is South Africa (0.05). Different levels of financial development imply different possibilities of usage of currency derivatives for hedge foreign exchange risks.

Table 1: Countries from the data set according to the Financial Development Index

	Country	FD index		Country	FD index		Country	FD index
1	Switzerland	0.96	8	Sweden	0.77	14	Turkey	0.53
2	Canada	0.9	9	Singapore	0.75	15	Russia	0.49
3	UK	0.9	10	China	0.65	16	Poland	0.47
4	US	0.9	11	Norway	0.65	17	Hungary	0.41
5	Japan	0.89	12	Brazil	0.63	18	Mexico	0.4
6	Australia	0.88	13	New Zealand	0.59	19	South Africa	0.05
7	South Korea	0.81						

According to the indicated heterogeneity between currency turnover, the difference between financial systems from currencies countries and a possible heterogeneity in the relationship between a country's political risk and derivatives turnover, Granger non-causality test in heterogeneous panel proposed by [6] is applied. Under null hypothesis, they assumed there is no causal relationship for any of the units of the panel. Under alternative hypothesis, they allow two subgroups of units, i.e., one subgroup where the causal relationship does not exist and another subgroup where the causal relationship exists. An additional advantage of this method is its heterogeneous impact for each unit in both subgroups. More precisely, each unit has its own coefficient. Finally, the benefit of this method is that its standardized panel statistics has good properties in the presence of cross sectional dependence. Namely, according to empirically proved interconnections between different financial markets, we expect the existence of the cross sectional dependence between different currency derivative markets.
In line with [6], our research question can be formulated by the following equation:
our research question can be written by the following equation:

$$DER_{it} = \sum_{k=1}^{p} \gamma^{(k)} DER_{i,t-k} + \sum_{k=1}^{p} \beta_i^{(k)} PS_{i,t-k} + \alpha_i + \varepsilon_{it}, \; i = 1,\ldots, \mathrm{N}, \; t = 1,\ldots, \mathrm{T}, \tag{1}$$

with $p \in N$[1]. The method assumes that DER_{it} and PS_{it} are stationary. From Table 2, it is evident that DER_{it} and PS_{it} are stationary variables. $\gamma_i^{(k)}$ are the coefficients of the k-th lag of the dependent variable DER_{it}, $\beta_i^{(k)}$ are the coefficients of the k-th lag of the independent variable PS_{it}. α_i is the country's fixed or random effect while ε_{it} are i.i.d. $\left(0, \sigma_\varepsilon^2\right)$. According to the fact that derivatives react fast on the change in the country's political stability we choose one lag for Granger causality testing. For robustness, we used two lags, but the results did not vary significantly.

3 RESULTS

According to the fact that the Granger non-causality test requires stationary variables, our empirical part starts with the results of Pesaran unit root test [11] for panel data with cross sectional dependence. The results of unit root test are presented in Table 2.

[1] They also allow for instantaneous causality with a modification $p \in N \cup \{0\}$.

Table 2: The results of the Pesaran's unit root test

Variable	P value
DER	0.000
PS	0.000

The results of the unit root test indicate the stationarity of both variables. In the second step, the results of the Granger non-causality test in heterogeneous panel data is employed. Test results are presented in Table 3.

Table 3: The results of the Granger non-causality test in heterogeneous panel data

H0: PS does not causes DER		
	Value	p value
$\overline{Z}$	9.4014	0.0000
$\tilde{Z}$	9.2786	0.0000
Results by country		
Country	beta	p value
Australia	4.0664	0.8704
Brazil	-24.3917	0.869
Canada	21.6367	0.4537
China	-7.7356	0.339
Hungary	-0.8256	0.0311
Japan	-73.1267	0.2937
Mexico	-15.7874	0.0165
New Zealand	-13.0238	0.2156
Norway	-0.1116	0.9506
Poland	0.9292	0.2212
Russia	-88.564	0.0000
Singapore	-0.8837	0.5694
South Africa	-10.0915	0.0021
South Korea	20.4436	0.1718
Sweden	-2.3421	0.056
Switzerland	-7.1367	0.787
Turkey	-4.2784	0.0038
United Kingdom	-113.359	0.0016
United States	-259.4201	0.4773

Null hypothesis H_0: *There is no causal relationship for any of the countries in the panel,* is rejected with both $\overline{Z}$ and $\tilde{Z}$ with p value 0.000. For our data set, both values are adequate while for the dataset with a small T, only $\tilde{Z}$ is relevant [10]**.** Therefore, it can be concluded that there are two sub groups of countries. For the first sub group, the Granger causality does not exist (Australia, Brazil, Canada, China, Japan, New Zealand, Norway, Poland, Singapore, South Korea, Switzerland, and the United States), while for the second sub group of countries (Hungary, Mexico, Russia, South Africa, Sweden, Turkey, and the United Kingdom) causal relationship exists. However, it is visible that most of the estimated coefficients beta have a negative sign. Moreover, all statistically significant betas have a negative sign.

All countries where the political stability causes change in turnover on currency derivative markets have low Financial development index, with the exception of the UK and Sweden, which implies that in countries with not developed financial system political stability decreases the liquidity on derivative markets. This in turn implies that higher country risk motivates market participants to trade with currency derivatives. More precisely, political instability attracts more speculative traders on the currency derivate market.

4 CONCLUSION

This paper investigates the role of a country's political stability on the currency derivatives turnover. The results indicate that the growth of a country's political stability has a heterogeneous impact on the currency derivatives turnover. More precisely, our results reveal that the effect of political stability is more pronounced for currencies derivatives from the countries with less developed financial systems than for the currencies derivatives from the countries with a more developed financial system. However, these results impose a need for future research. First, it indicates that macroeconomic models of derivatives have to be extended with indicators of a country's political risk. Additionally, in further research the index of political risk has to be decomposed so as to discover which parts of the index are most connected with turnover of currency derivatives.

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THE IMPACT OF BUSINESS ECONOMICS STUDENTS' USE OF HEURISTICS ON THEIR PREDISPOSITIONS FOR LONG-TERM INVESTMENT DECISIONS

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Abstract: This paper deals with determining whether students of business economics master studies in Croatia are prone to using heuristics in investment decision making. It is assumed that these students have fundamental knowledge of finance and stock investment, indicating that they would prefer to use all available information in their investment decision making process. Research was conducted through an online survey among 223 students of graduate studies from Faculty of Economics, Business and Tourism in Split. Partial least squares structural equation modelling results showed that students' overconfidence and representativeness positively affect their predisposition for long-term investment decisions, while availability affects negatively.

Keywords: heuristics, overconfidence, representativeness, availability, behavioural finance, PLS-SEM

1 INTRODUCTION

Students at the end of their graduate studies in the field of business economics are expected to have more knowledge about finance theories. Therefore, by relying on their financial knowledge in stock investment activities, it is assumed that they would behave more rationally and use all available information in order to make a successful investment. However, it is known that people are often irrational and not able to collect all possible information, or process them in short period. Therefore, investors tend to simplify their decision making process by using heuristics, also known as shortcuts. It means that they use their previous experience based on similar situations while making a new decision, in order to reduce the risk of possible loss in uncertain situations [7, 8, 17].

There are several types of heuristics, such as representativeness, availability, anchoring, overconfidence and gambler's fallacy [6, 16, 21]. This research focuses on the impact of three types of heuristic biases: representativeness, availability and overconfidence on investment decision making among students of economics. Representativeness occurs when people tend to emphasize recent experience, while ignoring the long term rate. For example, they expect the stock prices of companies with several continuous time periods of successful business to continue to rise in the future. In this way, investors may make forecasts which are inappropriate for the present relevant situation [8, 16, 17]. Availability can be recognized when people excessively rely on the use of easily available information, thus limiting their investment options. It can often be connected to people's preference to invest in local stocks, instead of diversifying and optimizing their portfolio [16, 21]. One of the most commonly used heuristics is overconfidence. It can be defined as overestimating personal skills, knowledge and judgements. Therefore, individuals may often believe that they possess better abilities to invest compared to others [11, 17, 21].

Researchers have found different conclusions about the impact of different heuristics on decision making. According [8], investors are prone to heuristics and representativeness and availability positively affect investment decisions. According to [20] investors' representative bias causes improved investment decisions. A positive influence of representativeness on investment decisions has been found in more research [5, 8, 13], indicating that this bias can actually improve investment decisions. Other researchers argue that representativeness negatively affects decision making, because of irrational trading mistakes [17]. As for availability, researchers have also not found a unique conclusion about its impact on investment decisions [2, 5, 8, 17, 21]. Overconfidence was the most often analysed heuristic, which has also not shown a consistent pattern of impact on decisions. According to [16], overconfidence can "improve persistence and determination, mental facility, and risk tolerance." Similarly, more authors have found a positive influence of overconfidence on decision making of investors [1, 2, 11, 13]. Overconfidence may contribute to the emergence of new ideas, which can benefit the financial market [22]. On the other hand, there was also some evidence of a negative impact of overconfidence on investment decisions [12, 17], claiming that by relying on these heuristics, investors make less reliable decisions.

Investment decisions are observed through the allocation of funds and preference for long-term or short-term investment. The aim of this research is determining if heuristics affect business economics students' predispositions for beneficial long-term investment decisions, i.e. investment period longer than one year [13]. Therefore, three research hypotheses are stated. Firstly, it is hypothesised that representativeness positively affects investment decisions, since sometimes past stock trends can actually be a true indicator of a good investment. Similarly, it is assumed that overconfidence positively affects investment decisions, because experiential decisions can lead to long-term investment benefits. However, third hypothesis assumes a negative influence of availability on investment decisions, since it is observed through the tendency of investors to invest in local stocks, which doesn't lead to an optimal portfolio, or long-term benefits of investment decisions. Since business economics students' predispositions are examined, it is worth mentioning that students tend to perceive themselves as knowledgeable, yet still tend to rely on easily available information and past trends of events in order to make financial decisions [19].

2 DATA AND METHODOLOGY

In order to collect research data, a survey questionnaire was designed according to previous research [9, 10, 13, 21]. The target population were the students of graduate studies in economics on the Faculty of Economics, Business and Tourism in Split, since they have fundamental knowledge in the field of finance. After defining the target population, the sampling was random, since the survey was distributed online to the students, with the final response of 223 students. In addition to the basic questions about the demographic characteristics of the respondents, the survey contained questions which reflect the students' tendency to use heuristics in investing, as well as their preferences for investments. Those questions were formed as statements, where the students had to evaluate their level of agreement which each statement on a scale from 1 to 5 (1=completely disagree, 5=completely agree). The sample consists mostly of female respondents (72.2%) and only 27.8% male respondents. The median age in the sample was 23 years. 80.7% of the students are currently studying in their first year of graduate studies, and 19.3% are currently in their second year.

In order to test the research hypotheses simultaneously, and since behaviour is not directly measurable, partial least squares structural equation modelling (PLS-SEM) was used. Namely, this research is more of exploratory nature and the assumption of distributional normality was not met, so the nonparametric PLS-SEM approach is considered suitable for data analysis. In addition, the model contains a single-item construct, which measures availability, thus confirming the adequacy of using PLS-SEM instead of covariance-based structural equation modelling (CB-SEM) [3, 4]. Data was analysed with SPSS 23 and SmartPLS 3 statistical software, which yielded results for the inner and outer model estimates, as well as the validity and reliability of the constructs.

3 EMPIRICAL RESULTS

The research model included four latent constructs: overconfidence (OC), representativeness (REP), availability (AV) and investment decision (ID). The convergent validity and reliability of the constructs is evaluated by examining the outer loadings, average variance extracted (AVE), composite reliability (CR) and Cronbach's alpha coefficient. The results are shown in Table 1. All of the outer loadings are relatively high (higher than 0.5) and they are statistically significant. This is connected to AVE, which is above 0.5 for all constructs, indicating that all constructs explain a substantial part of each indicator's variance [3]. CR values for the latent constructs are above the threshold of 0.70, indicating higher levels of reliability [3, 15]. Additionally, the traditional and more conservative measure of internal consistency is Cronbach's alpha coefficient. It can be seen that it yields satisfactory results for all constructs, giving somewhat lower value for REP. However, alpha usually results in lower values compared to CR, so it is useful to analyse both measures when analysing internal consistency reliability. True reliability usually lies between these two values [3, 15]. Since AV is a single-item construct, these measures have no meaning for it.

Table 1: Convergent validity and reliability of the constructs.

Latent variable	*Item**	*Outer loadings*	*AVE*	*CR*	*Cronbach's alpha*
Overconfidence (OC)	OC1	0.741***	0.526	0.814	0.728
	OC2	0.833***			
	OC3	0.615***			
	OC4	0.694***			
Representativeness (REP)	REP1	0.675***	0.533	0.787	0.594
	REP2	0.722***			
	REP3	0.827***			
Availability (AV)**	AV1	1.000***	1.000	1.000	1.000
Investment decision (ID)	ID1	0.774***	0.529	0.815	0.699
	ID2	0.810***			
	ID3	0.761***			
	ID4	0.531***			

*Items: OC1 – I believe that my skills and knowledge of stock market would help me to outperform the market; OC2 – I believe that I would rely on my previous experiences in the market for my next investment; OC3 – I believe that I would be sure that I can make the correct investment decision; OC4 – I believe that I would always refer the investing profit to my successful investment strategy; REP1 – I would buy 'hot' stocks and avoid stocks that have performed poorly in the recent past; REP2 – I would be careful while investing in stocks of companies which have made losses recently; REP3 – I would use trend analysis of some representative stocks to make investment decisions; AV1 – I believe that I would prefer to buy local stocks than international stocks because the information of local stocks is more available; ID1 – I believe that I would allot funds that will produce long term benefits; ID2 – I believe that I would regularly review, compare and take instant decision on my investment performance; ID3 – I believe that I would do market research before taking any shot term investment; ID4 – I believe that I would allot more funds for the long term than short term.

** single-item construct

**** Significant at 0.01 level*

Table 2 shows the analysis of the discriminant validity of the latent constructs through the heterotrait-monotrait ratio (HTMT) of the correlations. HTMT shows the ratio of the between-trait correlations to the within-trait correlations, and its value should be less than 0.85 in order to support the existence of the discriminant validity [3, 15]. In this case, all of the HTMT values are relatively low, indicating that there is no problem with the discriminant validity and that each construct is truly distinct from other constructs in the model.

Table 2: Discriminant validity of the constructs according to HTMT ratio.

	AV	***ID***	***OC***	***REP***
AV				
ID	0.207			
OC	0.230	0.310		
REP	0.048	0.564	0.422	

The next analysis refers to the inner (structural) model. The path coefficients along with the p-values are shown in Figure 1. It can be seen that all of the paths are significant at 0.01 level. OC and REP show a positive influence on ID, with REP having a slightly stronger influence. On the other hand, AV negatively affects ID. This confirms all research hypotheses. It means that students who tend to believe that they would rely on their skills in investing and those who believe that they would use trend analysis and buy more popular stocks, tend to have predispositions for long-term investment decisions. Furthermore, students who believe that they would prefer investing in local stocks, due to information availability, tend to have less predispositions for long-term investment decisions. The value of the coefficient of determination (R^2) can be seen inside the ID construct and it is 0.206. It shows in-sample predictive power of the model, thus confirming the high predictive power [3, 14]. Specifically, it shows that the model explains 20.6% of the variance in ID.

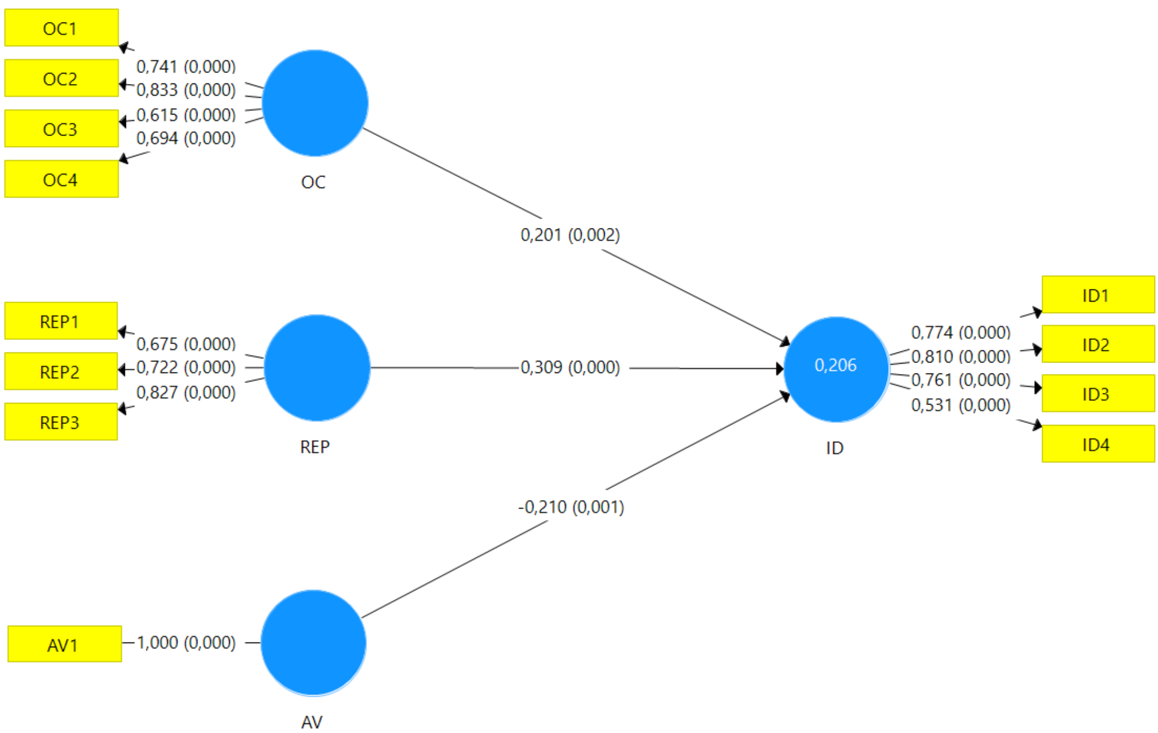

Figure 1: Path diagram with standardized estimates and p-values.

The model can also be tested for its out-of-sample predictive power through the PLS Predict procedure. By comparing the root mean squared error (RMSE) and mean absolute error (MAE) of the PLS model to the linear regression model (LM), it can be seen that the values for all indicators of the key endogenous construct ID are lower for PLS. In this case, it can be concluded that the model has high predictive power [18].

Table 3: PLS Predict results for out-of-sample predictive power.

	PLS		***LM***	
	RMSE	***MAE***	***RMSE***	***MAE***
ID1	0.843	0.664	0.861	0.678
ID2	0.855	0.694	0.873	0.705
ID3	0.853	0.685	0.871	0.694
ID4	0.991	0.816	1.011	0.822

4 CONCLUSION

This research focuses on the impact of business economics master students' use of heuristics on their predispositions for beneficial long-term investment decisions. While there is a number of research dealing with behavioural finance, it is still questionable how the use of heuristics influences investment decisions. According to previous research there are no uniform findings about the influence of heuristics on decision making.

This study was carried out on a sample of 223 students of graduate studies in business economics at the Faculty of Economics, Business and Tourism in Split, Croatia. It is expected that these students have underlying knowledge of finance and that a part of them are likely to become future investors at the stock market. The PLS-SEM analysis indicated that overconfidence and representativeness biases positively affect the students' predispositions to make long-term investment decisions. On the other hand, availability bias has shown a negative impact on investment decision making. This specifically shows that students with the tendency to overestimate their knowledge and skills believe that they would prefer long-term investments. Moreover, students with the tendency to analyse stock trends, buying popular stocks and relying on recent experiences also believe in their preference for long-term investment. However, if the students have the tendency to invest more in local stocks, because of the ease of information availability, it decreases their predispositions for long-term investments. The PLS-SEM model yielded high predictive power. Further research could include a comparative analysis of the business economics students' investment behavior in the present compared to their behavior in a future time period. It could also include multi-group analysis, in order to compare if there are differences between groups of students with different socio-demographic characteristics. Other behavioral factors can also be analysed in this context. For future research the additional recommendation is to confirm these research hypotheses on the relevant sample of investors on the stock market in the context of the predictors of their long-term investment decisions.

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ANALYSIS OF THE RELATIONSHIPS BETWEEN SLOVENIAN FUNCTIONAL REGIONS IDENTIFIED IN THE NETWORK

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Abstract: In this paper, we analyse the relationships between Slovenian functional regions that are considered as communities in a network. Functional regions were identified using the walktrap algorithm. We analyse the relationships between the functional regions as the networks calculated by force-directed algorithm, the Fruchterman-Reingold algorithm. The inter-regional relationships are studied for each year over the period between 2000 and 2017.

Keywords: functional regions, graphs, walktrap algorithm, Fruchterman-Reingold algorithm, commuting flows, interregional relationships, Slovenia.

1 INTRODUCTION

The idea of functionally connected and self-sustaining areas, called functional regions, is increasingly used in economic, social, environmental and spatial development analyses and for development decision-making [7]. Functional regions (FRs) are functionally cohesive areas based on horizontal spatial relationships in the form of spatial flows and interrelationships (interactions) between parts of the region. Functional regionalization is thus the process of grouping basic spatial units (BSUs) into FRs with the aim of generalising functional flows and relationships in a space. FRs are therefore also understood as areas of generalised patterns of flows and relationships in a space - usually as generalisations of social and economic functional relationships in an area. Studies on FRs consider a variety of flows, ranging from population flows, transportation flows, commodity flows, financial flows, information flows and other flows or interactions in space [1, 10, 17]. However, FRs are most commonly analysed through population flows, i.e., commuting and migration flows. When FRs are analysed by commuting flows they are considered as labour markets.

In this paper, the regional labour market definition of a functional region is used. A regional labour market consists of BSUs, in our study municipalities, that are closely linked by commuting flows. Most commuters travel a relatively short distance, and it is rare to find a commuter with a long commute. For medium and long commutes, Evers and Van der Veen [11] argue that commuting can be viewed as a substitute for migration because work and residence are geographically separated. When conditions exist that allow for (daily) commuting, people often choose to commute rather than to move closer to their workplace. And vice versa: poor commuting conditions may be perceived as a prerequisite for moving. Thus, better transport (reducing travel time, increasing travel comfort, etc.) and working conditions (flexible working hours, working from home occasionally, etc.) have a positive and significant impact on decisions regarding longer commuting. Lundholm [13] found that indeed the willingness to take on longer commutes creates the conditions that moderate the decision to migrate. This leads to the conclusion that improved commuting conditions hinder migration.

In this paper, we analyse the relationships between Slovenian functional regions that represent a longer commute. FRs are considered as communities in a network and were identified using the walktrap algorithm [15]. Relationships between FRs were analysed as networks calculated using the force-directed algorithm, the Fruchterman-Reingold algorithm [12]. Inter-regional commuting flows were examined for each year between 2000 and 2017.

The remainder of this paper is organised as follows. Section 2 contains the description of methodology. This is followed by the presentation of results and discussion in Section 3. Section 4 summarises and concludes the paper.

2 METHODOLOGY

In this paper, functional regions were modelled as regional labour markets as suggested by OECD [14] and Coombes et al. [6]. For that purpose, the complex systems of labour commuting between Slovenian municipalities for each year between 2000 and 2017 was described as a network. A network is a mathematical structure consisting of vertices with pairwise relationships represented by edges. Weights (w_{ij}) were assigned to each edge, according to the number of commuters registered between the two municipalities. w_{ij} represents the number of commuters from municipality *i* to *j*. Communities in the network, i.e., i.e., functional regions of the inter-municipal labour commuting flows, were identified using the walktrap algorithm [15]. This heuristic algorithm clusters vertex of the network based on a distance, *r*, that measures how connected two nodes are. The distance r_{ij} between nodes *i* and *j* is defined as shown in Equation (1), where P_{ik}^{t} is the probability of moving from node *i* to *k* after *t* steps, $d(k)$ is the degree of node *k* and *n* is the number of nodes in the network.

$$r_{ij} = \sqrt{\sum_{k=1}^{n} \frac{\left(P_{ik}^{t} - P_{jk}^{t}\right)^2}{d(k)}} \tag{1}$$

In the walktrap algorithm, the transition probabilities are estimated using random walk. Briefly, *Q* random walks of length *t* are taken from randomly selected nodes. In each transition, the walker travels from node *i* to node *j* with probability $w_{ij}/\sum_k w_{ik}$. Then, the transition probabilities P_{ik}^{t} are calculated as the fraction of walkers who ended in node *k* after *t* steps. Once the distance matrix r_{ij} has been calculated, vertices are aggregated using a hierarchical clustering algorithm.

When communities in a network, i.e., functional regions, had been identified for each year between 2000 and 2017, we analysed the relationships between them. For this purpose, networks were calculated considering only the connections between FRs. We plotted the networks using a force-directed algorithm, the Fruchterman-Reingold algorithm [12]. It models the edges as springs of stiffness equal to its weight. Then, it finds the configuration of lowest energy. This means that nodes with strong relationships are drawn together. Also, that nodes with many strong connections are located in the middle.

The identification of functional regions as well as the analysis of the networks of inter-regional connections were applied using the implementation included in the *igraph* R package [8] in R version 3.4.3 [16].

3 RESULTS AN DISCUSSION

Using the walktrap algorithm in the *igraph* R package [8], we have identified twelve different functional regions of Slovenia in the period between 2000 and 2017. Although not all of them are presented every year, they are relatively stable, some of them for just 2–3 years, but most of them for the majority of the analysed period. Plots on Figure 1 show the changes of functional regions, i.e., the communities of municipalities, through the years. A municipality is represented by the municipal centre. All municipalities that belong to the same FR are coloured with the same colour. Note that FR is denoted by the largest employment centre, i.e., a municipality with the highest number of employment places in the region.

In the analysed period of 2000–2017, there were 12 different FRs; namely (in the parentheses, there is an official code of a municipality): FR Ljubljana (61), FR Maribor (70), FR Celje (11), FR Koper (70), FR Novo mesto (85), FR Murska Sobota (80), FR Slovenj Gradec (112), FR Nova Gorica (84) respectively FR Big Nova Gorica (84), FR Nazarje (83), FR Tolmin (128), and FR Črnomelj (17). Note that two FRs include Nova Gorica as the largest employment centre: "Nova Gorica" and "Big Nova Gorica". The reason for this is that the Nova Gorica region absorbs the one named Tolmin in the data obtained for several years. However, the number of regions differ in analysed years.

Although a total of twelve different regions were identified, not more than nine communities were identified for a single year. Therefore, although there are some regularities in the network structure, some variations have taken place in the time period analysed. The structure of those municipalities located in the northeaster part of the country remained very stable in the 18 years analysed. FR Murska Sobota (80), FR Maribor (70) and FR Slovenj Gradec (112) are present in every year analysed, with almost no variation in the municipalities they include. On the other side, FR Nazarje (83) appears as a region for the networks constructed between 2000 and 2011; but, in year 2012 it has been absorbed by Celje (11), with all the municipalities previously belonging to Nazarje (83) being part of Celje (11) until the end of the period studied (2017).

The FR Ljubljana (61) is the biggest regions among the ones identified. This can be justified because Ljubljana is the capital of the country, as well as the main economic centre, so a large fraction of the employment force commutes to this city municipality. However, the FR Ljubljana (61) was fractured in the time period between 2000 and 2017.

In year 2008 Novo Mesto (85) appears as a new functional region, taking a relatively large fraction of the municipalities previously included in FR Ljubljana (61). This region remains as a stable FR in the time period analysed, even absorbing more municipalities.

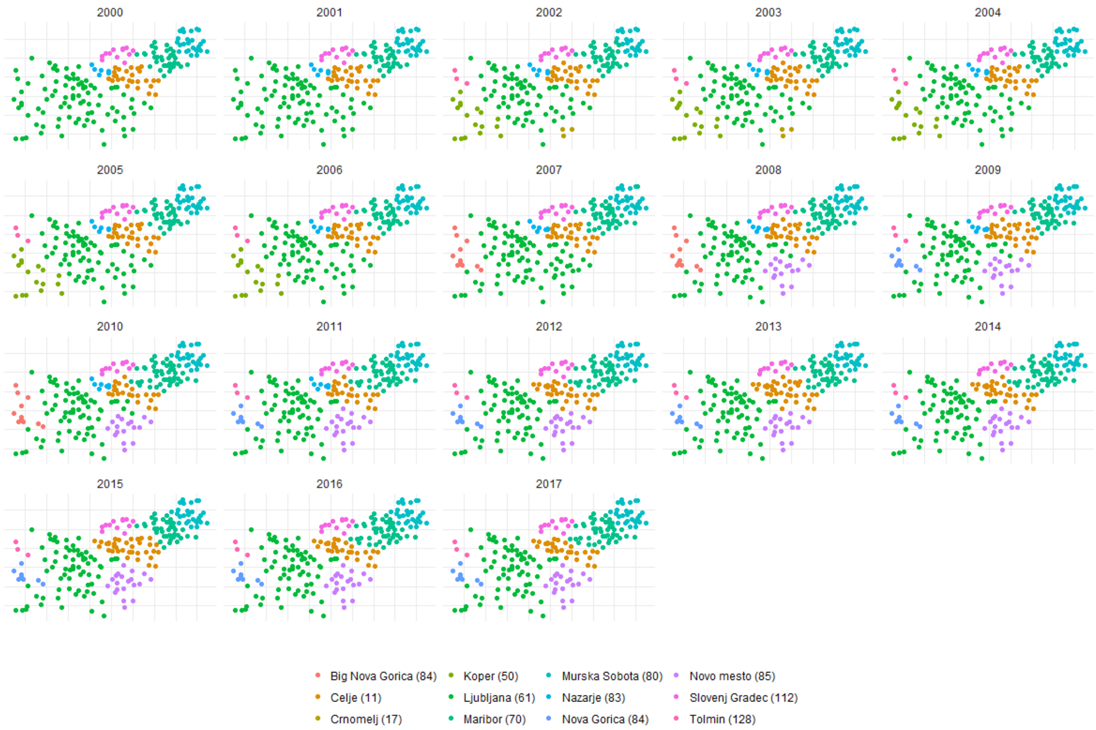

Figure 1: Municipalities in functional regions in Slovenia in 2000–2017
(notes: municipality is presented by municipal centre; there is official code of a municipality in the parentheses)

The structure in the western side of the country is more volatile than in the rest. In the time period between 2002 and 2006, every municipality in the western part of the country were part of two distinct regions: FR Koper (50) and FR Tolmin (128). In 2007, FR Ljubljana (61) extended its influence on the municipalities located in the southwest corner of the country. These municipalities had remained as part of Ljubljana until the end of the analysed period. In the period between 2007 and 2017, the structure of the municipalities located in the west part of the country was changed at a local level. In 2009 and 2011–2017, they are included in two distinct regions: FR Tolmin (128) and FR Nova Gorica (84). However, in years 2007, 2008 and 2010 they were part of the larger functional region Big Nova Gorica (84).

By summarizing changes of FRs the whole period (2000–2017), and especially in the last analysed period (2012–2017), we conclude that there were eight main functional regions identified in the networks by walktrap algorithm (from east to west of the country): FR Murska Sobota (80), FR Maribor (70), FR Slovenj Gradec (112), FR Celje (11), FR Novo mesto (85), FR Ljubljana (61), FR Nova Gorica (84) and FR Tolmin (128).

The relationships between functional regions were analysed in networks calculated by a force-directed algorithm, the Fruchterman-Reingold algorithm [12]. Plots on Figure 2 show the changes of networks between FRs through the analysed years. There are two general properties of networks: first, the edge width is not homogeneous, and, second, the edges are getting thicker. The first property indicates that there are much more commuters between FR Ljubljana (61) and FR Maribor (50), FR Ljubljana (61) and FR Celje (11), and FR Ljubljana (61) and FR Novo mesto (85) than between the rest. The second property indicates that there are more long-distance commuters nowadays than before. In the whole analysed period between 2000 and 2017, Ljubljana (61) has a central position. However, Maribor (70) and Celje (11) are located very close to Ljubljana (61), which indicates that there are strong relationships with many interactions between them. At the beginning of the analysed period, there was also strong relationship between FR Ljubljana (61) and FR Koper (50), but after FR Ljubljana (61) overtook the influence over FR Koper (50) in 2007, the relationship between FR Ljubljana (61) and new FR (Big) Nova Gorica (84) was no more so strong. Since 2007, the position of new FR Novo mesto (85) has been strengthening all the time.

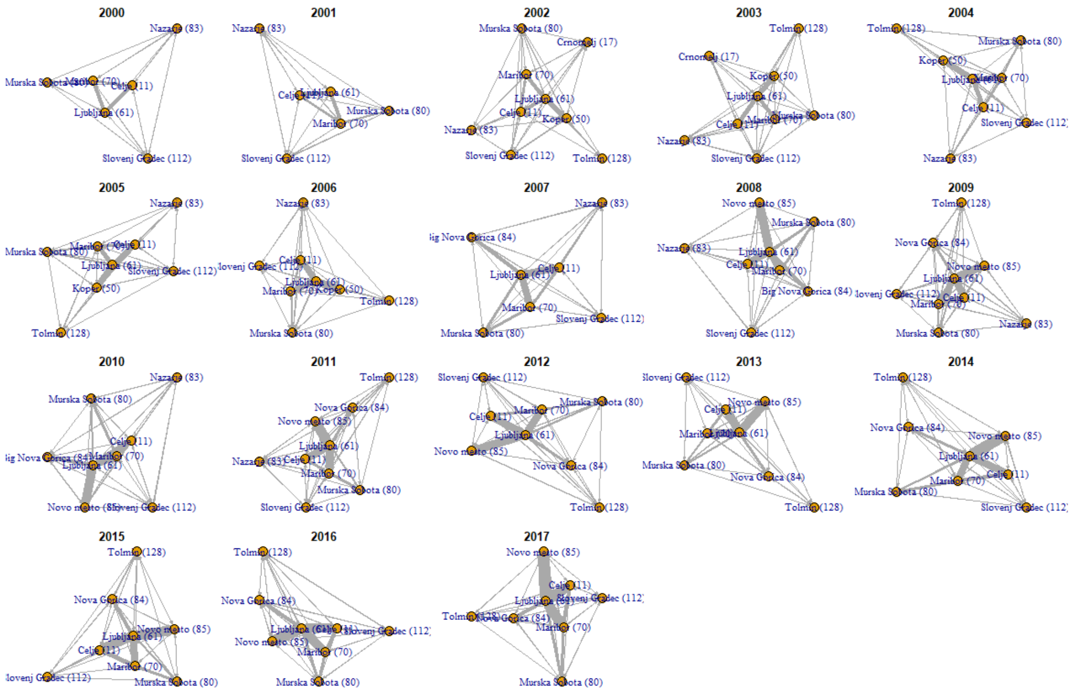

Figure 2: Networks between functional regions in Slovenia in 2000–2017
(note: there is official code of municipality in the parentheses)

4 CONCLUSIONS

In the paper, we analysed the changes in functional regions and their relationships in Slovenia from 2000 to 2017. We identified functional regions as communities in networks and analysed relationships between functional regions also in networks modelled by a force-directed algorithm, the Fruchterman-Reingold algorithm.

There were changes in FRs during the analysed period, changes in the number and size of regions. The structure of FRs was more stable in the eastern, which is a more rural part of the country, less developed and divided into a higher number of small municipalities. For the whole analysed period, twelve FRs appeared for Slovenia, but several of them only for one year or a short period. However, we can summarise that there were eight main FRs identified in the networks by the walktrap algorithm: FR Murska Sobota (80), FR Maribor (70), FR Slovenj Gradec (112), FR Celje (11), FR Novo mesto (85), FR Ljubljana (61), FR Nova Gorica (84) and FR Tolmin (128).

In the analyses of the relationships between FRs, which denotes long commute, we discovered two general properties of networks between FRs. The fact that the edge width between regional centres is not homogeneous, suggests that there are many more commuters from neighbouring FRs and even from FR Maribor (70), almost 100 km away, to FR Ljubljana (61) than between the other FRs. The second fact is that the edges between FRs become thicker and this suggests that there are more long-distance commuters nowadays than in the past. Our study also highlighted the position of FR Novo mesto (85), which has become increasingly stronger. Our findings are consistent with previous studies on commuting in Slovenia, which showed that the number of long-distance commuters is increasing, especially to and from Ljubljana [3, 9].

As a direction for future work, the walktrap algorithm analysed here could be compared with other graph-based methods for identifying functional regions, e.g. [2], as well as with other methods, e.g. the popular rule-based regionalization method CURDS [4, 5]. Moreover, network theory could be applied to analyse in depth the structure of functional regions at different levels (micro, mezzo and macro). In this study, we analysed the structure and relationships between functional regions in Slovenia until 2017. As a direction for future work, the research could also be extended for more recent data.

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ALGORITHMS BASED ON ANALYTIC LEARNING NEURAL NETWORKS FOR FINAL EXAM SCHEDULING

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Abstract: The automatic generation of schedules has been in the focus of researches for decades. The scheduling of oral final exams is a particular subtask of automatic scheduling problems, where special requirements constrain the state space. The problem is examined with analytic learning-based neural networks, and the results are compared with other solutions. The results show that there is an acceptable solution with neural network approaches for this complexity. Moreover, with some improvements, there can be solutions, which are better and fairer than the manually compiled schedules.

Keywords: scheduling, final exam scheduling, analytic learning neural network, neural network, Hopfield network, Boltzmann machine.

1 INTRODUCTION

The final exam is held at the end of the course in most universities. One form is the oral exam, where only one student takes the exam in front of an examining committee in a room at a time. Lecturers may have a special role, and only certain people are allowed to carry out these tasks.

The scheduling of final exams can be done manually. However, in a non-automated process, it is not easy to see through the whole schedule, whether all requirements are being met and whether the timing is suitable for everyone. It is also a very time-consuming process.

The complexity of the NP-complete combinatorial optimisation problem can be approached at several levels. There are too many possible combinations for scheduling people, on the order of 10^{462}different schedules for only 100 students. In addition, many final exam-specific conditions can be controversial. For example, the workload of instructors should be distributed equally, but certain tasks, such as chairing, secretarial duties, or examining certain subjects, can only be done by particular lecturers. Some supervisors may have much more students than others, and it may also be possible that not all the necessary teachers are available at a time.

The organisation of this paper is as follows. Besides Introduction, the paper features five sections. In Section 2, an overview is given about our previous researches in connection to this problem. Section 3 describes the neural networks based on analytical learning and shows how they could be used in combinatorial optimisation problems. Section 4 presents the structure of the proposed algorithm and goes along with the scheduling method of each participant. In Section 5, the results are examined and compared to our previous algorithms. Finally, Section 6 includes concluding remarks and explains the opportunities for further researches.

2 BACKGROUND

In this section, our previous researches are summarised in the topic of final exam scheduling. We worked with a simplified model of a homogeneous group of students scheduled in one room. A scoring system was created to determine the goodness of a given assignment. This scoring is a weighting of the individual requirements.

We have developed three different approaches: a genetic algorithm-based solution [4], a proprietary heuristic-based algorithm that tries to model the actual scheduling process by searching for pairs in graphs [1], and an integer linear programming-based solution [2]. With the latter, an adequate solution was achieved. However, as we tried to extend the model with parallel exams and heterogeneous groups, the state space exploded, and the algorithm we produced did not scale well [3].

Therefore, it would be worthwhile to try new approaches, which could be mixed with the IP-based one in a hybrid way to get a solution that could still be better and fairer than the manually constructed ones.

3 NEURAL NETWORKS FOR COMBINATORIAL OPTIMISATION PROBLEMS

Analytic learning networks are neural networks that implement associative memory. The simplest of these constructs is the Hopfield network [6], which is initially introduced for learning patterns and their noisy, distorted recognition.

3.1 Hopfield networks

Hopfield network can be written in a single-layer feedback structure. The outputs of the neurons are fed back to the inputs of each neuron through weighted connections, where the value of a neuron is calculated as follows. Here θ is a threshold, x_j is the value of the other neurons, and w_{ij} is the weight between two neurons.

$$x_i \coloneqq \operatorname{sgn}\left(\sum_j w_{ij}x_j - \theta_i\right) \tag{1}$$

3.2 Boltzmann machines

Stochastic extensions of Hopfield networks are Boltzmann machines [5]. This means that, in a limited proportion, we accept a change in the value of the neurons even if it causes the system to enter a higher energy state.

The operation of the neurons in the model can be described by a stochastic rule that determines the probability of the possible states after a value change:

$$P(x_i = 1) = \frac{1}{1+exp\left(\frac{-s_i}{T}\right)} \qquad s_i = \sum_j w_{ij}x_j + \theta_i \tag{2}$$

3.3 Combinatorial optimisation and NN-s

The above approaches can also be used in combinatorial optimisation problems if the number of possible solutions is finite, the quality of the solutions can be expressed numerically and compared to the quality of any other solution.

It is important to note that we will not necessarily obtain ideal solutions, but the goal is to obtain near-ideal solutions within a meaningful time. For this reason, neural networks are often used in a hybrid fashion with other methods. Hopfield first solved the travelling salesman problem with his nets [7] and later extended it to other combinatorial optimisation problems [10], and there are also many hybrid solutions[9].

The main difficulty in their application is to find an appropriate energy function such that the network, starting from a random initial configuration, stabilises in a state that gives a good solution to the problem. Nevertheless, the scalability of these methods is promising [8].

4 NN-BASED ALGORITHM FOR FINAL EXAM SCHEDULING

4.1 Structure of the network

The primary concern in building the network was to translate the requirements into energy functions. In other words, formulas had to be constructed for each case with an optimal solution expected at the optimal value.

Neurons are binary, i.e. they indicate whether or not a given person is assigned to a particular exam. The inputs of the network are the initial states of the neurons, while the outputs consist of the states of the same neurons. Thus, different states represent different semi-finished or finished schedules. Each instructor and student has 1-1 neuron for each time slot. The neurons are structured in the following order, i.e. first come the chairpersons, each with their possible appointment, then the secretaries, members, other instructors and students:

Chairpersons									Secretaries									Members									Other instructors									Students								
Chair.1			Chair.2			Chair…			Secr.1			Secr.2			Secr…			Memb.1			Memb.2			Memb…			Other1			Other2			Other…			Student1			Student2			Student…		
t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…	t1	t2	…

Figure 1: Structure of neurons

The neurons are henceforth denoted by x_{it} where i stands for a person (instructor or student) and t for an exam date.

4.2 Scheduling of chairpersons

The first step is to prepare the roster of chairpersons, which will explain how the network is set up in more detail.

A necessary requirement is to have precisely one chairperson assigned at a given time. This constraint could be mathematically formulated as the sum of the variables of the chairpersons added at a point in time being 1. This condition should be defined as an energy function, which indicates the energy of each mismatch, i.e., this function should be minimised. In this case, it will look as follows:

$$E_1:\ \gamma_1 \sum_{t\in T} \left(1 - \sum_{p\in P} x_{pt}\right)^2 \tag{3}$$

Here P denotes the set of presidents, T the time slices, γ_1 is a positive constant and is the weighting of each requirement (i.e., for essential requirements γ is a higher positive number, for less critical soft requirements γ is a lower positive number). Decomposing this function into terms gives the relation between each term, i.e., the weights are assigned to each element of the weight matrix, where each neuron is connected to the others. There are undirected edges between each neuron; hence the weight matrix is symmetric. Given this requirement, the weight matrix shown in Figure 2 is obtained. Here, it can be seen that a neuron x_0 is introduced with a constant value of one due to the one-term multiplications.

Another critical requirement is that the chairpersons should only be scheduled when they are available. This constraint can be described by the following energy function, where A_{pt} is a constant derived from the chairman's designated time availability.

$$E_2:\ \gamma_2 \sum_{p\in P} \sum_{t\in T} A_{pt} x_{pt} \qquad A_{pt} = \begin{cases} 0 & \text{available} \\ -M & \text{else} \end{cases} \tag{4}$$

For this requirement, a sufficiently large constant M must be taken out of the neuron if the chair is not available, thus helping to minimise its activation, i.e., to avoid it being scheduled.

	x0	x11	x12	x13	x14	x21	x22	x23	x24	x31	x32	x33	x34
x0	0	1	1	1	1	1	1	1	1	1	1	1	1
x11	1	0				-1				-1			
x12	1		0				-1				-1		
x13	1			0				-1				-1	
x14	1				0				-1				-1
x21	1	-1				0				-1			
x22	1		-1				0				-1		
x23	1			-1				0				-1	
x24	1				-1				0				-1
x31	1	-1				-1				0			
x32	1		-1				-1				0		
x33	1			-1				-1				0	
x34	1				-1				-1				0

Figure 2: Weight matrix for being a chair in every timeslot

	x0	x11	x12	x13	x14	x21	x22	x23	x24	x31	x32	x33	x34
x0	0												
x11		0	1										
x12		1	0										
x13				0	1								
x14				1	0								
x21						0	1						
x22						1	0						
x23								0	1				
x24								1	0				
x31										0	1		
x32										1	0		
x33												0	1
x34												1	0

Figure 3: Weight matrix for block-scheduling

Another relatively essential requirement, which is less important than the previous two, is that the chairpersons should be scheduled in blocks, i.e. preferably scheduled for one morning or afternoon at a time. This is facilitated by the following energy function, where B denotes the blocks containing a predetermined number of exams:

$$E_3:\ \gamma_3 \frac{1}{2} \sum_{p \in P} \sum_{b_i \in B} \sum_{t_1 \in b_i} \sum_{t_2 \in B_i} x_{pt_1} x_{pt_2} \tag{5}$$

Figure 3 shows a small example where the same colours indicate neurons associated with the same block of timeslots. It can be seen here that the weights are for ensuring that if a chair has already been assigned to one timeslot in a block, it will be assigned to the others.

Another condition for the chairpersons is that their workload must be balanced, which is a soft requirement. In practice, this means that the weighting of this energy function (γ_4) will be a lower positive constant. This is represented by the following energy function:

$$E_4:\ \gamma_4 - \frac{1}{2} \sum_{p \in P} \sum_{t_1 \in T} \sum_{t_2 \in T} x_{pt_1} x_{pt_2} \tag{6}$$

The assignment of the chairpersons is the sum of the energy functions presented above, i.e. $E_1 + E_2 + E_3 + E_4$ gives the total energy function if only the chairpersons are considered.

4.3 Scheduling of other people

The conditions associated with the other people from the schedule are added to those defined earlier, thus extending the total weight matrix defined by the energy functions.

The secretaries form a disjoint set with the chairpersons, and the exact requirements are considered for them, but with smaller weights in each case, i.e. the γ values for them may be smaller. Based on these considerations, the joint assignment of the chairpersons and the secretaries will result in the following energy function:

$$\begin{aligned} E = {} & \gamma_1 \sum_{t \in T} \left(1 - \sum_{p \in P} x_{pt}\right)^2 + \gamma_2 \sum_{p \in P} \sum_{t \in T} A_{pt} x_{pt} + \gamma_3 \frac{1}{2} \sum_{p \in P} \sum_{b_i \in B} \sum_{t_1 \in b_i} \sum_{t_2 \in B_i} x_{pt_1} x_{pt_2} + \\ & \gamma_4 \frac{-1}{2} \sum_{p \in P} \sum_{t_1 \in T} \sum_{t_2 \in T} x_{pt_1} x_{pt_2} + \gamma_5 \sum_{t \in T} \left(1 - \sum_{s \in S} x_{st}\right)^2 + \gamma_6 \sum_{s \in S} \sum_{t \in T} A_{st} x_{st} + \\ & \gamma_7 \frac{1}{2} \sum_{s \in S} \sum_{b_i \in B} \sum_{t_1 \in b_i} \sum_{t_2 \in B_i} x_{st_1} x_{st_2} + \gamma_8 \frac{-1}{2} \sum_{s \in S} \sum_{t_1 \in T} \sum_{t_2 \in T} x_{st_1} x_{st_2} \end{aligned} \tag{7}$$

For the other instructors, it was also necessary to consider the timing and the best possible balancing of loads and have at least one instructor in the role of a member attending the exam.

In addition, a condition was made to minimise the number of other instructors, thus facilitating the merging of roles. For example, if the chair is also the supervisor of a student, the student should sit the exam simultaneously as the supervisor is sitting the exam as chairman.

For students, an important constraint was that each student should be listed exactly once. In addition, it had to be ensured that the student's instructor also took part in the examination, if possible. A closer link between the neurons of the student and his/her instructor should be established. If the student appears in an exam, a positive weight should be applied to the neurons of the instructor. A similar condition had to be imposed on the examiners; the only difference is that the algorithm can choose one examiner from several instructors.

4.4 Difficulties with Hopfield networks

With Hopfield nets, it is easy for complex tasks to get stuck in a local optimum. Random configurations have been designed to avoid this situation. Namely, the network can start from different initial states, and the current neuron is randomly selected. This randomisation has already caused improvements in some cases but could still be trapped in a local optimum.

In addition, synchronous and asynchronous operations were compared. In the former, several neurons can change their values simultaneously, while in the latter, only one neuron at a time, so states move between adjacent configurations. Asynchronous operation is more natural, but the synchronous operation can solve the aforementioned problem, so this is also examined. In addition, a stochastic operation is also realised by Boltzmann machines with simulated annealing. The results of these will be discussed in the next chapter.

5 CASE STUDY

The algorithm was tested on a real test set with 100 students with Bachelor's degrees (from the Department of Automation and Applied Informatics, BME). In Hopfield nets, the network is easily trapped in a local optimum, giving very different results in each run, for example, completely different schedules with different workloads. This problem was solved by the options mentioned earlier, and Boltzmann machines could achieve uniform workloads.

For Boltzmann machines, it was also essential to set the various parameters. The more freedom we gave the operation, the slower it converged towards the optimal solution. At each temperature, a neuron update with 3-5 times the number of neurons was performed. Moreover, the decrease in temperature was calculated as: $T_{k+1} = cT_k \quad c \in [0.8\,,\ 0.99]$. For fewer conditions, larger values of c were manageable, but as the network became more complex and more computations had to be performed, values closer to 0.8 gave a meaningful solution in the runtime-good solution threshold.

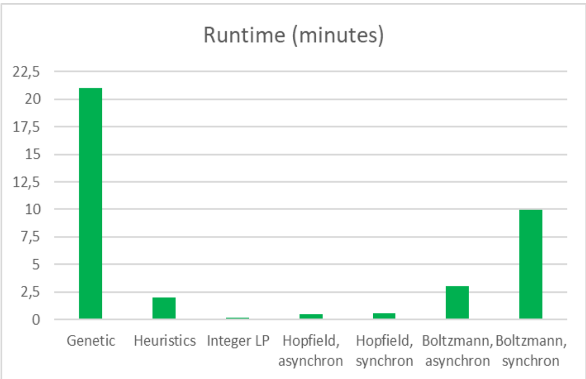

Figure 4: Comparison of running times

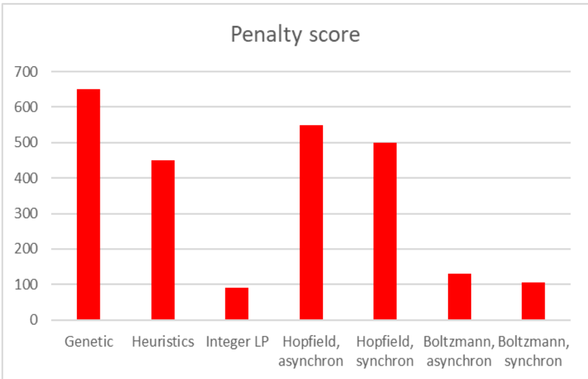

Figure 5: Comparison of average penalty scores

The results were also compared in terms of running time (see Figure 4) and penalty score (see Figure 5) and compared with the three algorithms that had been previously developed.

The Boltzmann machine was slower than the Hopfield, and that the synchronous operation was always slower than the asynchronous. However, all NN-based algorithms were orders of magnitude faster than the previous genetic algorithm-based solution. The Hopfield network-based solutions also rivalled the integer LP-based solution in terms of runtime.

However, the results should be evaluated in terms of the number of penalty scores. Indeed, the figure shows that the slowness of the Boltzmann machine pays off to a large extent, as it generated much better schedules than Hopfield networks. The synchronous operation also yielded slightly better results, but overall it may not be worth using this solution for Boltzmann machines when time is limited. The Boltzmann machine's results are close to the best LP-based algorithm's in terms of scores and outperform the other previous algorithms.

5 CONCLUSIONS

For a specific subset of the scheduling tasks, for a simplified model of final exam scheduling, an acceptable solution was previously developed, but it did not scale well. For this reason, it was deemed necessary to try newer approaches, which, if they yield meaningful results, may be worthwhile to mix with the previous algorithms. We examined neural network-based options, which gave promising results. The Boltzmann machine with stochastic operation has succeeded in producing a good schedule similar to the IP-based one. It is also more promising in terms of scaling than previous methods, according to the literature. The future plan is to combine these two approaches to produce better schedules than manually produced ones.

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EXACT METHOD FOR THE WORST OPTIMAL VALUE OF AN INTERVAL TRANSPORTATION PROBLEM

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Abstract: We consider the interval transportation problem, in which the supply and demand vectors and the transportation costs are uncertain and can be perturbed independently within the known lower and upper bounds. The main goal is to compute the worst value, which is optimal for some feasible scenario of the interval transportation problem. We derive an exact method for solving this NP-hard problem, based on duality and complementary slackness. Then, we show that the method can be competitive with the currently used heuristic algorithms.

Keywords: transportation problem, interval programming, optimal value range

1 INTRODUCTION

Optimization under uncertainty forms an integral part of mathematical programming for tackling various practical problems in operations research. Throughout the years, several different approaches to model uncertainty in optimization problems have been proposed, handling different sources of inexactness, imprecision or vagueness inherently present in a given problem. In this paper, we consider the model of interval programming [10], in which we assume that the uncertain data can be independently perturbed within known lower and upper bounds.

Namely, we focus on the transportation problem [5], which is one the widely studied and used models in operations research. The objective of the transportation problem is to find a transportation plan for shipping a given commodity from a set of supply centers to the customers, while minimizing the total transportation costs. Since the input data of the problem (i.e., the supply and demand parameters and the transportation costs) are not always known exactly in advance, we assume that only the lower and upper bounds on these values are given. This setting leads to the model of an interval transportation problem [2, 9].

We first review the basics of interval linear programming and formulate a mathematical model of an interval transportation problem. One of the main questions addressed in interval programming is the so-called optimal value range problem, which aims at computing the best and the worst value that is optimal for some scenario of the uncertain model [10]. The main part of the paper is thus devoted to computing the worst (finite) optimal value [6, 4], which was recently proved to be NP-hard for the class of interval transportation problems [7]. Computation of the optimal value range for a special case of interval transportation problems with costs immune against the transportation paradox was addressed in the literature [3]. Here, we show an exact method for computing the worst value for general interval transportation problems and analyze its performance against the formerly proposed heuristic algorithms [8, 11, 1].

2 INTERVAL TRANSPORTATION PROBLEM

Let us review the necessary terminology and notation related to the interval transportation problem that is used throughout the paper.

Interval data. We use the symbol $\mathbb{IR}$ to denote the set of all closed real intervals. Hereinafter, we denote intervals and interval vectors by bold letters. Given two real vectors $\underline{v}, \overline{v} \in \mathbb{R}^n$ satisfying $\underline{v} \leq \overline{v}$, we define an *interval vector* $\mathbf{v} \in \mathbb{IR}^n$ as the set

$$\mathbf{v} = [\underline{v}, \overline{v}] = \{v \in \mathbb{R}^n : \underline{v} \leq v \leq \overline{v}\},$$

where $\underline{v}$ and $\overline{v}$ are the lower and upper bound of the interval vector $\mathbf{v}$, respectively.

Problem formulation. Consider a set of m *sources* (or supply centers) denoted by $I = \{1, \dots, m\}$ and a set of n *destinations* (or customers) denoted by $J = \{1, \dots, n\}$. Each source $i \in I$ has a limited *supply* s_i and each destination $j \in J$ is associated with a *demand* d_j to be satisfied. We assume that both of these quantities are uncertain and can vary within the given (non-negative) intervals $\mathbf{s}_i = [\underline{s}_i, \overline{s}_i]$ and $\mathbf{d}_j = [\underline{d}_j, \overline{d}_j]$, respectively. Finally, the interval $\mathbf{c}_{ij} = [\underline{c}_{ij}, \overline{c}_{ij}]$ denotes the uncertain *unit cost* of transporting goods from source i to destination j. The objective of the problem is to find a minimal-cost transportation plan for shipping goods from the sources to the destinations such that the supply and demand requirements are satisfied.

Given the interval supply and demand vectors $\mathbf{s} \in \mathbb{IR}^m$, $\mathbf{d} \in \mathbb{IR}^n$ and the transportation costs $\mathbf{c} \in \mathbb{IR}^{m \times n}$, the *interval transportation problem (ITP)* can be formally represented by the interval linear programming model

$$\begin{aligned} \text{minimize} \quad & \sum_{i \in I} \sum_{j \in J} [\underline{c}_{ij}, \overline{c}_{ij}] x_{ij} \\ \text{subject to} \quad & \sum_{j \in J} x_{ij} \leq [\underline{s}_i, \overline{s}_i], && \forall i \in I, \\ & \sum_{i \in I} x_{ij} = [\underline{d}_j, \overline{d}_j], && \forall j \in J, \\ & x_{ij} \geq 0, && \forall i \in I, j \in J, \end{aligned} \tag{ITP}$$

where the non-negative variable x_{ij} corresponds to the amount of goods transported from source i to destination j. Here, the interval transportation problem is understood as the set of all linear programs (transportation problems) with the cost, supply and demand vectors lying in the corresponding interval vectors $\mathbf{c}, \mathbf{s}$ and $\mathbf{d} \in \mathbb{IR}^n$. A particular linear program in the interval transportation problem, which is determined by a cost vector $c \in \mathbf{c}$, supply vector $s \in \mathbf{s}$ and demand vector $d \in \mathbf{d}$, is called a *scenario* of the ITP.

Feasibility and optimality. Several different notions of feasibility and optimality have been proposed and studied in interval programming [10]. In this paper, we adopt perhaps the most common one–the notion of weak feasibility and optimality. A given solution vector $x \in \mathbb{R}^{m \times n}$ is called a *(weakly) feasible solution* of (ITP), if it is a feasible solution for at least one scenario of the problem. Similarly, the vector x is a *(weakly) optimal solution* of (ITP), if it is an optimal solution for some scenario.

Regarding the optimal values, the traditional goal in interval programming is to determine the *optimal value range* $[\underline{f}, \overline{f}]$, which is the interval bounded by the *best optimal value* $\underline{f}$ and the *worst optimal value* $\overline{f}$. For (ITP), we have

$$\begin{aligned} \underline{f} &= \inf \{f(c, s, d) : c \in \mathbf{c}, s \in \mathbf{s}, d \in \mathbf{d}\}, \\ \overline{f} &= \sup \{f(c, s, d) : c \in \mathbf{c}, s \in \mathbf{s}, d \in \mathbf{d}\}, \end{aligned}$$

where $f(c, s, d)$ denotes the optimal value of a given scenario of (ITP), with $f(c, s, d) = \infty$ if the scenario is infeasible. Note that this definition yields $\overline{f} = \infty$ if there is at least one infeasible scenario. Thus, it may also be desirable to compute the *worst finite optimal value* $\overline{f}_{\text{fin}}$, which can be found as the worst optimal value over the feasible scenarios:

$$\overline{f}_{\text{fin}} = \max\{f(c, s, d) : c \in \mathbf{c}, s \in \mathbf{s}, d \in \mathbf{d} \text{ with } \mathcal{F}(s, d) \neq \emptyset\}.$$

3 WORST (FINITE) OPTIMAL VALUE

In [4], we proposed a decomposition by complementary slackness to describe the set of all weakly optimal solutions of (ITP) by linear systems in the form

$$\begin{aligned}
&\sum_{j\in J} x_{ij} \leq \overline{s}_i, && && \forall i \in I,\\
\underline{d}_j \leq &\sum_{i\in I} x_{ij} \leq \overline{d}_j, && && \forall j \in J,\\
&u_i + v_j \leq \overline{c}_{ij}, && x_{ij} = 0, && \forall (i,j) \in K,\\
&u_i + v_j = \overline{c}_{ij}, && x_{ij} \geq 0, && \forall (i,j) \notin K,\\
&\sum_{j\in J} x_{ij} \geq \underline{s}_i, && u_i \leq 0, && \forall i \in L,\\
& && u_i = 0, && \forall i \notin L,
\end{aligned} \tag{1}$$

for all subsets $K \subseteq I \times J$ and $L \subseteq I$ (the decomposition was modified accordingly for the formulation presented in this paper). Note that the number of systems can be reduced by considering basic optimal solutions only. Characterization (1) can subsequently be used to compute the worst finite optimal value $\overline{f}_{\text{fin}}$ of the problem by maximizing the worst objective with vector $\overline{c}$ (thanks to non-negativity of the variables) over this optimal solution set.

While naively solving the exponential number of linear programs with constraints (1) may be intractable in most cases, it is still worth considering utilizing the exact description in a more efficient way by handling the complementary slackness constraints differently and exploiting the available optimization tools. To solve the problem, we can for example reformulate it as a mixed-integer linear program and use the existing techniques and algorithms created to tackle NP-hard problems to obtain the exact (or near-optimal) solution. Furthermore, we can also limit the computation time and use the characterization to find an approximation of the worst finite optimal value. In the following section, we show that such a method can be competitive with other previously proposed heuristics for approximating the worst value.

4 COMPUTATIONAL EXPERIMENTS

We tested the efficiency of the proposed method for computing the worst finite optimal value $\overline{f}_{\text{fin}}$ on two sets of benchmark instances from [11]. First, a test on a smaller set of 5 instances of different sizes was performed against the heuristic algorithms designed by Liu [9], Juman and Hoque [8] and Xie et al. [11]. Second, a larger set of 60 instances was used to compare our method to Xie's algorithm (which provides the best-quality solution from the former methods) and the newer algorithm proposed by Cerulli et al. [1].

Our method was implemented in Python 3.8 and we used Gurobi 9.1 to solve the corresponding mathematical models. Instead of decomposing the problem at hand into linear systems (1) or providing the explicit mixed-integer programming formulation, we utilized indicator constraints supported by Gurobi and other solvers to ensure complementary slackness (e.g. if $x_{ij} > 0$ then the equation $u_i + v_j = \overline{c}_{ij}$ must hold).

The experiment was carried out on a computer with a 16 GB RAM and an Intel Core i7-8650U processor. The results for the other algorithms are taken from [11] and [1], and thus the running times are only indicative.

In the first experiment, we used the interval transportation problems of sizes 3×5, 4×6, 5×10, 10×10 and 20×20 taken from [11, Tables 2–11]. Note that the sizes denote the number of supply centers m and the number of destinations n, rather than the number of constraints and variables in the resulting linear program. The results of the experiment together with running times of the tested methods are shown in Table 1.

$m \times n$	Exact formulation	Xie et al. [11]	Liu [9]	Juman & Hoque [8]
3×5	9555	9555	8615	8615
	0 s	38 s	1 s	1 s
4×6	15060	15060	13235	13235
	0 s	51 s	1 s	12 s
5×10	13175	13175	9420	9330
	0 s	80 s	1 s	2 s
10×10	26350	26350	18840	18600
	1 s	127 s	1 s	3 s
20×20	9425 *	9405	9085	8210
	300 s	1686 s	1 s	11 s

Table 1: The worst obtained finite optimal values and running times (in seconds) of the four considered methods on instances of 5 different sizes from [11].
*The computation was terminated after 5 minutes.

For the instance sizes up to 10 supply centers and 10 destinations, the solver was able to compute the optimal solution almost instantly. The computed worst finite optimal value of the ITP was strictly higher than the values found by the two fast methods in all cases (the algorithm by Xie was also able to find the optimal solution, but it required more computation time). Thus, for the smaller instances, the formulation derived from (1) can be used to provide the value $\overline{f}_{\text{fin}}$ exactly, and in some cases even faster than a heuristic method.

As can be expected, the price for a high-quality solution of the problem rises with the larger instance sizes. However, even for the interval transportation problem with 20 supply centers and 20 destinations, after just one minute the solver was able to find a feasible solution (i.e., a weakly optimal solution of the ITP) with a value of 9350, which is already higher than the highest value computed by the other two fast methods. The computation was terminated after 5 minutes with the incumbent solution having a value of 9425, which is the highest obtained value of all four tested methods.

The second experiment was carried out on a set of 60 benchmark instances of 6 different sizes used in [11, Tables 13–18] and [1, Table 1]. The worst finite optimal values found by the respective algorithms and our exact formulation are presented in Table 2. For the exact formulation, the computation times are analogical to the ones shown in Table 1: the instances of sizes up to 10×10 were solved in 1 to 2 seconds (which is faster than the other two methods), while for the 20×20 instances the computation was terminated after 300 seconds.

Out of the 60 tested instances, the solution found using the proposed exact formulation (apart from the largest instances, this is the optimal value $\overline{f}_{\text{fin}}$) was strictly higher than at least one of the solutions found by the two heuristic methods in 15 cases, in 6 cases it was even higher than both of the other values. For the smaller instance sizes up to 10×10, the very short computation time is also an advantage of the exact method.

Size	Xie et al. [11]	Cerulli et al. [1]	Exact	Size	Xie et al. [11]	Cerulli et al. [1]	Exact
2×3	22800	22800	22800	5×10	25760	**25810**	**25810**
	27390	27390	27390		24980	**25055**	**25055**
	27390	27390	27390		19635	19635	19635
	27210	27210	27210		30260	30260	30260
	18570	18570	18570		23590	23590	23590
	30900	30900	30900		23075	23075	23075
	22020	22020	22020		22375	**22740**	**22740**
	18450	18450	18450		30000	30000	30000
	21450	21450	21450		24675	24675	24675
	14130	14130	14130		39985	39985	39985
3×5	16410	16410	16410	10×10	36180	36180	36180
	14820	14820	14820		43260	43260	43260
	20650	20650	20650		38915	38915	38915
	12940	12940	12940		38845	38905	**38915**
	16650	16650	16650		50150	50150	50150
	16540	16540	16540		29885	29885	29885
	10195	10195	10195		44100	**44145**	**44145**
	13360	12620	**13360**		41950	41950	**42420**
	11010	11010	11010		**37465**	37180	**37465**
	12915	12915	12915		48920	48920	48920
4×6	27125	27125	27125	20×20	9405	9405	**9425***
	20635	20635	20635		9015	9140	**9180***
	23615	23615	23615		9335	**9405**	9340*
	22375	22375	22375		8930	**9130**	**9130***
	19500	19500	19500		9275	**9420**	**9420**†
	11380	11380	11380		10220	**10320**	**10320***
	17245	17245	17245		8685	8630	**8700**†
	24180	24180	24180		9260	9260	9260*
	24060	24060	24060		9885	9885	9885†
	22825	22825	22825		9225	9220	**9350***

Table 2: The worst obtained finite optimal values of the three considered methods on 60 instances of the interval transportation problem of 6 different sizes from [11].
*The computation was terminated after 5 minutes.
†For three instances of size 20×20, the time limit was extended to 25 minutes (approximately the running time of the other two methods), since no solution was found within the original time limit.

5 CONCLUSION

We addressed the problem of computing the worst value optimal for some feasible scenario of an interval transportation problem. Using duality in linear programming and complementary slackness to describe the set of all weakly optimal solutions of the problem, we derived an exact method for computing the worst value. Although the method requires exponential time in the worst case, which is justified by NP-hardness of the considered problem, numerical experiments indicate that it can be competitive with the current heuristic algorithms for solving the problem. Moreover, even if the instance size is too large and the exact computation becomes intractable, the method can still provide a good approximation of the worst finite optimal value.

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THE INFLUENCE MONITORING PROBLEM

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Abstract: A new problem called influence monitoring is defined and studied for the Generalized Independent Cascade Problem. It is shown that the objective function of the problem is submodular by which the greedy algorithm can ensure an approximate ratio. The efficient implementation of the greedy method is described from algorithm design point of view.

Keywords: infection processes, influence maximization, greedy algorithm, network optimisation, network immunization

1 INTRODUCTION

The study of network infection processes plays an important role in several fields; in addition to epidemiology [9], it was successfully applied in sociology (spread of opinions) [8] or business and economics (marketing campaign [6] or risk management [3]) , to mention a few. The related research questions were formulated as a discrete optimisation problem in 2003 in the pioneering work of Kempe, Kleinberg and Tardos [10] The so-called influence maximization is defined by the following way: determine the most influential vertices in a directed edge-weighted graph (where edge weights are reflecting the infection probabilities) with respect to an infection process changing the status of the vertices according to a well-defined function of the incoming edges and incident vertices. Kempe et al proved that the problem is NP-hard, however for a wide class of infection processes the greedy algorithm provides a solution with a guaranteed approximation ratio. During the last 15 years the above work exposed an extraordinary interest in the scientific community and several generalization of the original problem were developed (for a review see e.g. [1]).

In this paper, instead of finding the most influential vertices, we will be focusing to identify those vertices through which the highest expected number of vertices are accessible in "infection chains". This "influence monitoring task" is different from the original problem, as the optimal solution is given by those vertices which are the best candidates to be "monitored" to decrease the influence of an infection process (instead of finding those vertices which are the most influential for an "outbreak"). Concerning the infection mechanism our study will concentrate on the generalization of the most widely used Independent Cascade model [6], however our approach can be generalized for all diffusion processes under the Generalized Threshold Model [10]. In this Generalized Independent Cascade Model each vertex has an initial "a priori" infection probability. We will prove that the greedy algorithm provides the same approximation factor as the influence maximization problem has and we will develop an efficient implementation of this method.

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The organization of this paper is as follows. In Section 2 we will present the necessary formal background on influence maximization and formally define the influence monitoring problem. In Section 3 as a main result we will develop the greedy method with all the technical details and will describe its approximability power. Finally, in Section 4 we will give a short conclusion. Because of space constraints proofs are omitted.

2 INFLUENCE MAXIMIZATION AND MONITORING

In this paper we will consider directed weighted general graphs. Our terminology will be standard, the set of vertices and set of edges will be denoted by $V(G)$ and $E(G)$, respectively. We are considering stochastic diffusion processes on networks (see e.g. [2]) in general, but because of space restrictions in this paper we will be focusing on one of the basic (and most popular) models, the Independent Cascade model. In this model the weight $w_{u,v} \in [0,1]$ for the edge (u,v) directed from u to v is expressing the probability by which u is forwarding the diffusion to v through this edge.

As an iterative process the *Independent Cascade (IC)* model [10] starts with a set S_0 of active vertices and in the i[th] iteration step the set of (previously inactive) vertices S_i will be activated by the vertices of S_{i-1}. The process will be terminated once S_i is empty. During the process a vertex u from S_{i-1} has a single chance to activate a neighbouring vertex v with probability $w_{u,v}$. If more than one vertex is trying to activate v in the same iteration, the attempts are realized in a random order and independently. The process is not deterministic, however the expected number $\sigma(S_0)$ of activated vertices can be used for a well-defined optimisation problem called *influence maximization* [10]: Given a positive integer k, find a set of vertex set S with size k such that $\sigma(S)$ is maximized.

Influence maximization is a hard problem, even for a fixed set S, the computation $\sigma(S)$ *is* #P-complete [5]. Nevertheless, in their pioneering paper Kempe et al [10] showed that by random sampling and direct simulation of the diffusion process, $\sigma(S)$ can be arbitrarily approximated. Furthermore, they have proved that using the greedy hill-climbing method (in each step choosing the vertex providing the largest marginal increase in $\sigma(S)$, the optimum can be approximated within a factor of $(1 - 1/e)$ (where e is the base of the natural logarithm). They have actually shown that the set function $\sigma(S)$ is a monotone nonnegative submodular function. This property of $\sigma(S)$ guarantees the above approximability by a classical result of Nemhauser et al [12]. A function that maps subsets of a finite ground set to real numbers is called *submodular* if the marginal gain by adding an extra element to a set S cannot be higher than the marginal gain by adding the same element to a subset of S. For more details about submodular optimisation see [11].

The IC model was generalized in [4] with assigning infection probabilities to the vertices as well. In the *Generalized Independent Cascade* (GIC) model the weighted directed graph is extended with *a priori infection probabilities* w_v for all $v \in V(G)$ and each vertex v becomes active independently with probability w_v at the beginning of the process. Having a random choice of infected vertices according to the a priori probabilities, the process is executed by the IC model. Concerning the stochastic feature of the model, at the end of the process an *a posteriori probability* w_v^* is obtained for each vertex v. As a generalization the sum of the values w_v^* provides the generalized function $\sigma(w)$. We will suppose that a graph G is given with infection probabilities on the edges as well as on the vertices for the rest of the paper.

With respect to the above stochastic process it can be a natural question to describe the "local influence" of vertices. Concerning the interpretation of the IC model an "instance infection" is a branching process (see e.g. [7] Chapter 21) an unweighted directed forest as an (unweighted) subgraph of G. Starting from the initially infected vertices a particular realization of infection in the cascade corresponds to a forest where each iteration will determine the next level of this forest. Therefore, concerning the whole stochastic process of G, it is a distribution of unweighted forests sampled from G. Each forest will be referred as a *forest instance infection* or simply *forest instance*.

Now considering a forest instance F and a vertex set $S \subseteq V(F)$, the *local influence value* $\mu_F(S)$ is defined as the number of descendants of S in F, i.e. the number of vertices accessible by a directed path from a vertex of S. Note that the elements of S are also counted in this manner (with paths of length zero). Finally, the *local influence index* $\mu_G(S)$ for the weighted graph G and $S \subseteq V(G)$ is the expected value of $\mu_F(S)$ for a random forest instance F in G. In this paper our goal is to optimize the local influence index:
In the *influence monitoring problem* for a given weighted graph G and positive integer k, determine the vertex set S with size k for which $\mu_G(S)$ provides the maximum value.

3 THE GREEDY ALGORITHM

We will be developing a greedy heuristic with a guaranteed approximation ratio. For that we are extending the concept of Kempe et al [10] for graph sampling with "live" and "blocked" edges (see also "complete simulation" in [4]). Concerning the attempt of infecting vertex v by vertex u with a probability $w_{u,v}$, we can consider it as flipping a coin of bias $w_{u,v}$ and generating unweighted edge to be "live" with probability $w_{u,v}$. Since each attempt is independent, we can "flip" for each edge independently and generating an unweighed graph instance. Concerning the result of GIC it has no relevance when the independent coin flips are realized, we can make it at the beginning of the process. In such a graph instance an infection from a vertex u to a vertex v is activated if and only if there exists a directed path from u to v. However, in contrast to influence maximization, in our influence monitoring problem the probability of activating by a particular edge in a graph instance is important (concerning multiple attempts to the same vertex); we will discuss it later.

Extending the sampling methodology of Kempe et al [10] by a *graph instance infection or graph instance* in short we will mean an unweighted graph sampling each edge *(u,v)* according to $w_{u,v}$ and determining initial activated vertices in a random manner according to a priori infection probabilities. Similarly to influence maximization and the original sampling of Kempe et al [10], graph G is equivalent to the a distribution of graph instances G' and $\mu_G(S)$ can be obtained as a linear combination of different $\mu_{G'}(S)$ values according to this distribution. The advantage of this approach is twofold. On one hand it provides a framework for approximating $\mu_G(S)$ by simulation (see complete simulation in [4]). On the other hand as linear combination of submodular functions is also submodular, it will be enough for an arbitrary graph instance G' that $\mu_{G'}(S)$ is submodular. As a consequence, by the results of [12] and considering the monotone and nonnegative properties of $\mu_G(S)$ we will get the guaranteed approximation for the greedy method.

Concerning the efficient implementation of the greedy method as well as proving submodularity of $\mu_{G'}(S)$ we will need to solve the following problem.

Problem 1. *Given a graph instance G' of G and* $S \subseteq V(G)$. *Determine a function* $\mu^*_{G'}(S, v)$ *which satisfies the following conditions for each vertex* $v \in V(G)$:

- $\mu_{G'}(S) = \sum_{v \in S} \mu^*_{G'}(S, v)$
- $\mu_{G'}(S \cup \{v\}) = \mu_{G'}(S) + \mu^*_{G'}(S, v)$ for each $v \in V(G) - S$

In order to solve the above problem, starting from the initially infected vertices of *G'* build up the directed breadth first search forest of *G'*. We will keep those edges only which are connecting two neighbouring levels of the forest. This reduced graph will be denoted by *BF[G']* and the set of edges of *BF[G']* is denoted by *BF[E']*. This graph is representing the collection of potential infection instances by IC in *G'* in such a way that the initially infected vertices are on $level_1$. Vertices in $level_2$ will be infected from $level_1$ and generally the vertices in $level_{i+1}$ are infected from $level_i$.

Suppose now that we have *r* levels in *BF[G']*. Clearly, for any vertex *v* in $level_r$, $\mu^*_{G'}(S, v) = 1$. Notice that starting from $level_r$ we can recursively backward calculate $\mu^*_{G'}(S, v)$. Indeed, if the indegree of *v* is *d*, then the infection can be realized by any incoming edge to *v* with probability *1/d*. By this observation it is easy to organize the calculation, which is described described in details in Algorithm 1.

Algorithm 1

Input: Breadth-first reduction *BF[G']* of graph instance *G'* with *r* levels and dedicated vertex set $S \subseteq V(G')$
Output: For each vertex $v \in V(G')$ the value of a function $\mu^*_{G'}(S, v)$ satisfying conditions described in Problem 1

```
 For each vertex v at level_r let μ*_G'(S,v) = 1
for i=r downto 2 do
  for each vertex v at level_i
       for each incoming edge (u,v)
              let label_{u,v}=1/d (where d is the indegree of v in BF[G']
  for each vertex u at level_{i-1}
       μ*_G'(S,u) = 1 + Σ_{u'∉S&(u,u)'∈BF[E']} label_{u,u'} · μ*_G'(S,u')
end for
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It can be proved by induction that the function $\mu^*_{G'}(S, v)$ produced by Algorithm 1 has the required properties as summarized below.

Proposition 1. *For each* $v \in V(G')$, *the function* $\mu^*_{G'}(S, v)$ *in Algorithm 1 satisfies the conditions of Problem 1 and the method runs in linear time of E(G').*

Analyzing Algorithm 1, based on the conditions defined in Problem 1 we can obtain the submodular property.

Proposition 2. *Function* $\mu_{G'}(S)$ *is submodular.*

As discussed earlier, the submodularity of $\mu_G(S)$ follows from Proposition 2 and it is also clear that $\mu_G(S)$ is monotone and non-negative.

Corollary 1. *Function* $\mu_G(S)$ *is monotone, non-negative and submodular.*

By Corollary 1 we can design the greedy method with guaranteed approximation described in Algorithm 2. Note that instead of the mean value we are using the sum for $\mu_G(S, v)$ in order to simplify calculation.

Algorithm 2

Input: Weighted graph G and positive integer k
Output: Vertex set S with cardinality k by greedy with respect to $\mu_G(S)$
Let $S = \emptyset$
For $i=1$ **to** k **do**
  Generate graph instances
  For each graph instance G' and for each vertex $v \in V(G)$, calculate $\mu^*_{G'}(S, v)$ according to *Algorithm 1*
  Let $\mu^*_G(S, v)$ be the sum of the $\mu^*_{G'}(S, v)$ values of all graph instances for each vertex $v \in V(G)$
  Let $S = S \cup \{v\}$ with v having maximum in $\mu^*_G(S, v)$
end for

Now we can summarize our finding by a direct consequences of the previous results.

Theorem 1. *Algorithm 1 provides a solution approximating the influence monitoring problem within a factor of* $(1 - 1/e - \varepsilon)$*, where where e is the base of the natural logarithm and ε is an arbitrary small positive number depending on the simulation.*

Note that the scale of approximation can depend on the simulation (the number and distribution of the graph instances), however, similarly to the influence maximization problem [10], this gap can be arbitrarily small.

4 CONCLUSION

In this paper we have introduced the influence monitoring problem for the Generalized Independent Cascade Model. We have proved that the objective function for this problem is nonnegative, monotone and submodular, thus using the classical result of Nemhauser et al, it is shown that the greedy method provides a solution within an approximation factor of $(1 - 1/e - \varepsilon)$, where where e is the base of the natural logarithm and ε is an arbitrary small positive number depending on the simulation. As a further research we are extending the results for a wider class of problems and will show the efficiency of the methodology with a comprehensive testing on artificial and real networks.

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BITCOIN PRICE DIRECTION FORECASTING USING NEURAL NETWORKS

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Abstract: This paper compares feedforward neural networks and logistic regression for Bitcoin direction forecasting, i.e. predicting whether the prices will go up or down in the next trading day. It uses and compares different internal and external factors from 2016 to 2021 to investigate if they can successfully predict direction of Bitcoin price movements. This paper contributes to the existing literature by defining the appropriate model for Bitcoin direction forecasting, by assessing the forecasting ability of different assets and by comparing the results through different periods including bearish, bullish and stable market conditions.

Keywords: attractiveness, Bitcon, logistic regression, neural networks, macro-finance factors

1 INTRODUCTION

Cryptocurrencies have attracted attention since the moment of their appearance, and especially in the last few years. Numerous research confirmed them as an asset class ([2]; [16]) as well as their contribution to portfolios in terms of Markowitz diversification ([18]; [15]). Its role as a hedge and/or safe heaven is analysed and the results indicate that cryptocurrencies can serve primarily as a diversifier ([6]; [4]), although some research found their hedge and/or safe haven properties in short investment horizons, for some specific assets or markets ([4]; [8]). Moreover, there are research trying to predict either cryptocurrency prices ([11]; [20]; [12]; [21]; [7]; [14]; [13]; [23]; [17]), volatility [24], returns ([19]; [1]; [16]; [3]) or direction ([9]; [22]; [13]; [17]; [5]). The direction forecasting, i.e. classification whether the Bitcoin prices will go up or down in the next trading day, is the main scope of this paper. Namely, Ji et al. [13], using profitability analysis, proved that classification is more effective than regression models for algorithmic trading, while Pabuçcu et al. [17] shown better model performances with classification rather than prediction.

Among the first papers that predicts Bitcoin price direction is Greaves and Au [9] who compare Support Vector Machine (SVM), Logistic regression (LR), Baseline model and Feedforward Neural Networks (FNNs). They obtain the highest classification accuracy of 55.1% with FNNs. On the other hand, Spilak [22] uses FNN, Recurrent NN (RNN) and a Long-Short Term Memory (LSTM) models to predict price directions of 8 cryptocurrencies. He finds that LSTM has the best accuracy for predicting direction for 5 most important cryptocurrencies and FNN for other 3. He obtained the accuracy of 51% on test set. Ji et al. [13] compare deep neural network (DNN), LSTM, convolutional NN (CNN), deep residual network, SVM, Gated Recurrent Units (GRU), linear and LR models for Bitcoin price prediction. LSTM slightly outperformed other models for price prediction, while DNN performed the best for classification. Pabuçcu et al. [17] forecast Bitcoin prices applying SVM, FNNs, Naïve Bayes (NB), Random Forest (RF) and LR. Empirical findings reveal that, RF has the highest forecasting accuracy for prediction, while FNN for classification. Chen et al. [5] use LR and Discriminant Analysis (DA) to achieve an accuracy of 66%, outperforming more complicated machine learning algorithms including RF, XGBoost, Quadratic DA, SVM and LSTM. However, previous research includes mostly bullish or stable market conditions, while the predictions in bearish markets and the crisis periods are not investigated. This paper compares different market conditions including the COVID crisis.

Moreover, this paper uses three-layered FNN for classification. Namely, FNNs are the most commonly used NNs with a property of "the universal approximator of any functional form of relationship between the observed variables" [10]. They can estimate the output with a high degree of accuracy, enabled by their flexible but also complex structure. In this paper, most of the NN structure parameters is held constant while the number of input and hidden neurons are varied to obtain the optimal NN with high out-of-sample classification accuracy. However, the choice of inputs is not straightforward. There can be distinguished internal and external factors as cryptocurrency price drivers [20]. Supply and demand (transaction cost, reward system, mining difficulty, coins circulation, rule changes) are the main internal factors while attractiveness, market trend, speculations, legalization, restrictions and macro-finance factors as external drivers. Most of the papers use the internal factors for prediction ([19]; [12]; [21]; [16]; [22]; [7]; [13]; [5]). Open, high, low, close prices ([11]; [7]; [23]) as well as only past closing prices ([3]; [1]) or technical indicators are used as predictors ([11]; [22]; [17]). Moreover, majority of the papers confirm the attractiveness as an important factor that influences cryptocurrency prices ([19]; [21]). Few papers use macro-finance factors ([19]; [21]; [16]; [22]; [5]) and report the lack of statistical significance if used in parametric models. Contrary, economic activity is found to be the most important exogenous volatility driver [24]. However, due to unfulfilled assumptions of the financial and macroeconomic time series, i.e. non-normality and nonlinearity, using linear parametric models is not suitable and leads to misinterpretation of the influence of certain variables and inability to predict properly the dependent variable of interest. Therefore, NNs should be used due to relaxed model assumptions. This paper compares different internal and external factors in their predictive power.

This paper contributes to the existing literature in several ways. Firstly, by defining the appropriate model for Bitcoin direction forecasting which yields better prediction accuracy compared to the benchmark model and to other empirical research that used more complex models. Secondly, by assessing the forecasting ability of different factors as a group and individually. Finally, by comparing the results through different periods including bearish, bullish and stable market conditions, as well as including the recent COVID crisis.

The remainder of the paper is organized as follows. Section 2 describes the data and methodology. Section 3 presents empirical findings with discussion of the results. Finally, conclusions and directions for future research are provided in Section 4.

2 DATA AND METHODOLOGY

From the apearance of Bitcoin to 2017 the market was characterised by a sluggish movement of prices and volumes (Figure 1). The first surge started in 2017. After a significant peak at the end of 2017 the prices dropped sharply at the beggining of 2018, followed by the intensive trading period. Continuous fluctuations in Bitcoin prices remained until the end of 2019 but with rather stable market conditions. Beggining of 2020 was characterised by a significant slump in prices due to the unknown circumstances of COVID crisis. Hovewer, the market recovered fast and experienced a significant upward trend in the 2020 that continued in 2021. Based on different features of price movements in different periods the dataset is divided into four subperiods, i.e. from 4.2016 to 12.2017 for training and the first 100 days in 2018 for testing, from 4.2016 to 12.2018 for training and the first 100 days in 2019 for testing, from 4.2016 to 12.2019 for training and the first 100 days in 2020 for testing and from 4.2016 to 12.2020 for training and the first 100 days in 2021 for testing. The prediction in bearish market is considered in 2018, stable market in 2019, crisis period in 2020 and bullish market in 2021.

Figure 1: All-time Bitcoin prices and volumes
Source: https://coinmarketcap.com/currencies/bitcoin/ [12.05.2021]

FNN and LR are used for prediction whether Bitcoin prices will go up (1) or down (0) in the next trading day. Bitcoin log-returns from previous period have all the models along with returns on gold, oil, S&P500, REIT, VIX, USDEUR, 3-month Treasury bills, 10-Year Treasury bond and attractiveness as exogenous inputs are used in FNNs and LR in model 1. Models from 2 to 10 have only one of external factors. Market capitalization, 30-days volatility, total issuance, free float supply, current supply, mean tx fee, mean hash rate, mean difficulty and mean block size as exogenous inputs are used in model 11. Models from 12 to 20 have only one of internal factors, while model 21 has 10 inputs that had high accuracy in most models (gold, S&P500, VIX, attractiveness, market capitalization, 30-days volatility, total issuance, mean tx fee, mean hash rate, mean difficulty) (Table 1). Internal factors are retrieved from Coinmetrics (charts.coinmetrics.io/network-data), macro-financial data from FRED (fred.stlouisfed.org) and attractiveness from Google trends (trends.google.com/trends), from April 2016 to April 2021. Variables are transformed to log-returns to become stationary. Only attractiveness is not transformed using log-returns since it is available at weekly basis and that transformation would yield to lots of zeros.

LR is estimated using *glm* function in *R*. The logistic function is:

$$P(A) = \frac{e^{\beta_0+\beta_1 x_{t,1}+\beta_2 x_{t,2}+\ldots+\beta_p x_{t,p}}}{1+e^{\beta_0+\beta_1 x_{t,1}+\beta_2 x_{t,2}+\ldots+\beta_p x_{t,p}}} \tag{1}$$

where $P(A)$ is the probability that Bitcoin prices will go up. The goal is to obtain parameters β_i, $i = 1,2,\ldots,p$. Denoting $g(x) = \beta_0 + \beta_1 x_{t,1} + \ldots + \beta_p x_{t,p}$ and applying logistic transformation, a linear relationship between the log-odds and independent variables is:

$$\ln \frac{P(A)}{1-P(A)} = \ln \frac{\frac{e^{g(x)}}{1+e^{g(x)}}}{1-\frac{e^{g(x)}}{1+e^{g(x)}}} = \ln e^{g(x)} = g(x) = \beta_0 + \beta_1 x_{t,1} + \beta_2 x_{t,2} + \ldots + \beta_p x_{t,p} \tag{2}$$

FNN forwards information from inputs though hidden neurons to output, using weights and activation functions to connect consecutive layers. Backpropagation learning algorithm is used to estimate the weights. FNN in (3) is estimated using *nnet* function in *R:*

$$y_t = f\left(w_{co} + \sum_{h=1}^{q} w_{ho} f\left(w_{ch} + \sum_{i=1}^{p} w_{ih} x_{t,i}\right)\right) + \varepsilon_t, \tag{3}$$

where y_t is the output vector of a time series, i.e. dependent variable, x_t is the input matrix with p variables, while $f(\cdot)$ is logistic activation function. Weights w_{co} and w_{ch} are constant terms of output and hidden neurons respectively. Weights w_{ih} and w_{ho} are the connections between inputs and hidden neurons and between hidden neurons and output respectively. ε_t is an error term. FNNs are estimated by modifying inputs and hidden neurons. The grid search of 5, 10, 15, 25 and 50 hidden neurons is used to find the optimal FNN. Other NN parameter specifications are held constant, i.e. learning rate is 0.00001, maximal number of iterations is 10000 and initial weights are chosen at random.

3 RESULTS AND DISCUSSION

In 2018 most of the models did not successfully predict the Bitcoin price direction (Table 1.1). However, in bearish period attractiveness and 30-days volatility can be satisfactory predictors with 60% testing accuracy. Also gold and mean hash rate predicted Bitcoin price direction quite precisely.

Most of the models predicted Bitcoin price direction extremely well in 2019 (Table 1.2), with most of accuracies being over or equal to 55% which is higher than reported in empirical research ([9]; [22]). The highest prediction accuracy of 62% is achieved with 10-year Treasury bonds, 61% with total issuance and mean hash rate, while gold, S&P500 and VIX achieved accuracy of 59%. Mean difficulty and 30 days volatility performed also good.

In 2020, most of the models could not predict the downward trend (Table 1.3). However, attractiveness predicted Bitcoin direction well (59% accuracy) as in [19]; [21]. Internal factors performed poorly.

Most of the models predicted quite well Bitcoin price direction in 2021 (Table 1.4). The highest accuracy of 60% is reached with VIX while internal factors showed better results, especially market capitalization, 30-days volatility, total issuance and mean tx fee.

LR in only 2 cases outperformed FNN. Finally, including both internal and external factors with only 5 neurons led to high prediction accuracy (61-62%) no matter the period.

4 CONCLUSION

In this paper, FNN and LR are compared to investigate their ability to forecast Bitcoin price direction, i.e. to predict whether the prices will go up or down in the next trading day. Different internal and external factors are used in period from 2016 to 2021. The resarch confirmed the ability of a simple FNNs with lower number of hidden neurons to accurately predict the Bitcoin price direction, compared both to previous research and to LR, reaching the highest prediction accuracy of 62% with a combination of internal and external factors in all periods. The attractiveness is confirmed as the best predictor in bearish and COVID crisis periods. Gold, S&P500, VIX and 10-year Treasury bonds are good predictors in stable market conditions, while in bullish market VIX has good predictive power. Market capitalization, mean hash rate and total issuance stand out as good predictors in most periods.

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Table 1: Out-of-sample accuracy for different variables and hidden neurons in FNN and LR in four different periods

	h	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
100 days in 2018	5			0.49	0.50	0.50	0.51			0.51		**0.55**	0.48	0.52	0.52	0.53		0.49	0.51	0.50	0.50	**0.61**
	10	**0.58**	0.47	0.48	0.50	0.53	0.54		0.48		0.54	**0.56**	0.47	0.50	0.45	0.49		**0.59**	0.49	0.48	0.50	0.53
	15	0.47	0.45	**0.56**	0.50	0.44	0.49	0.52	0.49		**0.60**	**0.58**	0.54	0.49	0.41	0.50	0.50	**0.59**	0.57	0.50	0.51	**0.56**
	25	0.52		0.50	0.50	0.48	0.54		0.49		**0.56**	0.52	**0.59**	0.50	0.46			**0.59**	0.46	0.50	0.51	0.45
	50	0.51		0.51	0.50		0.52		0.48		0.41	0.51	**0.60**	0.49	0.44			0.52	**0.57**	0.50	0.48	0.51
	LR	0.52		0.50	0.50				0.50	0.50	0.50	0.54	0.50		0.52	0.50	0.50	0.52	0.50	0.50	0.50	**0.55**
100 days in 2019	5	**0.55**	**0.56**	**0.55**	**0.56**	0.53	**0.57**		**0.57**	**0.58**	**0.56**	0.47	0.47	**0.55**	0.52			0.54	**0.56**		0.53	**0.61**
	10	0.46	**0.55**	**0.55**	**0.57**	0.55	**0.58**		0.53	**0.56**	**0.56**	0.47	0.49	**0.56**	0.53	**0.57**		0.51	**0.57**	**0.55**	0.49	0.54
	15	**0.55**	**0.56**	**0.59**	**0.56**	0.53	**0.59**	0.54	0.54	**0.57**	**0.56**	0.48	0.54	**0.58**	0.50	**0.55**	0.53	**0.55**	0.51	**0.56**	0.54	0.54
	25	0.43	**0.58**	**0.58**	**0.55**	**0.58**	0.46	0.54	0.52	**0.61**	**0.56**	0.47	0.54	**0.55**	**0.60**	0.52	0.53	**0.58**	0.50	**0.57**	0.50	**0.55**
	50	0.54	**0.56**	**0.57**	**0.59**	**0.56**	0.51	0.54	0.52	**0.62**	0.48	0.48	0.50	**0.55**	**0.61**	0.50	0.53	0.49	**0.61**	**0.56**	0.45	0.44
	LR	**0.58**	**0.55**	**0.55**	**0.55**	**0.56**	**0.55**	**0.55**	**0.55**	**0.55**	**0.55**	0.48	0.50	**0.55**	0.53	**0.55**	0.53	0.53	**0.55**	**0.55**	0.55	0.47
100 days in 2020	5	0.52	0.52	0.50	0.49	0.52	0.50	0.52	0.52	0.51	0.48	0.47	0.46	0.48	0.53	0.51		0.53	0.54	0.51	0.48	**0.61**
	10	0.51	0.48	0.53	0.53	0.51	0.45	0.54	0.51	0.51	0.49	0.47	0.45	0.47	0.54	0.51	0.50	0.51	**0.55**		0.46	0.44
	15	0.52	0.49	**0.55**	0.54	0.53	**0.57**	0.52	0.49	0.54	0.45	0.48	0.47	0.46	0.47	0.53	0.53	0.43	0.50	0.51	0.52	0.52
	25	0.51	0.51	0.50	0.54	0.51	0.50	0.52	0.46	0.47	0.50	0.47	0.52	0.46	0.54	0.51	0.53	0.53	0.48	0.53	0.54	0.41
	50	0.50	0.50	0.54	**0.56**	0.53	0.52	0.51	0.54	0.49	**0.59**	0.48	0.47	0.54	0.50	0.51	0.54	**0.55**	0.51	0.54	**0.57**	0.44
	LR	0.49	0.51	**0.55**	0.52	**0.55**	0.52	0.52	0.52	0.51	0.52	0.47	0.45	0.52	0.50	0.51	0.51	**0.55**	0.52	0.52	0.52	0.50
100 days in 2021	5		**0.55**	0.49	0.54	**0.57**	**0.57**	0.54	0.49	**0.58**		0.47	**0.61**	**0.60**	0.52	0.54	0.53	0.54	0.47	0.54	**0.55**	**0.62**
	10	**0.60**	0.54	0.51	**0.56**	**0.55**	**0.60**	0.54	0.46	**0.58**	0.44	0.47	0.54	**0.56**	**0.60**	**0.55**	0.54	**0.57**	0.49	**0.55**	**0.55**	**0.60**
	15	**0.55**	0.54	**0.55**	**0.56**	0.53	0.52	**0.56**	0.53	0.53	0.42	0.48	**0.60**	**0.56**	**0.55**	0.53	0.52	0.47	0.54	**0.55**	0.51	0.47
	25	0.54	0.54	0.53	**0.56**	0.54	**0.60**	**0.56**	**0.56**	**0.55**	0.49	0.47	**0.57**	**0.57**	0.54	**0.55**	0.53	**0.60**	0.49	0.52	0.46	0.47
	50	0.45	**0.56**	**0.56**	0.54	**0.57**	**0.56**	0.54	**0.55**	**0.56**	0.48	0.48	**0.63**	**0.55**	0.54	0.53	0.53	**0.55**	0.54	0.54	0.48	0.48
	LR	**0.55**	0.54	0.54	0.54	**0.56**	0.53	0.54	**0.57**	0.53	**0.55**	0.52	**0.58**	0.52	0.53	0.53	0.53	**0.55**	0.53	0.54	0.52	**0.58**

Source: authors' calculations in R

Note: Bitcoin log-returns from previous period are included in all models. Model 1 has also returns on gold, oil, S&P500, REIT, VIX, USDEUR, 3-month Treasury bills, 10-Year Treasury bond and attractiveness. Models 2-10 have only one of external factors. Model 11 has market capitalization, 30-days volatility, total issuance, free float supply, current supply, mean tx fee, mean hash rate, mean difficulty and mean block size. Models 12-20 have only one of internal factors. Model 21 has 10 inputs that had high accuracy in most models (gold, S&P500, VIX, attractiveness, market capitalization, 30-days volatility, total issuance, mean tx fee, mean hash rate, mean difficulty)

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EFFECTIVE DECISION MAKING IN LOCAL GOVERNMENT USING THE HYBRID APPROACH BASED ON MULTI-CRITERIA DECISION-MAKING METHODS AND MACHINE LEARNING

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Abstract: This paper deals with making decisions in local government units in the case of evaluating the projects of non-governmental organizations (NGOs) in the city of Zabok. There are 18 active NOGs in the city and they send their proposals to the city and depending on the quality of the proposals, the city determines the budget size they will fund. There are 17 criteria in the process of evaluation. The process requires the participation of experts that are capable of evaluation, and the city faces certain issues regarding the experts: it is hard to find them, and there is no budget to pay them. Additionally, the multi-criteria decision-making (MCDM) methods used in the process of evaluation are complex, and the process is time-consuming. In this paper, the combined MCDM & machine learning approach is used. There are several benefits of using the proposed approach. The approach applies long-term knowledge about the applicants in the evaluation of projects which is in the line with the rules of the public call. Also, the number of experts is now decreased since the neural network contains experts0 knowledge.

Keywords: local government, decision making, multi criteria decision making, SNAP, neural networks

1 INTRODUCTION

The decision-making process in local/regional government units is the most often task in local government units. The decisions are made in all departments. The decisions are primarily focused on citizens who live in local government units, which can act individually or organized through non-government organizations (NGOs). This paper deals with the decision making process in the City of Zabok in Croatia. The focus is on funding the NGOs in Zabok. This cooperation between government units and citizens is an essential aspect of implementing structured dialogue [1].
This paper is structured as follows. Section 2 contains the background of the topic that covers the context and state of the art. Section 3 describes the methodology of the proposed hybrid approach. Section 4 contains the demonstration of the hybrid approach implementation in the case of the City of Zabok. Section 5 presents a discussion of the results.

2 BACKGROUNDS: THE CONTEXT AND STATE OF THE ART

Supporting the NGOs in terms of finance is a yearly activity of most local and regional government units. The support is, in most cases, a vital financial resource for NGOs. Due to many reasons, limited financial resources must be correctly and fairly distributed to NGOs. The process of financing NGOs is roughly divided into several phases [2]:

1. The government unit publishes a public call for NGO projects. The public call contains all information essential for applicants on preparing proposals, deadlines, and different legal aspects of the call.
2. NGOs create project proposals and send them to the government units before the deadline, respecting the instructions.
3. After the proposals arrive at the government unit, the process of their evaluation starts. This process can be divided into several steps (formal checks, quality checks, requests for upgrading the proposals). In this process, the proposals should be evaluated by experts respecting different criteria. The output of this phase is a list of projects that will be supported with the amount of financial support that can be allocated to each accepted project. The amount of the financial support depends on the legible and eligible costs in the financial plan as well as the quality of the project proposal. The criteria that can be covered in the evaluation phase can include:
   a. The capabilities of the applicant to implement the project (including project partners if the project is planned to be implemented in partnership),
   b. The successfulness of the applicant in conducting the projects in previous years,
   c. The level in which the project activities meet the priorities of the public call,
   d. Project quality, relevance, feasibility,
   e. Budget of the project,
   f. Other criteria.

   To ensure higher level of objectivity in evaluating the projects, it is recommended that several experts participate in project evaluations.
4. The final decision on projects funding.
5. Projects' implementation.
6. Reporting on project implementation.

From the perspective of government units, the complexity of the decision-making projects is related to two aspects: the multi-criteria character of the decision-making problem and experts. Government units often face different challenges in that process. Some of them are:

- The availability of experts to participate in the evaluation process is often low.
- The costs of experts that participate in the evaluation process can be high. In many cases, government units do not have money for this purpose.
- The methods that can be helpful in terms of evaluation (ex. the analytic hierarchy process AHP, the analytic network process ANP, …) are often very complex.
- The evaluation process is time-consuming.

In this paper, we propose a hybrid approach to deal with those challenges. The approach is not entirely novel – there are already hybrid approaches that combine multi-criteria decision-making methods with data mining techniques (such as neural networks). Combined AHP and ANN models are providing decision support systems in the domain of machine tools selection [3], [4], for heart failure prediction [5], ANN serves as a tool for supporting the decision-making process [6].

However, there are several novelty aspects in the proposed approach:

1. The application field of the hybrid approach is new: currently, known hybrid approaches are applied in different fields than local government fields.
2. In the hybrid approach, we use a multi-criteria method called SNAP (social network analysis process) instead of using more known methods, such as AHP or ANP. The SNAP has several advantages when compared to other methods in terms of complexity.

3 THE METHODOLOGY

The problem of selecting the NGOs that will get the financial support and determining the size of the support is primarily a multi-criteria decision-making problem. At first sight, there is no need to combine some multi-criteria decision-making methods with data mining techniques because the multi-criteria method can deal with all aspects of the problem. Indeed, the multi-criteria methods are already applied for the purposes which are similar or the same as in this paper [7].

However, if we want to deal with all challenges described in Section 2, then the hybrid approach is mandatory. Multi-criteria methods can be used to evaluate the projects each year, but then, each year, we need to engage experts to participate in the evaluation process. If we do not pay them, they will not agree to participate again and again. Also, in terms of criterion 2 from the previous section, if change experts from year to year, a new expert cannot adequately evaluate that criterion because they do not have the experience with applicants in terms of previous projects. Therefore, combining the multi-criteria methods with the data mining technique (neural network) is welcome. In new cycles of funding, when the hybrid approach is applied, the network will contain experts' knowledge, and it is not needed that in future implementations of the model, we repeatedly include new (or same) experts again. Additionally, the model contains long-term knowledge about the criteria and alternatives of the problem (among which are information related to criterion 2).

Several multi-criteria methods can be used here: voting methods, ranking methods, simple additive weighting method, the AHP, Electre, Prometheus, the ANP, and others. More straightforward methods are used when we have a situation in which there are no dependencies between the criteria in the decision-making problem. In our case, we have those influences, so we must use a multi-criteria method that can deal with the influences, such as ANP [8]. The ANP is a very complex method. There are many unfavorable characteristics of it [9], and they were the reason why new methods, called SNAP, are created [10], [11]. The SNAP is partly based on ANP [12], and it includes the application of the PageRank centrality [13]. It also diminishes most of the unfavorable aspects of the ANP.

To conclude this section, the proposed hybrid approach has the following steps:

1. The multi-criteria analysis based on SNAP combined with normalization using the composite index:
   a. Determining criteria weights:
      i. The starting point is a matrix of influences between the criteria from the call, $\boldsymbol{C}$ (17 criteria in total)
      ii. In the second step, we are dividing each value from the previous matrix with the maximum sum of columns, which is increased by 1, matrix $\boldsymbol{S}$
      iii. Calculate $\boldsymbol{G = \alpha \cdot A + (1 - \alpha) \cdot E, \alpha = 0.85}$
      iv. Calculate the matrix $\boldsymbol{I - G}$.
      v. Then we calculate the inverse of matrix $\boldsymbol{I - G}$.
      vi. Multiplication of $\boldsymbol{G}$ and $(\boldsymbol{I - G})^{-1}$
      vii. Calculation of the sum of rows (ΣR) and columns (ΣC) of $\boldsymbol{G}(\boldsymbol{I - G})^{-1}$ and their difference, $\boldsymbol{d}$. The difference should then be normalized. There are several ways to do it: using the absolute value of the smallest value (difference) or any other higher number. Increasing the normalization value will result in more minor differences between the priorities on end. When the normalization value, $\boldsymbol{n}$, is chosen, it should be added to differences, $\boldsymbol{d + n}$. All values are positive, and it is possible to calculate the criteria weights (normalization by sum).

b. Determining the local priorities of the alternatives. To do this part, we can apply some of the regular procedures for alternatives' normalization, such as normalization using the minimum value, normalization using the maximum value, normalization to 0-1 range, Euclid normalization, pairwise comparisons normalization, or others.
c. Calculate the alternatives' final priorities using the composite index approach (as in the simple additive weighting (SAW) method).

2. Data mining analysis using the neural network approach (ANN):
   a. Creating the ANN structure (selecting network type, creating network geometry).
   b. Learning process (preparing learning data, training the neural network based on results of the first phase – now, the network will 'learn' all information about experts' opinions in terms of alternatives evaluation).
   c. ANN application (model deployment, using the model by adding data about new project proposals. This part is to be implemented in the second public call.

Due to the limitation of the paper, known approaches such as the neural network, normalization, and composite index are not detailed described.

To conclude the methodology, when the government unit decides to use this approach, in the first year, the first step of the methodology is applied, and in the following years, the second part of the approach is applied: the network will acquire knowledge from the first call and being upgraded with new proposals. This will result in decreasing the number of experts needed to participate in the evaluation. Also, the knowledge about the quality of proposals and implementations from previous years will be implicitly included in decision making to obtain priorities in the current call.

4 THE APPLICATION OF THE APPROACH IN THE CASE OF THE CITY OF ZABOK

In the case of the City of Zabok (public call: financing the NGOs), we will demonstrate a hybrid approach that is proposed in this paper. There are 17 criteria that are important in terms of public call:

1. Applicant experience and professional capacity to implement the project.
2. Experience and professional capacity to implement the project of partners.
3. Management experience of project consortium and inclusion of volunteers.
4. Definition of project team and definition of obligations of team members.
5. Relevance of the project for the goals of the public call.
6. Definition and feasibility of project goals.
7. Feasibility of project activities.
8. Clarity of results and their feasibility of implementing the activities.
9. Definition of project users.
10. Solving users' problems.
11. The exploitation of the project.
12. Applicability of projects' methodology in other government units.
13. The reality of costs.
14. Costs and activities compliance.
15. Participation in previous public calls.
16. Participation in Zabok priorities.
17. New priorities definition.

The criteria weights were obtained using SNAP. In the first year, 18 projects (alternatives) were applied. In the case of the City of Zabok, each year, almost the same NGOs apply projects.

All 18 projects were evaluated, and local priorities (priorities respecting each criterion) were obtained. Finally, the total priorities of the alternatives were obtained using the composite index approach.

In the second year, firstly, the ANN network is trained. Figure 1 presents the structure of the neural network. As parameters of quality of the predictive model, we observed R-square measure for the reliability of the model and Root Mean Square Error (RMSE) as a model error. The parameters are given in Table 1. The predictive model is highly reliable, and the model has a low error rate.

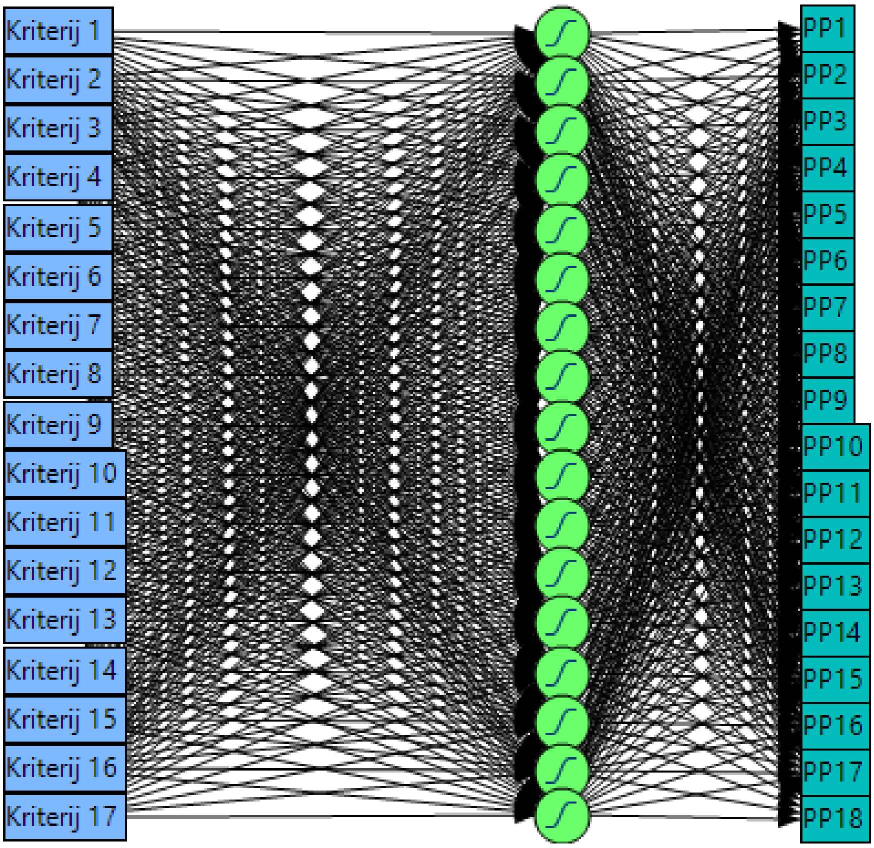

Figure 1: The structure of the neural network in the case of the City of Zabok

Table 1: Parameters of quality of the predictive model

Measures	***Value***
RSquare	0,9298407
RMSE	0,0512665
Mean Abs Dev	0,044018
-LogLikelihood	-7,758896
SSE	0,0131413
Sum Freq	5

Now, when the network is reliably trained, we can use it for a new public call for predicting projects` priorities by a single decision-maker saving time and effort for the new decision making process. In software SAS JMP 15, by using the function Prediction profiler, we can, by including only one expert, evaluate all new projects. The benefit of the profiler is to facilitate the selection process in terms of effort and time-saving for decision-makers, which is also emphasized in [14]. In addition, a new city that is in choosing stage of NGO projects can use the proposed ANN unless the proposed AHP structure is not significantly different.

5 DISCUSSION AND CONCLUSION

In this paper, we proposed a hybrid approach for more effective decision making in local government (financing NGOs) as a possible solution to the lack of experts needed for the evaluation of project proposals. This is the early phase of the approach, and improvements can be designed in future research. The approach can be correctly evaluated in several cases through a 2-public calls period: In the first call, we apply the multi-criteria analysis. In the following call(s), we can apply both multi-criteria analysis again and neural networks analysis – and finally, compare the results obtained. Potential problems of the approach are related to the possible low understanding of the methods in the approach which can influence the approach acceptance (skepticism). One limitation of the research is related to the fixed number of criteria and applicants which might not have to be the case in all LGUs.

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SIX WAYS HOW TO DEFINE ROBUST PARETO OPTIMALITY UNDER DOUBLE INTERVAL UNCERTAINTY

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Abstract: We deal with a multiobjective linear programming problem that is subject to a double uncertainty. In both cases, we consider uncertainty in the form of interval values that cover the true unobservable values. First, we suppose that the costs in the objective functions are linear functions with interval coefficients. Second, we suppose that we have an interval estimation of weights of the particular criteria. This double uncertainty mathematically leads to six different concepts of efficiency (Pareto optimality). We provide a characterization of each of them. We also investigate computational complexity of the decision problem whether a given solution is efficient. It turns out that some of the concepts are polynomial, some are polynomial under the assumption of fixed number of criteria, and some are co-NP-hard to check.

Keywords: multiobjective linear programming, interval analysis, robust optimization, weighted scalarization.

1 INTRODUCTION

A multiobjective linear programming problem. We consider a multiobjective linear programming problem in the form

$$\max \ Cx \ \text{ subject to } \ Ax \leq b, \tag{1}$$

where $A \in \mathbb{R}^{m\times n}$, $b \in \mathbb{R}^m$ and $C \in \mathbb{R}^{p\times n}$. We suppose that the feasible set is nonempty. Throughout the paper, inequalities $\leq$ and $<$ are understood entrywise.

The basic concept of an optimal solution is efficiency (Pareto optimality). Recall that a feasible solution x^* is called efficient if there is no other feasible solution x such that $Cx \geq Cx^*$ and $Cx \neq Cx^*$. One of the basic methods to solve (1) is to employ a weighted sum scalarization, which has the form of a linear program

$$\max \ \lambda^T Cx \ \text{ subject to } \ Ax \leq b. \tag{2}$$

It is known [3, 16] that each efficient solution is an optimal solution of (2) for some $\lambda > 0$, and conversely each optimal solution of (2) with $\lambda > 0$ is efficient to (1). This means that scalarizations with positive weight completely characterize efficient solutions.

Interval costs and weights. In this paper we suppose that the objective function coefficients are not exact, but we have deterministic lower and upper bounds for the exact values. That is, we know only an interval matrix $\boldsymbol{C}$ comprising the exact value (for more general uncertainty sets see, e.g., [2]). By definition, an interval matrix is the set of matrices

$$\boldsymbol{C} = [\underline{C}, \overline{C}] = \{C \in \mathbb{R}^{p\times n};\ \underline{C} \leq C \leq \overline{C}\},$$

where $\underline{C}, \overline{C} \in \mathbb{R}^{p \times n}$, $\underline{C} \leq \overline{C}$, are given matrices. We will also use the notion of the midpoint and the radius matrix, which are defined respectively as

$$C_c := \frac{1}{2}(\underline{C} + \overline{C}), \quad C_\Delta := \frac{1}{2}(\overline{C} - \underline{C}).$$

Similar notation is used for interval vectors, considered as one column interval matrices, and for interval numbers. Interval arithmetic is described, e.g., in the textbooks [5, 12].

We recall two basic concepts of efficiency studied in the context of interval multiobjective programming [1, 6, 11, 13]. A feasible solution x^* is possibly efficient if it is efficient for at least one $C \in \boldsymbol{C}$, and it is necessarily efficient if it is efficient for every $C \in \boldsymbol{C}$. Necessarily efficient solutions are very robust, but the drawback is that it might happen that there is no such solution. It is also computationally demanding to check for necessarily efficiency [8] even though there are various sufficient conditions [7] that can be employed. The recent approaches utilize maximum regret techniques; see [14, 15]. In contrast, possibly efficiency is polynomially decidable (both checking possibly efficiency of a given solution [11] and checking there is at least one possibly efficient solution [10]), and there are typically many of them.

It is often difficult for a user to give precise weights to objectives. It is more natural for him/her to provide us with a range of possible weights. Thus we suppose that intervals for possible weights are given in addition, too. In particular we consider weights $\lambda \in \boldsymbol{\lambda} = [\underline{\lambda}, \overline{\lambda}]$, where $\underline{\lambda} > 0$. The interval vector of weights naturally introduces other solutions concepts and gives a decision maker flexibility to choose a right degree of robustness and the model that fits the interpretation of the interval entries.

Six concepts of efficiency. The goal of this paper is to discuss the possible definitions of robust efficiency for interval objectives $\boldsymbol{C}$ and interval weights $\boldsymbol{\lambda}$. A feasible solution x^* is called:

- (I)-efficient if $\exists \lambda \in \boldsymbol{\lambda}\ \exists C \in \boldsymbol{C}$ such that x^* is an optimal solution to (2);
- (II)-efficient if $\exists \lambda \in \boldsymbol{\lambda}\ \forall C \in \boldsymbol{C}$ such that x^* is an optimal solution to (2);
- (III)-efficient if $\forall C \in \boldsymbol{C}\ \exists \lambda \in \boldsymbol{\lambda}$ such that x^* is an optimal solution to (2);
- (IV)-efficient if $\forall \lambda \in \boldsymbol{\lambda}\ \exists C \in \boldsymbol{C}$ such that x^* is an optimal solution to (2);
- (V)-efficient if $\exists C \in \boldsymbol{C}\ \forall \lambda \in \boldsymbol{\lambda}$ such that x^* is an optimal solution to (2);
- (VI)-efficient if $\forall \lambda \in \boldsymbol{\lambda}\ \forall C \in \boldsymbol{C}$ we have that x^* is an optimal solution to (2).

From the definition, we can directly deduced the following relations between these kinds of efficiencies: (VI)⇒(II)⇒(III)⇒(I) and (VI)⇒(V)⇒(IV)⇒(I).

In the following section, we discuss the six concepts more in detail. We will derive a characterization for each type of efficiency. We will also address the computational complexity issues and classify the problems in the polynomial vs. NP-hard categories.

Notation. The symbol I_n denotes the identity matrix of size n, $0_{m,n}$ denotes the zero matrix of size $m \times n$, A_{i*} denotes the ith row and A_{*i} the ith column of a matrix A. We use $e = (1, \ldots, 1)^T$ for the vector of ones of a convenient length. The diagonal matrix with entries $s = (s_1, \ldots, s_n)^T$ is denoted by $\mathrm{diag}(s)$.

2 CHARACTERIZATION AND COMPLEXITY OF THE PARTICULAR CONCEPTS

Throughout this section we assume that a feasible solution x^* is given. We consider the general case, so we do not require x^* to be a basic or a nondegenerate solution. We define the index set of active constraints

$$P := \{i;\ (Ax^*)_i = b_i\}.$$

Denote by $|P|$ the cardinality of P, and by A_P we denote the restriction of matrix A to the rows indexed by P. By [16] (or using optimality conditions in linear programming for (2)) we have that x^* is efficient for a particular realization $C \in \boldsymbol{C}$ if and only if the system

$$A_P^T y = C^T \lambda, \quad y \geq 0, \quad \lambda > 0 \tag{3}$$

is feasible. If it is the case, then λ is the corresponding vector of weights and y (embedded in the right dimension) is an optimum of the dual problem to (2).

2.1 Case (I): $\exists \lambda \in \boldsymbol{\lambda}\ \exists C \in \boldsymbol{C}$

Proposition 2.1 *The solution x^* is (I)-efficient if and only if the linear system*

$$\underline{C}^T \lambda \leq A_P^T y \leq \overline{C}^T \lambda, \quad y \geq 0, \quad \overline{\lambda} \geq \lambda \geq \underline{\lambda}.$$

is feasible with respect to variables $y \in \mathbb{R}^{|P|}$ and $\lambda \in \mathbb{R}^p$.

Proof. By (3), x^* is (I)-efficient iff there is $C \in \boldsymbol{C}$ such that the linear system

$$A_P^T y = C^T \lambda, \quad y \geq 0, \quad \overline{\lambda} \geq \lambda \geq \underline{\lambda}$$

is feasible. As C varies in $\boldsymbol{C}$, the vector $C^T\lambda$ attains any value in the interval vector $[\underline{C}^T\lambda, \overline{C}^T\lambda]$. This yields the statement. □

As a consequence, (I)-efficiency is polynomially decidable by linear programming. For the other kinds of efficiency, the situation is worse.

2.2 Case (II): $\exists \lambda \in \boldsymbol{\lambda}\ \forall C \in \boldsymbol{C}$

For $s \in \{\pm 1\}^n$ we denote by $C_s \in \boldsymbol{C}$ the matrix $C_s := C_c + C_\Delta \operatorname{diag}(s)$. That is, in ith column of C_s, either all entries are the right-end points of the intervals (if $s_i = 1$), or all entries are the left-end points of the intervals (if $s_i = -1$).

Proposition 2.2 *The solution x^* is (II)-efficient if and only if the linear system*

$$A_P^T y_s = C_s^T \lambda, \quad y_s \geq 0, \ s \in \{\pm 1\}^n, \quad \underline{\lambda} \leq \lambda \leq \overline{\lambda} \tag{4}$$

is feasible in variables $\lambda \in \mathbb{R}^p$ and $y_s \in \mathbb{R}^{|P|}$, $s \in \{\pm 1\}^n$.

Proof. We need to find $\lambda \in \boldsymbol{\lambda}$ such that the system (3) is solvable for each $C \in \boldsymbol{C}$. By the theory of interval systems [4, 9] (and the so called strong solvability) a system $Ax = b$, $x \geq 0$ is solvable for each $b \in \boldsymbol{b}$, where $\boldsymbol{b} = [\underline{b}, \overline{b}]$ is an interval vector, if and only if it is solvable for each b such that $b_i \in \{\underline{b}_i, \overline{b}_i\}$, $i = 1, \ldots, n$. Using this fact we get that solvability of (3) for each $C \in \boldsymbol{C}$ is reduced to solvability of (3) for matrices of type C_s, $s \in \{\pm 1\}^n$. This gives us the master system (4) since λ has to be a common solution for each subsystem. □

System (4) is exponentially large. We can hardly make better since this kind of efficiency reduces to a hard case [8], even for problems with one objective function.

Proposition 2.3 *It is a co-NP-hard problem to decide if x^* is (II)-efficient.*

2.3 Case (III): $\forall C \in \boldsymbol{C}\ \exists \lambda \in \boldsymbol{\lambda}$

Proposition 2.4 *The solution x^* is (III)-efficient if and only if for each $s \in \{\pm 1\}^n$ the linear system*

$$A_P^T y = C_s^T \lambda, \quad y \geq 0, \quad \underline{\lambda} \leq \lambda \leq \overline{\lambda}$$

is solvable.

Proof. We need to check that the system

$$A_P^T y = C^T \lambda, \quad y \geq 0, \quad \overline{\lambda} \geq \lambda \geq \underline{\lambda}$$

is solvable for each $C \in \boldsymbol{C}$. Again, using the results on strong solvability of interval systems [4, 9] we can reduce solvability only to matrices of type C_s, $s \in \{\pm 1\}^n$. □

Notice the difference to the case of (II)-efficiency. In (4) we have one large system, whereas herein we have many but small systems.

For the case of only one criterion (i.e., $p = 1$), (III)-efficiency coincides with necessary efficiency. That is why it is hard from the point of view of computational complexity.

Proposition 2.5 *It is a co-NP-hard problem to decide if x^* is (III)-efficient.*

2.4 Case (IV): $\forall \lambda \in \boldsymbol{\lambda}\ \exists C \in \boldsymbol{C}$

For $s' \in \{\pm 1\}^p$ we denote by $\lambda_{s'} \in \boldsymbol{\lambda}$ the vector $\lambda_{s'} := \lambda_c + \mathrm{diag}(s')\lambda_\Delta$. Geometrically, $\lambda_{s'}$ is a vertex of the box $\boldsymbol{\lambda}$ in space $\mathbb{R}^p$. That is, we have $(\lambda_{s'})_i \in \{\underline{\lambda}_i, \overline{\lambda}_i\}$ for each $i = 1, \ldots, p$.

Proposition 2.6 *The solution x^* is (IV)-efficient if and only if for each $s' \in \{\pm 1\}^p$ the linear system*

$$\underline{C}^T \lambda_{s'} \leq A_P^T y \leq \overline{C}^T \lambda_{s'}, \quad y \geq 0$$

is solvable.

Proof. Let $\lambda \in \boldsymbol{\lambda}$. As in the proof of Proposition 2.1 we have that point x^* is optimal to (2) for some $C \in \boldsymbol{C}$ if and only if the system

$$\underline{C}^T \lambda \leq A_P^T y \leq \overline{C}^T \lambda, \quad y \geq 0$$

is feasible. Thus we need to check feasibility of the above system for each $\lambda \in \boldsymbol{\lambda}$. Since the system describes a convex polyhedral set, it is sufficient to check for feasibility of the vertices of $\boldsymbol{\lambda}$ only. □

Notice that this characterization is exponential in p, but not in n. So the proposition provides an effective way to check for (IV)-efficiency in a polynomial time as long as the number of criteria is small. Generally, the problem is hard. This is easy to see – take $\boldsymbol{C} := I_n$ as a real matrix and then (IV)-efficiency reduces to necessary efficiency with respect to one objective function $\boldsymbol{\lambda}^T C x = \boldsymbol{\lambda}^T x$, which is a co-NP-hard problem [8].

Proposition 2.7 *It is a co-NP-hard problem to decide if x^* is (IV)-efficient.*

2.5 Case (V): $\exists C \in \boldsymbol{C}\ \forall \lambda \in \boldsymbol{\lambda}$

Proposition 2.8 *The solution x^* is (V)-efficient if and only if the linear system*

$$A_P^T y_{s'} = C^T \lambda_{s'}, \quad y_{s'} \geq 0, \quad s' \in \{\pm 1\}^p, \quad \underline{C} \leq C \leq \overline{C}$$

is solvable in variables $C \in \mathbb{R}^{p \times n}$ and $y_{s'} \in \mathbb{R}^{|P|}$, $s' \in \{\pm 1\}^p$.

Proof. Let $C \in \boldsymbol{C}$. In view of (3), we need to check $\{C^T \lambda;\ \lambda \in \boldsymbol{\lambda}\} \subseteq \{A_P^T y;\ y \geq 0\}$. Since both sets are convex, it is sufficient to verify $C^T \lambda \in \{A_P^T y;\ y \geq 0\}$ for the vertices of $\boldsymbol{\lambda}$ only. Therefore, the problem reduces to finding a matrix $C \in \boldsymbol{C}$ such that (3) is solvable for each $\lambda_{s'}$, $s' \in \{\pm 1\}^p$. □

Similarly to (IV)-efficiency, the characterization is exponential in p, but not in n. This is good news for the case with a small number of criteria. However, in general, the problem is still intractable for the same reason as in the case of (IV)-efficiency.

Proposition 2.9 *It is a co-NP-hard problem to decide if x^* is (V)-efficient.*

2.6 Case (VI): $\forall \lambda \in \boldsymbol{\lambda}\ \forall C \in \boldsymbol{C}$

Proposition 2.10 *The solution x^* is (V)-efficient if and only if for each $s \in \{\pm 1\}^n$ and each $s' \in \{\pm 1\}^p$ the linear system*

$$A_P^T y = C_s^T \lambda_{s'}, \quad y \geq 0$$

is solvable.

Proof. Using a similar argument as for the previous case of (V)-efficiency, we need to check that for each $C \in \boldsymbol{C}$ and each $s' \in \{\pm 1\}^p$ the system

$$A_P^T y = C^T \lambda_{s'}, \quad y \geq 0$$

is solvable. Using analogous ideas as for (III)-efficiency, we obtain that this system is solvable for each $C \in \boldsymbol{C}$ if and only if it is solvable for each matrix of type C_s, $s \in \{\pm 1\}^n$. Therefore we arrive at the final characterization of (VI)-efficiency. □

Since this case comprises the problem of checking for necessary efficiency of a feasible solution (when $p = 1$), we again conclude that the problem is co-NP-hard [8].

Proposition 2.11 *It is a co-NP-hard problem to decide if x^* is (VI)-efficient.*

3 CONCLUSION

We introduced six natural concepts of efficient solutions in multiobjective linear programming with interval costs and with interval estimations of weights. This gives the decision maker a flexibility in choosing the right model, depending on what kind of uncertainty is modelled by intervals and what degree of robustness the decision maker aims to.

We characterized all the proposed kinds of efficiency, and the characterizations also provide a way how to check that a given feasible solution is efficient. Several kinds are computationally hard, but some of them are either polynomially solvable or they are efficient as long as the number of criteria is small (which is the typical situation in the real world). Notice that we dealt with efficiency of a general feasible solution. Provided it is a nondegenerate basic solution, stronger results can possibly be obtained. This will be the subject of future research.

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SUFFICIENT MATRICES AND LINEAR COMPLEMENTARITY PROBLEMS

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Sufficient matrices (SU) have been introduced by Cottle et al. (1989). The class of $P^*(\kappa)$-matrices, for given nonnegative real parameter κ, has been defined by Kojima et al. (1991). The union for all possible κ parameters of $P^*(\kappa)$-matrices forms the class of P^*-matrices. Väliaho (1996) proved that the P^*-matrices are exactly those which are sufficient. Unfortunately, there is an important, negative result related to sufficient matrices. P. Tseng (2000) proved that decision problem related to the membership of matrices for P_0- and column sufficient matrices are all co-NP-complete.

The aim of this talk to overview some properties of sufficient matrices and their relation to linear complementarity problems. Furthermore, we are planning to discuss some preliminary results related to the constructions of sufficient matrices.

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MONOPSONY IN LABOR MARKET: SHORT-RUN PROFIT MAXIMIZATION MODEL FROM DUALITY PERSPECTIVE

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Abstract: Duality in microeconomic theory relies on the assumption that the economic agents take prices as given. This paper applies the duality concepts on monopsony in the labor market which influences the wage it charges, by introducing the non-wage determinant of the labor supply. The short-run normalized profit maximization problem is reformulated and analyzed from a duality perspective. The duality between the pseudo production and short-run normalized profit functions is illustrated and a version of Hotelling's lemma is given.

Keywords: monopsony in the labor market, short-run normalized profit function, duality, Hotelling's lemma, microeconomic theory.

1 INTRODUCTION

Duality is a well-known concept in microeconomic theory. It states that a firm´s technology and consumer preferences can be equally well described by the production (utility) function as well as with the cost (expenditure), profit, and other value functions under certain regularity conditions as a result of the Fenchel duality theorem from the convex analysis [4,5]. Many theorems were stated establishing relationships between these functions [7,9]. The duality has its many empirical application advantages in the form of econometric estimation of technology and preferences by using a rich set of flexible functional forms. Additionally, comparative statics results can be derived more elegantly [7]. The mathematical origin of the application of duality in microeconomic theory lies in the representation of closed convex set as an intersection of its supporting halfspaces determined by prices which the economic agents take as given [4,5,7]. However, some literature applied duality concepts in the analysis of consumers and producers which have market power, as in the case of monopoly [7,12], oligopoly [2], and monopsony in the product market [7]. The analysis in this paper follows the duality results between the production function and the short-run normalized profit function of a perfectly competitive firm [9,11]. However, it takes the challenge of applying these results in the analysis of the short-run normalized profit maximization model of monopsony in the labor market by following the logic of Diewert in the monopoly case [5]. Monopsony refers to the market of a single buyer [10] and is very often analyzed in labor markets [3]. More on the static profit maximization model of monopsony can be found in [6].

The scientific contribution of this paper consists in the application of duality concepts in the special newly set structure of the short-run profit maximization model of monopsony in the labor market. Such a structure of the mentioned model is established that allows the direct application of duality results between the so-called pseudo production function and the short-run normalized profit function and illustration of these results. This was enabled by the introduction of the non-wage determinant of the labor supply and by defining the pseudo labor and pseudo production function.

The remainder of the paper is organized as follows. After Introduction Section 2 formulates the primal problem, in which the starting point is the pseudo production function. The choice variable for this primal profit maximization problem is the below-defined pseudo labor and the value function is the short-run normalized profit function. In Section 3 the dual problem is analyzed, where the starting point is the derived short-run normalized profit function and the pseudo production function is recovered. Special attention is given to the first-order necessary conditions of both optimization models which express a version of Hotelling´s lemma in this special case. The final section concludes.

2 SHORT-RUN NORMALIZED PROFIT MAXIMIZATION MODEL IN MONOPSONY IN THE LABOR MARKET

For the analysis of labor supply behavior, economists use the neoclassical model of labor-leisure choice [8]. Let us assume for our purpose that the monopsonist faces the following upward-sloping inverse labor supply function,

$$w(L) = z * S(L) \tag{1}$$

where w represents the wage, $z > 0$ represents the influence of other non-wage factors on the labor supply, L is the quantity of labor, S is the function of labor with $S'(L) > 0$.
In the primal approach, the technology of monopsonist in the short-run is represented by the production function, $x_0 = f(L, \overline{K})$, where x_0 is the quantity of production, L is the quantity of labor, and $\overline{K}$ is the fixed level of capital. The usual assumptions of the production function representing technology in the short run can be found in [8], while the analysis of duality for the perfectly competitive firm producing multiple outputs with multiple inputs can be found in [7].

We assume that the monopsonist takes the product price, $p > 0$, as given. The short-run profit maximization model of a monopsonist is the result of maximizing the difference between total revenue and variable costs in the short run and can be written as:

$$\max p * f(L, K) - w(L) * L. \tag{2}$$

By inserting the inverse labor supply function (1) in (2) the following model is obtained

$$\max p * f(L, K) - z * S(L) * L. \tag{3}$$

Finally, by dividing both terms in (3) with p, the short-run normalized profit maximization model reduces to

$$\max_{L>0} f(L, \overline{K}) - \frac{z}{p} * S(L) * L. \tag{4}$$

Each term in (4) is expressed in the units of production. We assume that sufficient regularity conditions on f and S are satisfied so that the problem has a solution, which is well defined. The choice variable is the quantity of labor and the solution to (4) gives the demand function for labor and the short-run normalized profit function, $\pi\left(\frac{z}{p}, \overline{K}\right)$ of a monopsonist for the given supply function of labor.

In what follows, the problem in (4) will be reformulated and analyzed from a duality perspective. This is why the new function is introduced, which can be named the pseudo labor function,

$$y \equiv S(L) * L = \frac{w(L)*L}{z}. \tag{5}$$

Pseudo labor function is obtained by dividing labor costs by z. The parameter z in this context can be interpreted as the price of pseudo labor. Therefore, the duality results can be applied [9,11]. If $\pi\left(\frac{z}{p}, \overline{K}\right)$ is differentiable, the derivative of the normalized short-run profit function with respect to z recovers y^*, which for the given supply function of labor, gives the demand function for labor. This result can be named a version of Hotelling´s lemma in a monopsony.

Therefore, the primal short-run normalized profit maximization model of a monopsony, where the choice variable is the pseudo labor, is represented by the following optimization model

$$\max_{y>0} f^*(y) - \frac{z}{p} * y \ , \tag{6}$$

where $f^*(y)$ can be interpreted as the short-run pseudo production function. It is assumed that the problem formulated in (6) has an interior solution. The first-order necessary conditions reduce to the following equality

$$\frac{\partial f^*(y)}{\partial y} = \frac{z}{p}. \tag{7}$$

The left-hand side of the equation can be interpreted as the marginal product of pseudo labor and the right-hand side as the real price of pseudo labor. This representation of the first-order necessary conditions of a short-run normalized profit maximization model of a monopsony is equivalent to the perfectly competitive firm´s first-order necessary conditions for the profit maximization model when the quantities of inputs are the choice variables.

The solution of the equation in (7) is the demand function for pseudo labor, $y(\frac{z}{p}, \bar{K})$. It should be noted however that if the functional forms for the production function and the labor supply function are more complicated, solving this equation could be tedious, and sometimes it is impossible to explicitly express the pseudo labor function. It is obvious, however, that this equation gives explicitly the inverse demand function for pseudo labor. We will return to this issue later in the paper. When the solution to (7) is inserted into the objective function, the normalized profit function for the given supply function of a monopsonist is obtained, $\pi\left(\frac{z}{p}, \bar{K}\right) \equiv f^*\left(y(\frac{z}{p}, \bar{K})\right) - \frac{z}{p} * y(\frac{z}{p}, \bar{K})$.

3 FROM THE SHORT-RUN NORMALIZED PROFIT FUNCTION TO THE PSEUDO PRODUCTION FUNCTION IN MONOPSONY

Below we start from the normalized profit function and show how to reconstruct the pseudo production function we started with. Let´s start from the real price of pseudo labor equal to $(\frac{z}{p})^0$, when the profit-maximizing level of pseudo labor is y^0. If the real price of pseudo labor changes, the quantity of pseudo labor could be adjusted to maximize profit or stay fixed at y^0. Profit when adjusting cannot be lower than the amount of profit when being passive and the following inequality follows

$$\pi\left(\frac{z}{p}, \bar{K}\right) \geq \ f^*(y^0) - \frac{z}{w} * y^0 \text{ and} \tag{8}$$

$$f^*(y^0) \leq \pi\left(\frac{z}{p}, K\right) + \frac{z}{p} * y^0 \ . \tag{9}$$

At $\frac{z}{p} = (\frac{z}{p})^0$ (9) becomes equality since the pseudo labor y^0 is optimal at $(\frac{z}{p})^0$. It follows that the pseudo production function is the result of the optimization problem in which the sum of normalized short-run profit and real pseudo cost of labor is minimized. The choice variable in this optimization model is the real price of pseudo labor,

$$f^*(y) \equiv \min_{\frac{z}{p}} \pi\left(\frac{z}{p}, K\right) + \frac{z}{p} * y \tag{10}$$

The first-order necessary conditions for an interior solution reduce to the following equality

$$\frac{\partial\left(\frac{\pi}{p}\right)}{\partial\left(\frac{z}{p}\right)} + y = 0, \tag{11}$$

$$-\frac{\partial\left(\frac{\pi}{p}\right)}{\partial\left(\frac{z}{p}\right)} = y. \tag{12}$$

To solution to this equation gives the inverse demand function for pseudo labor, $\frac{z}{p}(y)$. When we insert this function into the objective function of the stated optimization problem in (10), the pseudo production function is reconstructed. However, it can be noticed that (12) explicitly gives the demand function for pseudo labor, the solution to the primal optimization problem represented by (6). Therefore (12) expresses that in equilibrium the optimal pseudo labor is obtained by the derivative of the short-run normalized profit function with respect to the real price of pseudo labor and it can be interpreted as a version of Hotelling´s lemma. For the given supply function of labor, the demand function for labor for the given supply function of labor for the monopsonist can be obtained by finding the inverse function of (5).

4 ILLUSTRATION OF DUALITY CONCEPTS ON THE SHORT-RUN NORMALIZED PROFIT MAXIMIZATION IN MONOPSONY

To illustrate an application of duality concepts on the short-run normalized profit maximization model of a monopsonist, let us assume that the technology of a monopsonist´s production process is represented by the Cobb-Douglas production function

$$x_0 = f(L, K) = L^{\frac{1}{2}}K^{\frac{1}{3}}. \tag{13}$$

The short-run production function, which expresses production as a function of labor, for the fixed level of capital in the short run $K = 1$ in the example reduces to

$$x_0 = f(L, K = 1) = L^{\frac{1}{2}}. \tag{14}$$

The inverse supply function of labor is for simplicity represented by the following linear function,

$$w(L) = z * S(L) = z * b * L, \tag{15}$$

where $b > 0$ is a parameter and z a non-price determinant of the labor supply.
The pseudo labor function defined in (5) is represented by the following function

$$y = S(L) * L = b * L^2. \tag{16}$$

To directly apply the concepts of duality on the short-run normalized profit maximization model of a monopsonist, below the alternative model as presented in (4) is solved. The choice variable is pseudo labor.
The first step is to express the pseudo production function or the production function as a function of pseudo labor, $f^*(y)$. From (16) labor is expressed as a function of the pseudo-labor,

$$L(y) = \frac{1}{b^{\frac{1}{2}}} * y^{\frac{1}{2}} \tag{17}$$

and using (14) gives the pseudo production function

$$f^*(y) = x_0(y) = \frac{1}{b^{\frac{1}{4}}} * y^{\frac{1}{4}} = b^{-\frac{1}{4}} * y^{\frac{1}{4}} \tag{18}$$

The short-run normalized profit function is the result of the following optimization problem:

$$\frac{\pi}{p}(\frac{z}{p}, K = 1) \equiv \max_{y>0} b^{-\frac{1}{4}} * y^{\frac{1}{4}} - \frac{z}{p} * y \tag{19}$$

First-order necessary condition for an interior solution reduces to the following equation:

$$\frac{1}{b^{\frac{1}{4}}} * \frac{1}{4} * y^{-\frac{3}{4}} = \frac{z}{p} \tag{20}$$

from which the demand function for pseudo labor follows

$$y = b^{-\frac{1}{3}}(\frac{p}{4*z})^{\frac{4}{3}} = b^{-\frac{1}{3}}4^{-\frac{4}{3}}\left(\frac{z}{p}\right)^{-\frac{4}{3}}. \tag{21}$$

However, the equation in (20) directly gives the inverse demand function for pseudo labor. As you will see below, this is the solution to the dual optimization model, formulated in (10). By inserting the pseudo labor in the objective function, the short-run normalized profit function of a monopsonist for the given supply function is obtained,

$$\frac{\pi}{p} = b^{-\frac{1}{4}} * \left(b^{-\frac{1}{3}}4^{-\frac{4}{3}}\left(\frac{z}{p}\right)^{-\frac{4}{3}}\right)^{\frac{1}{4}} - \frac{z}{p} * b^{-\frac{1}{3}}4^{-\frac{4}{3}}\left(\frac{z}{p}\right)^{-\frac{4}{3}} = \frac{3}{4} * (\frac{1}{4*b})^{\frac{1}{3}}(\frac{z}{p})^{-\frac{1}{3}} \tag{22}$$

The application of Hotelling´s lemma brings us back from the profit function to the pseudo labor function, from which, for the given supply function, the labor demand function can be derived.

$$y = \frac{-\partial\pi}{\partial z} = \frac{3}{4} * p * \frac{1}{3} * z^{-\frac{2}{3}}(\frac{p}{4*b})^{\frac{1}{3}} = b^{-\frac{1}{3}}(\frac{p}{4*z})^{\frac{4}{3}} = b^{-\frac{1}{3}}\left(\frac{p}{z}\right)^{\frac{4}{3}}(\frac{1}{4})^{\frac{4}{3}} = b^{-\frac{1}{3}}4^{-\frac{4}{3}}\left(\frac{z}{p}\right)^{-\frac{4}{3}} \tag{23}$$

Dually, if we start from the short-run normalized profit function, using (10) the pseudo production function is the solution of the following optimization model:

$$f^*(y) \equiv \min_{\frac{z}{p}} \frac{3}{4} * (\frac{1}{4*b})^{\frac{1}{3}}(\frac{z}{p})^{-\frac{1}{3}} + \frac{z}{p} * y \tag{24}$$

For an interior solution, the first-order necessary condition expresses the following equality

$$\frac{3}{4} * -\frac{1}{3} * \left(\frac{1}{4*b}\right)^{\frac{1}{3}} * \frac{z}{p}^{-\frac{4}{3}} + \ y = 0 \tag{25}$$

$$\frac{1}{4} * \left(\frac{1}{4*b}\right)^{\frac{1}{3}} * \frac{z}{p}^{-\frac{4}{3}} = \ y \tag{26}$$

This equation needs to be solved to get us to the inverse demand function for pseudo labor,

$$\frac{z}{p} = \frac{1}{b^{\frac{1}{4}}} * \frac{1}{4} * y^{-\frac{3}{4}} \tag{27}$$

the same as in (20). It is easy to see that (26) brings us directly to the demand function for pseudo labor as in (21).

$$y = b^{-\frac{1}{3}}(\frac{p}{4*z})^{\frac{4}{3}} = b^{-\frac{1}{3}}\left(\frac{p}{z}\right)^{\frac{4}{3}}(\frac{1}{4})^{\frac{4}{3}} \tag{28}$$

Finally, when the inverse demand function for pseudo labor is inserted into the objective function, the pseudo production function we started with at the beginning of the analysis is reconstructed,

$$f^*(y, K) = \frac{3}{4} * \left(\frac{1}{4*b}\right)^{\frac{1}{3}} * \left(\frac{1}{b^{\frac{1}{4}}} * \frac{1}{4} * y^{-\frac{3}{4}}\right)^{-\frac{1}{3}} + \frac{1}{b^{\frac{1}{4}}} * \frac{1}{4} * y^{-\frac{3}{4}} * y = b^{-\frac{1}{4}} * y^{\frac{1}{4}}. \tag{2}$$

5 CONCLUSION

This paper relies on the duality results between the production function and the short-run normalized profit function of a perfectly competitive firm and takes the challenge of applying these results in the analysis of the short-run normalized profit maximization model of monopsony in the labor market. Such a structure of the short-run normalized profit maximization model of monopsonist in the labor market is set, which allows direct application of duality results between the pseudo production function and the short-run normalized profit function and illustration of these results. This was enabled by the introduction of the non-wage determinant of the labor supply and by defining the so-called pseudo labor and pseudo production function. Future research should be devoted -to an assessment of the model from an empirical standpoint and to the derivation of comparative statics results.

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OPTIMAL TAXATION OF A MONOPOLY WITH COBB- DOUGLAS PRODUCTION FUNCTION FOR TWO INPUTS AS A BILEVEL PROGRAMMING PROBLEM

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Abstract: The paper formulates the problem of optimal tax policy for profit maximizing monopolist as a bilevel programming problem. The output of the monopolist is described by the Cobb-Douglas production function of two inputs – labour and capital. Tax is modelled as an amount per unit product. Government is the leader and determines tax amount with the objective of maximizing its tax revenue. Monopolist is the follower who, given the leader's tax decision, decides about input levels and thus output quantity with the objective of maximizing the profit.

Keywords: optimal tax revenue, profit maximizing monopolist, Cobb-Douglas production function, two inputs, bilevel programming

1 INTRODUCTION

Long-run profit maximization is a very important and well-studied problem (see for example [11],[12]). Output is often described as a production function of two inputs, labor and capital, with production function taking the form of the Cobb-Douglas or the CES production function. On the other hand, taxation is one of the most important instruments of fiscal policy. One of the key aspects in designing tax policy is tax revenue ([9], [10]). However, despite the abundant literature on optimal taxation ([1], [2], [3], [4], [5], [6], [13]) as well as on the long-run profit maximization, these two problems are usually considered separately, although there is a natural relationship between the two. Therefore, this paper studies the relationship between the taxation and profit maximization of a monopolist by introducing the hierarchical structure and models the problem as a bilevel programming problem ([7], [8], 14]).

The paper proposes the following model. Government is the leader and acts first by choosing tax amount with the goal of maximizing its tax revenue. Tax is expressed as an amount per unit product. However, in choosing its tax policy, a government has to take into account the response of the follower who, given the leader's tax decision, chooses input levels with the objective of maximizing follower's long-run profit function. Here the production quantity is described by the Cobb-Douglas production function of two inputs, labor and capital. Both input and output markets are assumed to be competitive.

The paper is organized as follows. After the introduction in the first section, notation used in the paper is presented in the second chapter. The third section formulates and solves the model for the case of two inputs. Conclusions are given in the final section.

2 NOTATION

The paper uses the following notation:

K, L	inputs of capital and labor, respectively
r, w	unit costs of capital and labor, respectively
α, β	output elasticities of inputs of capital and labor, respectively
t	the tax amount per unit product
p	the market price of the product

The market price p, unit costs of labor w and capital r, as well as output elasticities α and β are assumed to be fixed and given non-negative real numbers.
The total production quantity is described by the Cobb-Douglas production function with two inputs

$$Q(K,L) = K^{\alpha} L^{\beta} \tag{1}$$

where $\alpha, \beta \geq 0$ are output elasticities of the inputs.

3 THE MODEL

The model assumes that the tax revenue comes only from tax on output quantity and that the tax is expressed as an amount per unit product. Therefore, the government's tax revenue is a function of tax amount t and output quantity Q:

$$T(t,Q) = tQ, \tag{2}$$

that is

$$T(t,K,L) = tK^{\alpha} L^{\beta}. \tag{3}$$

The government chooses tax amount per unit product t, but it cannot affect output level Q (which is a function of input levels K and L) controlled by the follower. Therefore, in making its decision it has to take into account the response of the follower. As for the follower, since p is the price consumers pay on the market for the product, the price monopolist receives per unit product is equal to $p-t$. Consequently, monopolist's profit function is a function of tax amount t and input levels K and L:

$$\begin{aligned} \Pi(K,L) &= (p-t)Q - rK - wL \\ &= (p-t)K^{\alpha} L^{\beta} - rK - wL. \end{aligned} \tag{4}$$

The problem of determining optimal tax policy can now be formulated as the following bilevel programming problem:

$$\max_{t} T(t,K,L) = tK^{\alpha} L^{\beta} \tag{5}$$

$$\text{s. t. } \max_{K,L} \Pi(t,K,L) = (p-t)K^{\alpha} L^{\beta} - rK - wL \tag{6}$$

Here, variable t is controlled by the leader, while variables K and L are controlled by the follower.

Theorem 1. The optimal solution of the problem (5)-(6) is achieved for the tax amount

$$t^{*} = p\left(1-\alpha-\beta\right) \tag{7}$$

and input levels

$$K^{*} = p^{\frac{1}{1-(\alpha+\beta)}} \left(\alpha+\beta\right)^{\frac{1}{1-(\alpha+\beta)}} \left(\frac{\alpha}{r}\right)^{\frac{1-\beta}{1-(\alpha+\beta)}} \left(\frac{\beta}{w}\right)^{\frac{\beta}{1-(\alpha+\beta)}} \tag{8}$$

$$L^* = p^{\frac{1}{1-(\alpha+\beta)}} (\alpha+\beta)^{\frac{1}{1-(\alpha+\beta)}} \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-(\alpha+\beta)}} \left(\frac{\beta}{w}\right)^{\frac{1-\alpha}{1-(\alpha+\beta)}}, \tag{9}$$

for which the output is equal to

$$Q^* = p^{\frac{\alpha+\beta}{1-(\alpha+\beta)}} (\alpha+\beta)^{\frac{\alpha+\beta}{1-(\alpha+\beta)}} \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-(\alpha+\beta)}} \left(\frac{\beta}{w}\right)^{\frac{\beta}{1-(\alpha+\beta)}}. \tag{10}$$

The value of the maximal tax revenue is equal to

$$T(t^*) = p^2 (1-\alpha-\beta)\cdot(\alpha+\beta)^{\frac{\alpha+\beta}{1-(\alpha+\beta)}} \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-(\alpha+\beta)}} \left(\frac{\beta}{w}\right)^{\frac{\beta}{1-(\alpha+\beta)}} \quad . \tag{11}$$

The following inequalities on output elasticities should hold:

$$0 \le \alpha, \beta < 1 \quad \text{and} \quad \alpha+\beta<1, \tag{12}$$

that is, the Cobb- Douglas production function should have decreasing returns to scale.

Proof. First we solve the follower's profit maximization problem (6). Let tax amount t be arbitrary but fixed. From the first order conditions on (6), we obtain the system of equations (13)-(14):

$$\Pi_K(K,L) = (p-t)\alpha K^{\alpha-1} L^{\beta} - r = 0 \tag{13}$$

$$\Pi_L(K,L) = (p-t)\beta K^{\alpha} L^{\beta-1} - w = 0, \tag{14}$$

that is

$$r = (p-t)\alpha K^{\alpha\text{-}1} L^{\beta} = (p-t)Q_K \tag{15}$$

$$w = (p-t)\beta K^{\alpha} L^{\beta-1} = (p-t)Q_L. \tag{16}$$

In other words, in the optimum, the value of marginal products of inputs of capital and labor, $(p-t)Q_K$ and $(p-t)Q_L$, should equal the costs of capital and labor, respectively.

From (15) and (16) we obtain

$$\frac{r}{w} = \frac{\alpha}{\beta}\cdot\frac{L}{K}. \tag{17}$$

Note that the right hand side of (17) is equal to Q_K / Q_L, that is to the slope of the production function (1). From (11) it follows that

$$L = \frac{\beta}{\alpha}\cdot\frac{r}{w}\cdot K. \tag{18}$$

By substituting (18) into (13) we obtain the input of capital K which for a given tax policy t maximizes the follower's profit function:

$$K^*(t) = (p-t)^{\frac{1}{1-(\alpha+\beta)}} \left(\frac{\alpha}{r}\right)^{\frac{1-\beta}{1-(\alpha+\beta)}} \left(\frac{\beta}{w}\right)^{\frac{\beta}{1-(\alpha+\beta)}}. \tag{19}$$

By substituting (19) into (18), the corresponding expression for optimal input level of labor L as a function of t is obtained:

$$L^*(t) = \left(p-t\right)^{\frac{1}{1-(\alpha+\beta)}} \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-(\alpha+\beta)}} \left(\frac{\beta}{w}\right)^{\frac{1-\alpha}{1-(\alpha+\beta)}}. \tag{20}$$

The Hessian of the follower's profit function is given by

$$H = \begin{bmatrix} (p-t)\alpha\left(\alpha-1\right)K^{\alpha-2}L^{\beta} & (p-t)\alpha\beta K^{\alpha-1}L^{\beta-1} \\ (p-t)\alpha\beta K^{\alpha-1}L^{\beta-1} & (p-t)\beta\left(\beta-1\right)K^{\alpha}L^{\beta-2} \end{bmatrix}. \tag{21}$$

Therefore, from the sufficient conditions on the optimal solution of the follower's profit maximization problem (6) we obtain:

$$D_1 = (p-t)\alpha\left(\alpha-1\right)K^{\alpha-2}L^{\beta} < 0 \tag{22}$$

$$\begin{aligned} D_2 &= (p-t)^2\alpha\beta\left(\alpha-1\right)\left(\beta-1\right)K^{2\alpha-2}L^{2\beta-2} - (p-t)^2\alpha^2\beta^2K^{2\alpha-2}L^{2\beta-2} \\ &= (p-t)^2\alpha\beta K^{2\alpha-2}L^{2\beta-2}\left(1-\alpha-\beta\right) > 0 \end{aligned} \tag{23}$$

From (22) and (23) it follows that in order for the stationary point, defined by (19) and (20), to be the maximum of the follower's problem (6), the following constraints on values of output elasticities α and β should hold:

$$0 \le \alpha, \beta < 1 \text{ and } \alpha + \beta < 1. \tag{24}$$

In other words, the Cobb-Douglas production function (1) should have decreasing returns to scale. If (24) holds, the Cobb-Douglas production function (1) is also strictly concave and strictly quasiconcave, with strictly convex isoquants and strictly decreasing marginal rates of substitution.

This solves the follower's problem (6) for arbitrary but fixed tax amount t. It remains to solve the leader's problem (5). By substituting (19) and (20) into (5), the tax revenue is obtained as a function of t:

$$T(t) = t\left(p-t\right)^{\frac{\alpha+\beta}{1-(\alpha+\beta)}} \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-(\alpha+\beta)}} \left(\frac{\beta}{w}\right)^{\frac{\beta}{1-(\alpha+\beta)}}. \tag{25}$$

In a more compact form, this function can be written as

$$T(t) = A \cdot t \cdot \left(p-t\right)^{\frac{\alpha+\beta}{1-(\alpha+\beta)}}, \tag{26}$$

Where

$$A = \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-(\alpha+\beta)}} \left(\frac{\beta}{w}\right)^{\frac{\beta}{1-(\alpha+\beta)}}. \tag{27}$$

From the first order conditions on (25), we obtain

$$T'(t) = A \cdot \left(p-t\right)^{\frac{\alpha+\beta}{1-(\alpha+\beta)}} \cdot \left(1 - \frac{\alpha+\beta}{1-\left(\alpha+\beta\right)} \cdot \frac{t}{p-t}\right) = 0. \tag{28}$$

Since the case of $p-t=0$ can be rejected, it suffices to consider the case when

$$1-\frac{\alpha+\beta}{1-(\alpha+\beta)}\cdot\frac{t}{p-t}=0. \tag{29}$$

By solving (28) we obtain the optimal tax amount t^* as

$$t^*=p(1-\alpha-\beta). \tag{30}$$

From (24) we know that $\alpha+\beta<1$ holds (since the Cobb-Douglas production function (1) has decreasing returns to scale), and therefore t^* is strictly positive.

From the second order conditions on (25), we obtain

$$T''(t)=-\frac{\alpha+\beta}{1-(\alpha+\beta)}A(p-t)^{\frac{\alpha+\beta}{1-(\alpha+\beta)}-1}\frac{2\left[1-(\alpha+\beta)\right]p-t}{\left[1-(\alpha+\beta)\right](p-t)}\leq 0 \tag{31}$$

Since $\alpha+\beta<1$ and $p>t$, inequality in (31) holds if and only if

$$2(1-\alpha-\beta)p\geq t. \tag{32}$$

This inequality holds for stationary point (30) of the problem (25). Therefore, t^* given by (30) maximizes the leader's tax revenue function.

Relations (10) and (11) are obtained by substituting (19), (20) and (32) into (1) and (5) respectively. This completes the proof of the theorem. □

4 CONCLUSIONS

The paper formulates the new bilevel programming models for determining optimal tax policy for government maximizing tax revenue in presence of profit maximizing monopolist whose output is described by the Cobb-Douglas production function. The government's tax revenue comes from tax on output quantity, with tax expressed as an amount per unit product. The model assumes competitive input and output markets. The model is formulated for the case of two inputs, labor and capital, and optimal solutions is derived. Future work will study properties of the optimal solution as well as formulate the generalization of the problem.

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A NEW METHODOLOGY TO SOLVE DECENTRALIZED MULTI-LEVEL MULTI-OBJECTIVE LINEAR FRACTIONAL PROGRAMMING PROBLEM

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Abstract: This paper presents a new methodology for decentralized multi-level multi-objective linear fractional programming (DML_MOLFP) problem solving. To solve DML_MOLFP problem we use Charnes–Cooper's method to linearize the linear fractional objective functions, and Matejaš-Perić (MP) method to determine aspired values of the variables controlled by the decision makers on the decision levels and to determine the best compromise non-nominated solution for the decision makers on all decision making levels. To illustrate the presented methodology an example with 6 linear fractional objective functions, 12 variables and 34 linear constraints has been solved. The presented example indicate the possibility of the efficient determination of the preferred non-dominated solution.

Keywords: Decentralized multi-level; Linear fractional programming; Multi-level programming; Preferred solution

1 INTRODUCTION

Many business enterprises are organized as decentralized hierarchical multilevel systems. Each level has its own goals that can be in conflict with each other and in relation to the goals at the other levels. Goals can be expressed through different ratios: profit/engaged funds, profit/costs, production/costs, production/labor expended, etc. Decision-making is complex in such systems because the achievement of lower-level goals depends on the achievement of higher-level goals and vice versa. In addition, the degree of efficiency of the entire system depends on the degree of achievement of goals at all levels. Maximizing the goals of decision makers by levels leads to the irrationality of the whole system, so cooperation is necessary both among decision makers within the same level and among decision makers at different levels. In order to achieve a high degree of efficiency of decision-making in such complex systems, the application of the methodology of multi-objective programming becomes inevitable.

If the goals of decision makers of decentralized multilevel systems can be expressed by the linear fractional functions that need to be maximized on a set of linear constraints, then we have a DML_MOLFP problem. There are numerous of methodologies that have been proposed to solve the DML_MOLFP problem ([1], [2], [3], [5], [7], [8]).

Here we propose a new methodology for efficiently solving the DML_MOLFP problem. The proposed methodology involves the application of two different methods. The Charnes-Cooper's method [4] is used to solve the problem of maximizing individual linear fractional objective functions on the set of linear constraints, while the Charnes-Cooper's method and

MP method [6] are used to determine aspiration levels of the decision makers for the objective functions and the variables they controlled and to solve the entire DML_MOLFP model to obtain the preferred non-dominated solution.

2 DECENTRALIZED MULTI-LEVEL MULTI-OBJECTIVE LINEAR FRACTIONAL PROGRAMMING PROBLEM

Consider a decentralized L-level MOLFP maximization problem at all levels. Let DM_l denote the decision-maker at the l^{th} level who controls the decision variables $\mathbf{x}_l = (x_{l1}, x_{l2}, ..., x_{l n_l}) \in \mathbf{R}^{n_l}$, $l = 1, 2, ..., L,$ where $\mathbf{x} = (\mathbf{x}_1, \mathbf{x}_2, ..., \mathbf{x}_L) \in \mathbf{R}^n$, $n = n_1 + n_2 + ... + n_L$. In addition, suppose that $\mathbf{f}_l(\mathbf{x}) : \mathbf{R}^{n_1} \text{x} \, \mathbf{R}^{n_2} \text{x} ... \text{x} \, \mathbf{R}^{n_L} \to \mathbf{R}^{K_l}, l = 1, 2, ..., L$ are the DM_l's, $l = 1, 2, ..., L,$ objective function vectors.

Mathematically, the DML_MOLFP maximization problem can be formulated as ([3]):

First level: $\max\limits_{\mathbf{x} \in \mathbf{S}} (f_{11}(\mathbf{x}), f_{12}(\mathbf{x}), ..., f_{1K_1}(\mathbf{x}))$

where DM_1 controls variables $\mathbf{x}_1 = (x_{11}, x_{12}, ..., x_{1n_1})$.

Second level: $\max\limits_{\mathbf{x} \in \mathbf{S}} (f_{21}(\mathbf{x}), f_{22}(\mathbf{x}), ..., f_{2K_2}(\mathbf{x}))$

where DM_2 controls variables $\mathbf{x}_2 = (x_{21}, x_{22}, ..., x_{2n_2})$.

....

L^{th} level: $\max\limits_{\mathbf{x} \in \mathbf{S}} (f_{L1}(\mathbf{x}), f_{L2}(\mathbf{x}), ..., f_{LK_L}(\mathbf{x}))$

where DM_L controls variables $\mathbf{x}_L = (x_{L1}, x_{L2}, ..., x_{Ln_L})$,

$\mathbf{S} = \left\{ \mathbf{x} \in \mathbf{R}^n : \mathbf{A}_1\mathbf{x}_1 + \mathbf{A}_2\mathbf{x}_2 + ... + \mathbf{A}_L\mathbf{x}_L \le \mathbf{b}, \mathbf{x} \ge \mathbf{0}, \mathbf{b} \in \mathbf{R}^m, \mathbf{0} \in \mathbf{R}^n \right\}$,

where $f_{lk} = \dfrac{\mathbf{c}_1^{lk}\mathbf{x}_1 + \mathbf{c}_2^{lk}\mathbf{x}_2 + ... + \mathbf{c}_L^{lk}\mathbf{x}_L + \alpha^{lk}}{\mathbf{d}_1^{lk}\mathbf{x}_1 + \mathbf{d}_2^{lk}\mathbf{x}_2 + ... + \mathbf{d}_L^{lk}\mathbf{x}_L + \beta^{lk}}, k = 1, 2, ..., K_l, l = 1, 2, ..., L,$ $\mathbf{c}_l^{lk} = (c_{l1}^{lk}, c_{l2}^{lk}, ..., c_{l n_l}^{lk})$, $\mathbf{d}_l^{lk} = (d_{l1}^{lk}, d_{l2}^{lk}, ..., d_{l n_l}^{lk})$, $\alpha^{lk}, \beta^{lk} \in \mathbf{R}$, $\mathbf{A}_l \in \mathbf{R}^{m, n_l}$ is constraint matrix.

3 DECENTRALIZED MULTI-LEVEL MULTI-OBJECTIVE LINEAR FRACTIONAL PROGRAMMING METHODOLOGY

To solve the DML-MOLFP problem we propose a methodology based on Charnes–Cooper's method and MP method. Charnes–Cooper's method was used to linearize objective functions on the set of constraints, and MP method was applied to solve multi-objective linear programming problems. The proposed methodology requires an active participation of all decision makers in the problem-solving process and ensures reaching the preferred solution in a simple way in a few steps. After obtaining an initial compromise solution, the process of negotiation among decision makers is conducted in such a way that decision makers who have achieved a high percentage of their aspirations enable increase the realization of aspirations to dissatisfied decision makers in a way that satisfied decision makers reduce their aspirations.The algorithm for obtaining the preferred solution of the DML-MOLFP problem can be constructed in the following way:

In the first step the Charnes–Cooper's method is applied to linearize all linear fractional objective functions on the set of constraints **S** to find optimal (marginal) solutions separately for each objective functions at all levels and form the payoff table. Determining optimal solutions of the linear fractional problem

$$\max_{\mathbf{x}\in\mathbf{S}} f_{lk} = \frac{\mathbf{c}^{lk}\mathbf{x}+\alpha^{lk}}{\mathbf{d}^{lk}\mathbf{x}+\beta^{lk}},\ l=1,2,...,L;\ k=1,2,...,K_l,\ \ S=\{\mathbf{x}:\mathbf{A}\mathbf{x}\le\mathbf{b},\ \mathbf{x}\ge 0\} \tag{1}$$

applying the Charnes–Cooper's method is done by solving the following linear programming problem:

$$\max_{\mathbf{y},t\in\mathbf{S}'} f_{lk}^{'} = \mathbf{c}^{lk}\mathbf{y}+t\alpha^{lk};\ l=1,...,L;\ k=1,2...,K_l;$$

$$\mathbf{S}'=\left\{\mathbf{y},t\in\mathbf{R}^{n+1}:\mathbf{A}\mathbf{y}-t\mathbf{b}\le\mathbf{0},\ \mathbf{d}^{lk}\mathbf{y}+t\beta^{lk}=1,\ \mathbf{y}\ge 0,\ t>0\right\} \tag{2}$$

The vector $\mathbf{x}$ is obtained from $\mathbf{x}=\mathbf{y}/t$.

In the second step, the decision makers determine the aspiration values of their objective functions and the variables they control. For the aspiration values of the objective functions $(d_{lk}^{'})$, decision makers can use their individual optimal values $(f_{lk}^{'*})$. To determine the aspiration values of the variables they control on the level l (l = 1, 2, …, L) $(d_{lj}^{'})$ we propose using the Charnes–Cooper's method for the linearization of the objective functions and application of the MP method for solving multi-objective linear programming problems. The following linear programming problem is solved for each level:

$$\max_{\mathbf{y},t,\lambda\in\mathbf{S}_l^{"}} \lambda,\ \ \mathbf{S}_l^{"}=\left\{\begin{matrix}\mathbf{y},t,\lambda\in\mathbf{R}^{n+2}:\mathbf{A}\mathbf{y}-t\mathbf{b}\le 0,\ \mathbf{d}^{lk}\mathbf{y}+t\beta^{lk}\le 1,\ \mathbf{y}\ge 0,\ t>0,\\ \mathbf{c}^{lk}\mathbf{y}+t\alpha^{lk}\ge\lambda f_{lk}^{'*},\ k=1,2,...,K_l\end{matrix}\right\},\ \ l=1,2,...,L. \tag{3}$$

From $\mathbf{x}=\mathbf{y}/t$ the vector $\mathbf{x}$ is obtained.

In the third step, to obtain a solution that takes into account the initial aspiration values of the decision makers by levels for their objective functions and decision variables they control, the Charnes–Cooper's linearization method and MP method are applied and the following linear programming problem is solved:

$$\max_{\mathbf{y},t,\lambda\in\mathbf{S}"} \lambda,$$

$$\mathbf{S}"=\left\{\begin{matrix}\mathbf{y},t,\lambda\in\mathbf{R}^{n+2}:\mathbf{A}\mathbf{y}-t\mathbf{b}\le 0,\ \mathbf{d}^{lk}+t\beta^{lk}\le\mathbf{1},\ \mathbf{y}\ge 0,\ t>0,\\ \mathbf{c}^{lk}\mathbf{y}+t\alpha^{lk}\ge\lambda\mathbf{d}_{lk}^{'},\ y_{lj}\ge d_{lj}^{'},\ l=1,2,...,L,\ k=1,2,...,K_l,\ j=1,2,...,n_l\end{matrix}\right\}. \tag{4}$$

The first compromise efficient solution is obtained from $\mathbf{x}=\mathbf{y}/t$.

After that, in the fourth step, the decision makers negotiate the obtained compromise solution. If all of them are satisfied with the obtained solution, the solution process is stopped and the obtained solution becomes preferred for all decision makers. However, if one or more decision makers are dissatisfied with the obtained solution, then satisfied decision makers should reduce the aspiration levels of their objective functions and the variables they control to increase the percentage of aspiration levels achieved by dissatisfied decision makers. The process of reducing the aspiration values of objective functions and variables through negotiations continues until all decision makers are satisfied with the obtained solution, and this is accomplished through a finite number of steps (there is no possibility of spinning in a circle).

4 NUMERICAL EXAMPLE

Suppose a decentralized business system with three decision makers arranged in three levels. Each decision maker tends to maximize two linear fractional objective functions on a set of linear constraints $\mathbf{S}$.

Level 1

$$\max_{\mathbf{x}\in\mathbf{S}} f_{11}=\frac{x_{11}+3x_{12}-x_{21}-x_{22}}{x_{21}+x_{22}+x_{23}+x_{24}},\ \ \max_{\mathbf{x}\in\mathbf{S}} f_{12}=\frac{2x_{13}+3x_{14}-x_{23}-x_{24}}{x_{21}+x_{22}+x_{23}+x_{24}} \tag{5}$$

where DM1 controls variables $\mathbf{x}_1 = (x_{11}, x_{12}, x_{13}, x_{14})$.

Level 2

$$\max_{\mathbf{x}\in\mathbf{S}} f_{21} = \frac{2x_{21} + 3x_{22} - x_{31} - x_{32}}{x_{31} + x_{32} + x_{33} + x_{34}}, \ \max_{\mathbf{x}\in\mathbf{S}} f_{22} = \frac{5x_{23} + 8x_{24} - x_{33} - x_{34}}{x_{31} + x_{32} + x_{33} + x_{34}}$$

where DM2 controls variables $\mathbf{x}_2 = (x_{21}, x_{22}, x_{23}, x_{24})..$

Level 3

$$\max_{\mathbf{x}\in\mathbf{S}} f_{31} = \frac{16x_{31} + 18x_{32}}{0.5x_{31} + 0.4x_{32} + 5}, \ \max_{x\in S} f_{32} = \frac{12x_{33} + 8x_{34}}{0.3x_{33} + 0.5x_{34} + 6}$$

where DM3 controls variables $\mathbf{x}_3 = (x_{31}, x_{32}, x_{33}, x_{34})$,

$$\mathbf{S} = \left\{ \begin{array}{l} x_{11} + x_{12} + x_{13} + x_{14} + x_{21} + x_{22} + x_{23} + x_{24} + x_{31} + x_{32} + x_{33} + x_{34} = 120, \ x_{11} \le x_{12}, x_{13} \le x_{14}, \\ x_{21} \le x_{22}, \ x_{23} \le x_{24}, \ x_{31} \le x_{32}, \ x_{33} \le x_{34}, \ x_{11} + x_{12} + x_{13} + x_{14} \le 50, \ x_{21} + x_{22} + x_{23} + x_{24} \le 50, \\ x_{31} + x_{32} + x_{33} + x_{34} \le 50, \ 2 \le x_{11}, x_{12}, x_{13}, x_{14}, x_{21}, x_{22}, x_{23}, x_{24}, x_{31}, x_{32}, x_{33}, x_{34} \le 20 \end{array} \right\}.$$

Problem solving: In the first step we applied the Charnes–Cooper's method to determine the optimal (marginal) solutions of each objective function separately on the set **S**. The optimal solutions and pay-off values are presented in the tables 1 and 2.

Table 1: Optimal (marginal) solutions

Solution	Variable values											
	x_{11}	x_{12}	x_{13}	x_{14}	x_{21}	x_{22}	x_{23}	x_{24}	x_{31}	x_{32}	x_{33}	x_{34}
$\max_{\mathbf{x}\in\mathbf{S}} f_{11}$	20	20	5	5	2	2	8	8	20	20	5	5
$\max_{\mathbf{x}\in\mathbf{S}} f_{12}$	5	5	20	20	8	8	2	2	20	20	5	5
$\max_{\mathbf{x}\in\mathbf{S}} f_{21}$	5	5	20	20	20	20	5	5	2	2	8	8
$\max_{\mathbf{x}\in\mathbf{S}} f_{22}$	5	5	20	20	5	5	20	20	8	8	2	2
$\max_{\mathbf{x}\in\mathbf{S}} f_{31}$	2	2	11	11	2	2	20	20	20	20	5	5
$\max_{\mathbf{x}\in\mathbf{S}} f_{32}$	2	2	11	11	2	20	8	20	2	2	20	20

Table 2: Pay-off values

	f_{11}	f_{12}	f_{21}	f_{22}	f_{31}	f_{32}
$\max_{\mathbf{x}\in\mathbf{S}} f_{11}$	**3.8**	0.45	–0.6	1.88	29.57	10
$\max_{\mathbf{x}\in\mathbf{S}} f_{12}$	0.2	**4.8**	0	0.32	29.57	10
$\max_{\mathbf{x}\in\mathbf{S}} f_{21}$	–0.4	1.8	**4.8**	2.45	22.3	12.9
$\max_{\mathbf{x}\in\mathbf{S}} f_{22}$	0.2	1.2	0.45	**12.8**	10	5.26
$\max_{\mathbf{x}\in\mathbf{S}} f_{31}$	0.09	0.34	–0.6	5	**29.57**	10
$\max_{\mathbf{x}\in\mathbf{S}} f_{32}$	–0.28	0.54	1.36	3.64	10	**18.18**

In the second step we used Charnes–Cooper's method and MP method to determine the aspired values of the variables controlled by the decision makers at the levels 1, 2 and 3 (the relation (3)). The obtained solutions are presented in Table 3.

Table 3: Solutions by levels

Solution at levels	Variable values	Objective function values
1	$\mathbf{y_{11}=0.1}$; $\mathbf{y_{12}=1}$; $\mathbf{y_{13}=0.4}$; $\mathbf{y_{14}=1}$; y_{21}=0.2465; y_{22}=0.2465; y_{23}=0.2535; y_{24}=0.2535; y_{31}=1; y_{32}=1; y_{33}=0.25; y_{34}=0.25; t=0.05 x_{11}=2; x_{12}=20; x_{13}=8; x_{14}=20; x_{21}=4.93; x_{22}=4.93; x_{23}=5.07; x_{24}=5.07; x_{31}=20; x_{32}=20; x_{33}=5; x_{34}=5	f_{11}=2.607, f_{12}=3.293, f_{21}=–0.307, f_{22}=1.118, f_{31}=29.57, f_{32}=10
2	y_{11}=0.1; y_{12}=1; y_{13}=0.4; y_{14}=1; $\mathbf{y_{21}=0.2161}$; $\mathbf{y_{22}=1}$; $\mathbf{y_{23}=0.2839}$; $\mathbf{y_{24}=1}$; y_{31}=0.1; y_{32}=0.1; y_{33}=0.4; y_{34}=0.4; t=0.05 x_{11}=2; x_{12}=20; x_{13}=8; x_{14}=20; x_{21}=4.32; x_{22}=20; x_{23}=5.68; x_{24}=20; x_{31}=2; x_{32}=2; x_{33}=8; x_{34}=8	f_{11}=0.754, f_{12}=1.006, f_{21}=3.232, f_{22}=8.62, f_{31}=10, f_{32}=12.903
3	y_{11}=0.1; y_{12}=0.1; y_{13}=0.4; y_{14}=0.4; y_{21}=0.25; y_{22}=0.25; y_{23}=1; y_{24}=1; $\mathbf{y_{31}=0.1985}$; $\mathbf{y_{32}=1}$; $\mathbf{y_{33}=0.651}$; $\mathbf{y_{34}=0.651}$; t=0.05 x_{11}=2; x_{12}=2; x_{13}=8; x_{14}=8; x_{21}=5; x_{22}=5; x_{23}=20; x_{24}=20; x_{31}=3.97; x_{32}=20; x_{33}=13.02; x_{34}=13.02	f_{11}=–0.04, f_{12}=0, f_{21}=0, f_{22}=–0.788, f_{31}=28.27, f_{32}=16

Therefore, as initial aspiration values of variables controlled by decision makers at levels 1, 2 and 3 are used: $d_{11}^1 = 0.1,\ d_{12}^{'} = 1,\ d_{13}^{'} = 0.4,\ d_{14}^{'} = 1,\ d_{21}^1 = 0.2161,\ d_{22}^{'} = 1,\ d_{23}^{'} = 0.2839,$ $d_{24}^{'} = 1,\ d_{31}^1 = 0.1,\ d_{32}^{'} = 0.1,\ d_{13}^{'} = 0.4,\ d_{14}^{'} = 0.4.$

In the third step, to obtain the solution that takes into account the initial aspiration values of decision makers by levels for their objective functions and decision variables they control, the Charnes–Cooper linearization method and MP method are applied and the following linear programming problem is solved:

$$\max_{\mathbf{y},t,\lambda\in\mathbf{S}"} \lambda, \tag{6}$$

where

$$S" = \left\{ \begin{array}{l} y,t,\lambda : y_{11}+y_{12}+y_{13}+y_{14}+y_{21}+y_{22}+y_{23}+y_{24}+y_{31}+y_{32}+y_{33}+y_{34}-120t=0,\ y_{11}\le y_{12}, \\ y_{13}\le y_{14},\ y_{21}\le y_{22},\ y_{23}\le y_{24},\ y_{31}\le y_{32},\ y_{33}\le y_{34},\ y_{11}+y_{12}+y_{13}+y_{14}-50t\le 0,\ y_{21}+y_{22}+ \\ +y_{23}+y_{24}-50t\le 0,\ y_{31}+y_{32}+y_{33}+y_{34}-50t\le 0,\ y_{11}-2t\le 0,\ y_{12}-2t\le 0,\ y_{13}-2t\le 0, \\ y_{14}-2t\le 0,\ y_{21}-2t\le 0,\ y_{22}-2t\le 0,\ y_{23}-2t\le 0,\ y_{24}-2t\le 0,\ y_{31}-2t\le 0,\ y_{32}-2t\le 0, \\ y_{33}-2t\le 0,\ y_{34}-2t\le 0,\ y_{11}-20t\le 0,\ y_{12}-20t\le 0,\ y_{13}-20t\le 0,\ y_{14}-20t\le 0,\ y_{21}-20t \\ \le 0,\ y_{22}-20t\le 0,\ y_{23}-20t\le 0,\ y_{24}-20t\le 0,\ y_{31}-20t\le 0,\ y_{32}-20t\le 0,\ y_{33}-20t\le 0, \\ y_{34}-20t\le 0,\ y_{21}+y_{22}+y_{23}+y_{24}\le 1,\ y_{31}+y_{32}+y_{33}+y_{34}\le 1,\ 0.5y_{31}+0.4y_{32}+5t\le 1, \\ 0.3y_{33}+0.5y_{34}+6t\le 1,\ y_{11}+3y_{12}-y_{21}-y_{22}\ge 3.8\lambda,\ 2y_{13}+3y_{14}-y_{23}-y_{24}\ge 4.8\lambda, \\ 4.8\lambda,\ 2y_{21}+3y_{22}-y_{31}-y_{32}\ge 4.8\lambda,\ 5y_{23}+8y_{24}-y_{33}-y_{34}\ge 12.8\lambda,\ 16y_{31}+18y_{32}\ge \\ 29.57\lambda,\ 12y_{33}+8y_{34}\ge 18.18\lambda,\ y_{11}\ge 0.1\lambda,\ y_{12}\ge\lambda,\ y_{13}\ge 0.4\lambda,\ y_{14}\ge\lambda,\ y_{21}\ge 0.2161\lambda, \\ y_{22}\ge\lambda,\ y_{23}\ge 0.2839\lambda,\ y_{24}\ge\lambda,\ y_{31}\ge 0.1985\lambda,\ y_{32}\ge\lambda,\ y_{33}\ge 0.651\lambda,\ y_{34}\ge 0.651\lambda \end{array} \right\}$$

The solution of the model (6) is presented in Table 4.

Table 4: Solution of the model (6)

Variable values (percentage of aspiration realizations)	Objective function values (percentage of aspiration realizations)
y_{11}=0.0487; y_{12}=0.4667; y_{13}=0.0961; y_{14}=0.4754; y_{21}=0.05194; y_{22}=0.4833; y_{23}=0.0682; y_{24}=0.3965; y_{31}=0.0487; y_{32}=0.3515; y_{33}=0.5185; y_{34}=0.2185; t=0.0244; x_{11}=2 (100); x_{12}=19.15 (95.75); x_{13}=3.95 (49.38); x_{14}=19.51 (97.55); x_{21}=2.13 (49.31); x_{22}=19.84 (99.2); x_{23}=2.8 (49.3); x_{24}=16.27 (81.35); x_{31}=2 (50.38); x_{32}=14.43 (72.15); x_{33}=8.97 (68.89); x_{34}=8.97 (68.89)	f_{11}=0.913 (24.03), f_{12}=1.154 (24.04), f_{21}=1.378 (27.71), f_{22}=3.672 (16), f_{31}=24.783 (83.84), f_{32}=13.616 (74.9), $\lambda = 0,24$

The solution given in Table 4 should be presented to the decision makers, who should declare whether they are satisfied with the percentage of realization of the initial aspirations of their objective functions and the variables they control. We hypothesized that the decision-maker at the first level is not satisfied with the percentage of realization of his objective functions aspirations and that the decision-maker at the third level agreed to reduce the value of aspirations of his objective functions and the variables he controls. We solved model (6) with altered the aspirations of the decision maker at the level 3. The obtained solutions (without the values of the variables **y** and *t*) are given in Table 5.

Table 5: The solutions after negotiations with the decision makers

Solution of the model (6) with changes	Variable values (percentage of the aspiration realization)	Objective function values (percentage of the aspiration realization)
$16y_{31}+18y_{32}\geq 25\lambda,$ $12y_{33}+8y_{34}\geq 15\lambda,$ $y_{31}\geq 0.15\lambda,\quad y_{32}\geq 0.8\lambda,$ $y_{33}\geq 0.5\lambda,\quad y_{34}\geq 0.5\lambda$	x_{11}=2 (100); x_{12}=19.9 (99.5); x_{13}=8.39 (104.87); x_{14}=17.58 (87.9); x_{21}=2.24 (51.85); x_{22}=20 (100); x_{23}=2.95 (51.94); x_{24}=16.72 (83.6); x_{31}=2 (50.38); x_{32}=12.64 (63.2); x_{33}=7.79 (59.83); x_{34}=7.79 (59.83)	f_{11}=0.942 (24.79), f_{12}=1.189 (24,77), f_{21}=1.649 (34.35), f_{22}=4.399 (34.37), f_{31}=23.473 (79.38), f_{32}=12.737 (70.06), $\lambda=0,248$
$16y_{31}+18y_{32}\geq 20\lambda,$ $12y_{33}+8y_{34}\geq 10\lambda,$ $y_{31}\geq 0.1\lambda,\quad y_{32}\geq 0.6\lambda,$ $y_{33}\geq 0.4\lambda,\quad y_{34}\geq 0.4\lambda$	x_{11}=3.66 (183); x_{12}=20 (100); x_{13}=6.34 (79.25); x_{14}=20 (100); x_{21}=2.35 (54.4); x_{22}=19.95 (99.75); x_{23}=3.09 (54.4); x_{24}=17.35 (86.75); x_{31}=2 (50.38); x_{32}=10.31 (51.55); x_{33}=4.35 (33.41); x_{34}=10.59 (81.34)	f_{11}=0.968 (25.47), f_{12}=1.222 (25.46), f_{21}=1.917 (39.94), f_{22}=5.122 (40.02), f_{31}=21.492 (72.68), f_{32}=10.867 (59.77), $\lambda=0.2546$
$16y_{31}+18y_{32}\geq 10\lambda,$ $12y_{33}+8y_{34}\geq 6\lambda,$ $y_{31}\geq 0.1\lambda,\quad y_{32}\geq 0.6\lambda,$ $y_{33}\geq 0.4\lambda,\quad y_{34}\geq 0.4\lambda$	x_{11}=3.04 (152); x_{12}=20 (100); x_{13}=6.96 (87); x_{14}=20 (100); x_{21}=3.02 (55.09); x_{22}=18.88 (94.4); x_{23}=3.12 (54.93); x_{24}=18.02 (90.1); x_{31}=2 (50.38); x_{32}=6.6 (33); x_{33}=9.5 (72.69); x_{34}=9.5 (72.69)	f_{11}=0.985 (25.92), f_{12}=1.245 (25.94), f_{21}=1.913 (39.85), f_{22}=5.1 (39.84), f_{31}=17.453 (59.02), f_{32}=13.97 (76.84), $\lambda=0,2594$

5 CONCLUSIONS

The proposed methodology for solving the DML_MOLFP problem involves the simple application of the Charnes–Cooper's method and the MP method, enabling decision makers to be actively involved in the problem solving process. The MP method directs the negotiation process by providing information of aspiration levels which need to be reduced in order to increase the possible realization of dissatisfied decision makers.

For future research, it is proposed to test the effectiveness of a given methodology on problems with a large number of decision makers, objective functions, variables and constraints and test efficiency on real multilevel programming problems.

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Session 6:
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MULTIPLE CRITERIA UTILITY MODELS FOR SORTING INCORPORATING VETO RELATED PREFERENCE STRUCTURES

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Abstract: In this research, veto related structures are introduced into multi-attribute utility models for classification and sorting in order to allow for the principles of constructivism, incomparability and non-compensation of unsatisfactory preferences. Several extensions are proposed to incorporate veto into additive and multiplicative models. The first approach builds on the concepts of UTADIS and ELECTRE TRI methods. The ascending procedure is applied to sort alternatives by comparing their global evaluations to utility thresholds that define the bounds of adjacent categories. The assignment and incomparability categories are obtained in this way. The second approach to aggregate utility and veto pertains to the case of hierarchical sorting. Properties of sorting models are also studied. Several characteristics are determined with a simulation study, and a special veto independency condition is considered. Because it deals with the decision-making problematics of sorting, the presented research complements our previous study which has assessed risk aversion of veto for the case of ranking.

Keywords: multiple criteria decision analysis, utility theory, veto, sorting, preference modelling.

1 INTRODUCTION

Multi-attribute utility theory [7] aggregates preferential information in a fully compensatory manner, in contrast to outranking [11] which defines the veto threshold with the purpose to support the concepts of constructivism, incomparability and incompensation of preferences. Because these three phenomena can be useful in various decision-making settings, we have adopted the notion of veto functions in multi-attribute utility models from the outranking school within the scope of our past research work [2, 4], in order to allow for full or partial non-compensation of unsatisfactory preferences. We have primarily focused on the ranking problematics, but we have also defined some initial rules for sorting. However, the sorting procedure has not been thoroughly developed, and the properties of sorting models with veto related preference structures have not been formally or experimentally assessed. Moreover, our previous study has focused only on additive veto models, while other types of preference models, aggregation models and sorting procedures could be utilized as well. In particular, hierarchical sorting and multiplicative models can be applied.

The presented research builds on our previous work [2, 3, 4]. However, it advances and extends it considerably in the context of sorting. It follows several goals:

1. to completely and thoroughly define and utilize the sorting procedure that is derived from the initial concepts presented in our past papers;
2. to address hierarchical and multiplicative sorting models as a supplement to additive sorting models that incorporate veto;
3. to provide a formal basis to incorporate veto related preference structures into multi-attribute utility models for sorting;
4. to formally and experimentally determine the key properties of multi-attribute utility based sorting models that incorporate veto; and
5. to correlate non-compensatory veto criteria with compensatory utility criteria from the perspective of criteria structure.

According to Stewart and Losa, several valid reasons to incorporate veto into multi-attribute utility theory could be considered [14]. The common rationale comes form the fundamental concepts of outranking, which have been introduced to overcome certain limitations that are imposed by utility theory. Because basic techniques to incorporate veto into utility theory are of limited efficiency, we have introduced a global fully or partially non-compensatory veto criterion, which can be defined either in correspondence to one or more utility criteria or independently [2, 4]. Almeida and Palha et al. have proposed a similar method, in which a linear veto function is defined and aggregated into additive models for ranking [1] or sorting [12], respectively. Jimenez-Martin et al. [6] and Sabio et al. [10] have incorporated veto into additive multi-attribute utility models in the context of group decision-making. The method derives a ranking of alternatives, and is hence not suited for sorting.

Although classification and sorting represent two major decision problem formulations, there are no other documented applications of veto functions in multi-attribute utility models for sorting. On the other hand, veto modelling is a significant topic in the outranking based sorting. It is considered by several methods, most notably by ELECTRE TRI [9] and MR-Sort [8]. Other outranking sorting methods include PROMETHEE TRI, PROMSORT and PAIRCLASS. In relation to outranking models, various preference learning methods may be applied [5]. These methods originate from the disaggregation paradigm, and are able to learn sorting models, rules and parameters from assignment examples. They are often used to infer preferential parameters of ELECTRE TRI or MR-Sort models. The preference disaggregation principle can also be applied to multi-attribute utility theory. The most widely used are UTA methods [13], where UTADIS (*UTilites Additives DIScriminantes*) methods are specifically designed for sorting. However, UTA and UTADIS methods do not consider veto. They only address the inference of utility functions.

2 METHODOLOGY

The veto function $v_j(x)$ is specified for each veto criterion in accordance with the underlying concepts of utility theory by obeying the formal axiomatized approach of certain equivalence, so that criterion-wise values of alternatives are monotonously projected to the [0, 1] interval. If $v_j(x) = 1$, total incompensation occurs (strict veto). If $0 < v_j(x) < 1$, incompensation is partial (weak veto). Details on the veto criterion and the specification of veto function can be found in our previous paper [2]. Here, we focus on the sorting procedure, sorting rules and aggregation of preferences.

There exist several criteria aggregation models for the sorting problematic in relation with the multi-attribute utility function [17]. We propose some extensions to incorporate veto into two additive utility models. The first one is the basic approach in which a single global utility function is defined for all alternatives. This global utility serves as an index used to sort alternatives into predefined classes, so that the global utilities of alternatives are compared to utility thresholds that define the lower bounds of adjacent classes. The second veto extension pertains to the M.H.DIS method [16] in which $2(q-1)$ additive functions are developed to hierarchically sort alternatives.

2.1 Linear sorting procedure

Let $A = \{a_1, a_2, \dots, a_s\}$ be the set of alternatives and let $C_1, C_2, \dots, C_q$ represent the ordered categories or classes into which alternatives are sorted. Here, C_1 is the most preferred and C_q the least preferred category, respectively. Let m be the number of utility criteria and n the number of veto criteria, where m and n are not required to be equal. In the case when $m = n$, a direct complementary veto criterion is defined for each utility criterion. The marginal utility function for the i-th alternative and j-th utility criterion is denoted with $u_j(a_i)$, while $v_k(a_i)$ is the veto function for the i-th alternative and k-th veto criterion. Criteria weights are defined for utility criteria only and are denoted with w_j.

The aggregation of preference related information (concordance indices) and veto related information (discordance indices) is particularly well studied and developed in the context of ELECTRE type methods [9, 11]. A similar approach may be adopted to aggregate utility and veto in additive or multiplicative multi-attribute utility models. At first, the total utility of an alternative is calculated with the standard additive decomposition defined in equation (1) or, alternatively, with the multiplicative decomposition [15] in equation (2):

$$u(a_i) = \sum_{j=1}^{m} w_j u_j(a_i), \tag{1}$$

$$1 + Wu(a_i) = \prod_{j=1}^{m} 1 + W w_j u_j(a_i). \tag{2}$$

In (1) and (2), $u(a_i)$ is the total utility. The global scaling constant W is defined in the case of multiplicative decomposition if the sum of criteria weights or scaling constants is not equal to 1. In general, $\forall j = 1 \ldots m: 0 < w_j < 1$. It is necessary that veto reflects incompensation on the global level. It is hence derived with the product of inverse veto degrees:

$$\tilde{v}(a_i) = \prod_{k=1}^{n} 1 - \left(v_k(a_i)\right)^l. \tag{3}$$

The multiplicative aggregation of veto degrees allows the model to progressively weaken the overall utility of an alternative. In this way, both partial and complete incompensation may be achieved. The higher that $l \geq 1$ is, the less power the effect of veto has. Different values of l correspond to different fuzzy linguistic restrictions. The most simple approach is to aggregate compensatory utilities from (1) or (2) with noncompensatory veto information from (3) with the operator (4) that multiplies the total utility with the product of inverse veto degrees:

$$\sigma(a_i) = u(a_i)\tilde{v}(a_i). \tag{4}$$

If veto is not effective for any criterion, all multiplicands in equation (3) have the value of 1, hence the overall evaluation of the alternative equals to its total utility. If at least one veto criterion opposes a strict veto with regard to the alternative ($\exists k: v_k(a_i) = 1$), the product in (4) is equal to 0, which means that a_i is completely unacceptable due to total incompensation of preferences. When a weak veto occurs for at least one criterion ($\exists k: 0 < v_k(a_i) < 1$), the utility of a_i is reduced due to partial incompensation. A consequence is that a_i generally gets assigned to a worse category.

Based on the obtained $\sigma(a_i)$, $u(a_i)$ and $\tilde{v}(a_i)$ values, the alternative a_i may be sorted into one of predefined categories in several ways. The basic approach is to consider the overall evaluation $\sigma(a_i)$ as the indicator of how well a_i performs. In this case, only the relations of preference and indifference exist between a_i and categories $C_1, C_2, \ldots, C_q$ although the effect of veto is fully taken into account. Classification can be performed in the same way as in the UTADIS method [13], so that $\sigma(a_i)$ is compared to utility thresholds that define the lower and/or upper bounds $u^-(C_h)$ and $u^+(C_h)$ of each category:

$$a_i \in C_1 \Leftrightarrow \sigma(a_i) < u^+(C_1), \tag{5}$$

$$a_i \in C_h \Leftrightarrow \left(\sigma(a_i) \geq u^-(C_h)\right) \wedge \left(\sigma(a_i) < u^+(C_h)\right), 1 < h < q, \tag{6}$$

$$a_i \in C_q \Leftrightarrow \sigma(a_i) \geq u^-\left(C_q\right). \tag{7}$$

Although this approach can provide valid results, it does not consider incomparability, which is one of fundamental characteristics of veto based decision models. Because the inequality $\sigma(a_i) \leq u(a_i)$ always holds, relations of preference, indifference and incomparability (P, I, R) between the alternative a_i and the category C_h are inferred under the following conditions:

$$a_i P C_h \Leftrightarrow \sigma(a_i) \geq u^+(C_h), \tag{8}$$

$$a_i I C_h \Leftrightarrow \Big(\big(u^-(C_h) \leq u(a_i) \leq u^+(C_h)\big) \wedge \big(u^-(C_h) \leq \sigma(a_i) \leq u^+(C_h)\big)\Big), \tag{9}$$

$$a_i R C_h \Leftrightarrow \big(u(a_i) \geq u^-(C_h)\big) \wedge \big(\sigma(a_i) < u^-(C_h)\big). \tag{10}$$

In order to deal with incomparability, ELECTRE type methods use distillation procedures which process outranking relations between alternatives and profiles of categories [9]. Two key procedures are the descending or pessimistic procedure and the ascending or optimistic procedure. It is assumed that a sensible solution is to apply a modified ascending procedure. In this procedure, the alternative a_i is compared with subsequent categories in the ascending order starting with the lowest category C_1 and proceeding towards the highest category C_q. It gets assigned to the first category for which $a_i P C_h$ or $a_i I C_h$ holds true according to (8) and (9). Here, $1 \leq h \leq q$. The alternative is hence sorted into the best category with regard to which it is either preferred or indifferent. If a_i is incomparable to C_h according to (10), it may not be sorted into C_h, so effectively the best possible option that exhibits sufficient values of both $u(a_i)$ and $\sigma(a_i)$ is chosen for the assessment. All categories that are in relation R with a_i according to equation (10) are denoted as incomparable to a_i. This provides the decision-maker with additional preferential information on the assessments of alternatives. The sorting procedure is depicted on Figure 1 for the demonstrative case of two incomparable categories. There is always exactly one assignment category, and zero or more incomparable categories.

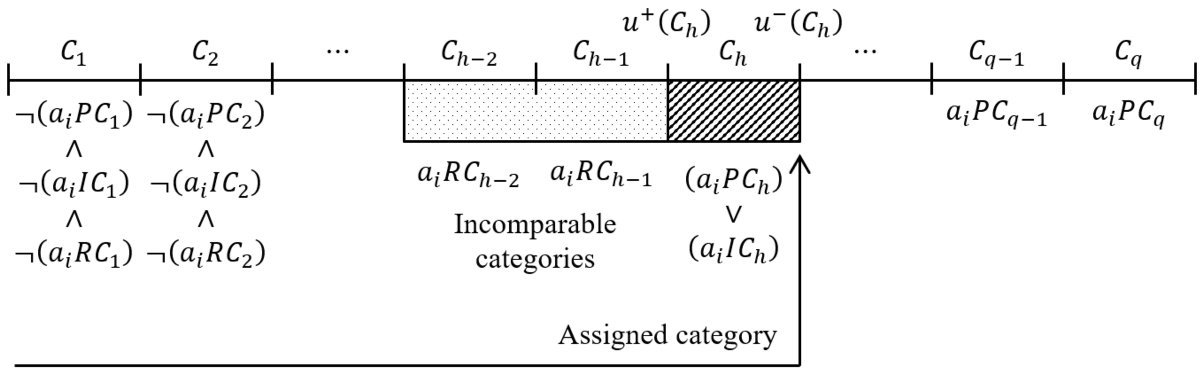

Figure 1: Ascending assignment procedure

2.2 Hierarchical sorting procedure

In this approach, two utility functions and two veto functions are modelled for each category. The procedure starts with the best category C_1. The overall utility function $u_1(a_i)$ describes the perceived utility according to which alternatives are sorted into C_1, while the veto function $v_1(a_i)$ gives the degree of opposition against the attempt to sort an alternative into C_1. Functions $u_{\sim 1}(a_i)$ and $v_{\sim 1}(a_i)$ are defined complementary to determine the suitability of sorting alternatives into the remaining categories $C_2, \dots, C_q$. These functions are aggregated with the following equations:

$$\sigma_1(a_i) = u_1(a_i)\left(1 - \big(v_1(a_i)\big)^l\right), \tag{11}$$

$$\sigma_{\sim 1}(a_i) = u_{\sim 1}(a_i)\left(1 - \big(v_{\sim 1}(a_i)\big)^l\right). \tag{12}$$

The standard sorting rule can then be used:

$$a_i \in C_1 \Leftrightarrow \sigma_1(a_i) > \sigma_{\sim 1}(a_i), \tag{13}$$

$$a_i \in \{C_2, \dots, C_q\} \Leftrightarrow \sigma_1(a_i) < \sigma_{\sim 1}(a_i). \quad (14)$$

When alternatives that belong to the category C_1 are distinguished from alternatives that should be sorted into other avaliable categories, the discrimination procedure continues with the category C_2 as opposed to the categories $C_3, \dots, C_q$. The values of $\sigma_2(a_i)$ and $\sigma_{\sim 2}(a_i)$ are hence calculated. This is repeated until the last two categories C_{q-1} and C_q are only left. The procedure is schematically shown on Figure 2.

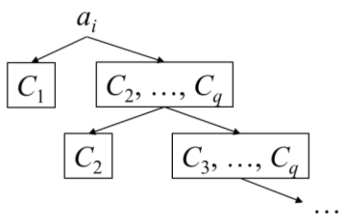

Figure 2: Schematic representation of hierarchical sorting

2.3 Formal properties with regard to MAUT

The introduced veto criterion and the proposed aggregation model can be justified only if the linearity, transitivity and monotonicity properties, as well as the independency conditions are satisfied [7, 15]. The proofs for the first two properties are straightforward, and are omitted. The monotonicity of the aggregation function $\sigma(a_i)$ is a consequence of the monotonicity of individual marginal functions. If $u_j(a_i)$ increases, the aggregated values of $u(a_i)$ and $\sigma(a_i)$ increase as well. On the contrary, the degree of $\sigma(a_i)$ decreases or stays the same if $v_k(a_i)$ increases. This implies that the condition of weak monotonicity is met, since the aggregated value is either constant or reflects the common trend of increasing marginal functions $u_j(a_i)$ and $v_k(a_i)$. According to the original utility theory, marginal utility functions $u_j(a_i)$ are monotonous. The same holds true for veto functions $v_k(a_i)$, because they are specified based on the axiom of continuity or certain equivalence. Therefore, for the veto degrees $v_k(a) > v_k(b)$ and the probabilities $p' > p''$ a relation between two lotteries exists which states that in the case when two lotteries result in the same degree of veto, the preferred lottery is the one that gives a higher veto with a lower probability:

$$[p'', v_k(a); 1 - p'', v_k(b)] > [p', v_k(a); 1 - p', v_k(b)]. \quad (15)$$

Because the veto function is, similarly to the standard utility function, formalized based on the axiom of certain equivalence, three theoretical independency conditions are satisfied. The first two conditions pertain to the preferential and value independency [15]. These types of independencies are universally relevant for utility criteria and veto criteria. In addition, a special veto independency condition has to be introduced in relation to the proposed model that integrates utility and veto. The following independencies are thus satisfied by the multi-criteria decision model that captures the utility and veto related preferential information:

- The criteria x and y are preferentially independent from the utility or veto criterion z, respectively, if bargaining about the values of x and y is not influenced by either the utility or veto of z.
- The criterion x is value independent from the utility or veto criterion y, respectively, if its preferential lotteries are not influenced by either the utility or veto of y.
- The independency of veto is met by the criterion x with regard to the criterion y if lotteries of veto degrees for x do not depend on utility degrees or veto degrees for y.

3 CONCLUSION

In the paper, we have incorporated veto related preference structures into multi-criteria utility models for sorting. We have defined the methodology and the sorting procedure, discussed formal properties of sorting models and provided a review of related work. Due to length limitations, we have omitted a scholarly example to illustrate the approach and we have not presented our experimental study. However, the experimental results show that veto may be a useful component of sorting models that are based on utility theory. It improves the ability to discriminate good options from suboptimal ones and to sort alternatives uniformly into the complete range of categories. This is presumably a consequence of the fact that additional preferential information on veto structures increases the expressiveness and completeness of quantitative models. Another strength of such sorting models is that they are able to cope with conflicting preferences. They expose outstanding criteria and alternatives, and they can clearly indicate when an alternative should not be directly compared with certain categories.

The proposed approach is relatively straightforward, intuitive and easy to comprehend for decision-makers. It can hence be applied in many real-life decision-making situations.

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HOW TO CREATE PIECEWISE LINEAR VALUE FUNCTIONS

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Abstract: This paper introduces a hybrid multi-attribute value theory and creative problem-solving approach to measuring local alternatives' values with respect to criteria on the lowest hierarchy level. It proposes a systematic approach to determine value functions, including the creation of piecewise linear functions by using the bisection method. As part of the comprehensive multi-criteria decision-making problem, the approach is illustrated on a practical problem of switch selection. The described procedure based on the six questions technique can be well used in group preference elicitation in the step of measuring local alternatives' values.

Keywords: piecewise linear value function, multi-criteria decision making, problem solving, six questions technique.

1 INTRODUCTION

In multi-criteria decision making (MCDM) based on assigning criteria weights, measuring alternatives' values encompasses measuring local alternatives' values with respect to each criterion on the lowest hierarchy level, and synthesis, i.e., measuring alternatives' values with respect to all criteria structured in a problem hierarchy. This paper introduces a hybrid multi-attribute value theory and creative problem-solving approach to measuring local alternatives' values with respect to criteria on the lowest hierarchy level. The local values of alternatives can be measured indirectly, e.g., by value functions or pairwise comparisons, or directly. According to [7], a direct specification of a set of parameter values can be difficult for decision makers since it requires considerable cognitive effort. For this reason, indirect specification of preference information is considered to be more user-friendly. The recognized advantage of the indirect over the direct approach is that it allows decision makers to investigate their evaluation of parts of the problem, i.e., alternatives according to criteria, and to elicit their preferences to alternatives with respect to each criterion on the lowest level.

We have already developed and applied the procedure for the criteria weighting based on questions, with applications in Information Technology (IT) selection problems [5]. Regarding measuring alternatives' values, however, it was noted that the existing MCDM methods often use simple monotonic linear value functions for measuring the alternatives' values and pointed out that the assumption of an increasing or decreasing linear function between a criterion level (i.e., over its entire range) and its value might lead to improper results [9]. A set of the following piecewise linear functions is proposed in [9]: increasing, decreasing, V-shape, inverted V-shape, increase-level, level-decrease, level-increase, decrease-level, increasing stepwise, and decreasing stepwise.

The approach proposed in this paper includes determining the decreasing piecewise linear value functions, with multiple (at least two) sections, based on the bisection method [2] by using the six questions technique – the creative problem-solving method used for problem definition. As part of the comprehensive MCDM problem, the approach is illustrated on a real-life problem of switch selection.

2 A SYSTEMATIC APPROACH TO DETERMINE VALUE FUNCTIONS

It is well known that the choice of an appropriate technique for assessment of value function depends on the decision problem, its context, and the decision maker's characteristics [8]. According to [10], decision making not only considers opinions and judgments, but also integrates historical data and expert knowledge. Based on the research, knowledge and experience in measuring local alternatives' values of the author of this paper, it has to be pointed out that the set of influential factors to the assessment of value function depends on the type of a criterion, the data, and decision maker's preferences.

The systematic procedure introduced in this paper includes the creation of piecewise linear function by using the bisection method. In this method, two objects are presented to a decision maker; he is asked to define the attribute level that is halfway between the objects in respect of the relative strengths of the preferences. We have already explained how to create increasing piecewise linear functions [11]. This paper delineates how to create the decreasing piecewise linear function with four sections by using a bisection method.

First, the two extreme points, the most preferred evaluation object x_{min} and the least preferred evaluation object x_{max} are identified and associated with values $v(x_{min}) = 1$, $v(x_{max}) = 0$. Then, a decision maker is asked to define a midpoint x_1, for which:

$$(x_{min}, x_1) \sim (x_1, x_{max}), \tag{1}$$

where ~ indicates the decision maker's indifference between the changes in value levels. While x_1 is in the middle of the value scale, we must have:

$$v(x_1) = 0.5\ v(x_{min}) + 0.5\ v(x_{max}) = 0.5. \tag{2}$$

Similarly, for the midpoint x_2 between x_{min} and x_1, for which:

$$(x_{min}, x_2) \sim (x_2, x_1), \tag{3}$$

we obtain:

$$v(x_2) = 0.5\ v(x_{min}) + 0.5\ v(x_1) = 0.75, \tag{4}$$

and for the midpoint x_3 between x_1 and x_{max}, for which:

$$(x_1, x_3) \sim (x_3, x_{max}), \tag{5}$$

we obtain:

$$v(x_3) = 0.5\ v(x_1) + 0.5\ v(x_{max}) = 0.25. \tag{6}$$

When measuring local alternatives' values with respect to each criterion on the lowest hierarchy level, it is important to ask the decision maker good questions. The term 'decision maker' includes both an individual and a group. For this purpose, we can use the six questions technique – the creative problem-solving method for problem definition, based on questions. The six questions technique is namely a structured method that examines a problem from multiple viewpoints. According to [4], it is best used with rational problems due to its complexity. Moreover, it can be used individually or in groups. A general summary of the six questions technique includes stating the problem using the question 'In what ways might…?', writing down who, what, when, where, why and how questions that are relevant to the problem, answering the above written questions, and examining responses and using them for problem redefinitions [4].

We propose the following process of determining the local alternatives' values:

1. In what ways might the local alternatives' values be determined?

2. The who, what, where, when, why and how questions regarding the local alternatives' values are put and written down.
3. The questions are answered, and the local alternatives' values are determined and re-determined.

3 A PRACTICAL CASE

Let us illustrate a systematic approach to determine value functions on a practical case of switch selection, from the viewpoint of an IT company that offers switches to small and medium-sized companies. Alternatives are the switches that can be offered (Table 1).

Table 1: Alternatives' data together with the methods of measuring local alternatives' values.

Attribute	***Data Type***	***Alternative***			***Measuring Local Alternatives' Values***
		Alternative 1	*Alternative 2*	*Alternative 3*	
Switching bandwidth	Quantitative: Gbps	176	128	880	Value function: LB: 128, UB: 880
Forwarding rate	Quantitative: Mpps	164	95.23	660	Value function: LB: 50, UB: 850
Power over Ethernet	Quantitative: W	600	195	600	Value function: LB: 0, UB: 600
Acoustic noise	Quantitative: dB	45	0	34.2	Pair-wise comparisons
Warranty	Mixed: years or verbal description	3	As long as the original end user continues to own or use the product	5	Pair-wise comparisons
Training	Quantitative: €	400	500	600	Value function: LB: 0, UB: 1000
Price	Quantitative: €	2500	2125	3500	Value function: LB: 1500, UB: 5000

Note: Gbps – Gigabits per second, Mpps – Mega packet per second, W – watt, dB – decibel, € – Euro, Alternative 1 – Dell EMC Switch N1524P [6], Alternative 2 – C1000-24P-4G-L [3], Alternative 3 – 6300M 24x 1G PoE / 4x SFP56 (JL662A) [1], LB – lower bound, UB – upper bound.

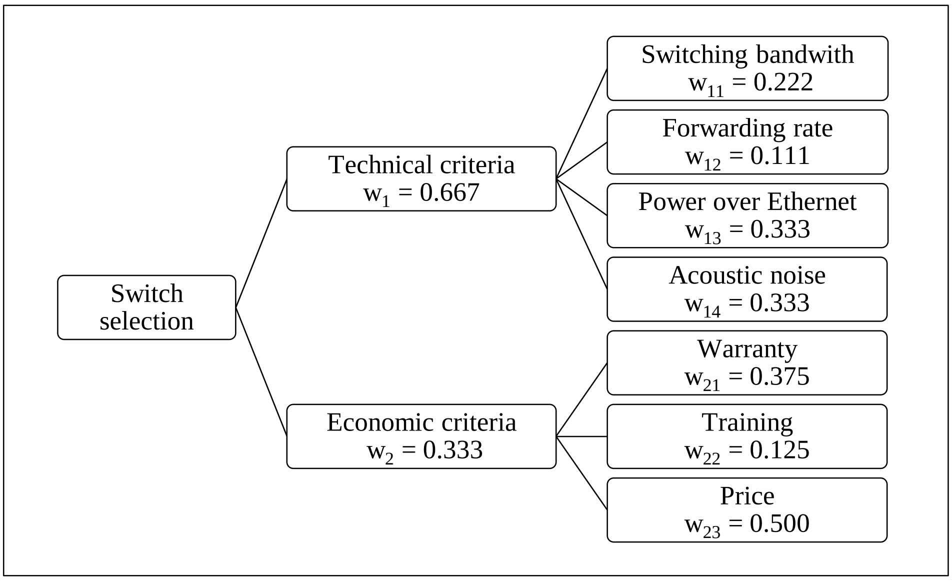

Figure 1: Criteria hierarchy and the weights.

The criteria hierarchy is presented in Figure 1. The criteria importance was together with the IT company's experts determined hierarchically by using the SMART method (see, e.g., [5]).

The decision-maker with appropriate knowledge for creative thinking techniques and for MCDM (in this case, the coordinator) asks and answers the typical question of the first step of the six questions technique process.

Q: In what ways might the local alternatives' values be determined?

A: Individually, in groups. Directly, indirectly, i.e., by using pairwise comparisons (verbal, numerical and graphical), value functions (simple-monotonic, exponential, piecewise linear).

When the local alternatives' values are determined in groups, the group participants are defined in the second and the third step of the proposed process.

Q: Who is responsible for this model building, including local alternatives' values determination?

A: Project manager, responsible for the defined problem solving, and local IT experts.

Q: Who is competent to express preferences about the local alternatives' values?

A: Problem experts and/or experts in the field described by the considered criterion.

Q: What are the additional necessary abilities of the group participants when measuring the local values of alternatives?

A: They should be capable of interdisciplinary co-operation.

After the participants of the group for solving the problem were defined, they answered the questions regarding the model, successively put by the coordinator:

Q: Where will the model be used?

A: In small and medium-sized companies.

Q: When will the model be applied for problem solving?

A: In 2021 and beyond.

As this paper is focused on indirect specification of preference information about alternatives with respect to each criterion on the lowest hierarchy level with value functions, we present in more detail the questions (put by the coordinator) and the participants' answers expressing preferences to measure the local alternatives' values with value functions. When the participants are not familiar with several ways of the local alternatives' ways determination, the coordinator briefly presents the ways of the determination of local alternatives' values. Then the following question should be put for each criterion on the lowest hierarchy level:

Q: With respect to the criterion on the lowest hierarchy level, how will the local alternatives' values be determined?

When the response covers value functions, further questions refer to a more accurate determination of the value function. In this paper, we present questions for the bisection method to determine the piecewise linear function with multiple – in this case four – sections, for measuring the local alternatives' values with respect to price (Table 1). To determine the decreasing linear piecewise linear function, the following questions are put and answered:

Q: Which is the most preferred evaluation object x_{min} so that $v(x_{min}) = 1$?

A: The most preferred evaluation object x_{min} is 1500 EUR.

Q: Which is the least preferred evaluation object x_{max} associated with $v(x_{max}) = 0$?

A: The least preferred evaluation object x_{max} is 5000 EUR.

Q: Why is x_{min} the most preferred evaluation object and x_{max} the least preferred evaluation object?

A: Because the greater the price, the less favorable the alternative.

For the determination of sections, a question based on (1) and (2):

Q: Which is a midpoint x_1, for which $(x_{min}, x_1) \sim (x_1, x_{max})$, where $\sim$ indicates the decision maker's indifference between the changes in value levels, so that $v(x_1) = 0.5\ v(x_{min}) + 0.5\ v(x_{max}) = 0.5$?

may be worded in a question that is more comprehensible to the decision-maker:

Q: Which is a midpoint x_1, which is considered to be equally unfavorable if the price increases from x_{min} to x_1, as if it increases from x_1 to x_{max}?

A: The increase of the price from 1500 to 2500 is equally unfavorable as its increase from 2500 to 5000.

The local value of x_1 is 0.5. So far, we determined the decreasing linear function with two sections. To obtain the decreasing linear function with four sections, the following questions based on (3) – (6) are put and answered:

Q: Which is a midpoint x_2, which is considered to be equally unfavorable if the price increases from x_{min} to x_2, as if it increases from x_2 to x_1, so that $v(x_2) = 0.75$?

A: The increase of the quantity from 1500 to 1800 is equally unfavorable as its increase from 1800 to 2500.

Q: Which is a midpoint x_3, which is considered to be equally unfavorable if the price increases from x_1 to x_3, as if it increases from x_3 to x_{max}, so that $v(x_3) = 0.25$?

A: The increase of the quantity from 2500 to 4000 is equally unfavorable as its increase from 4000 to 5000.

The determination of value functions as a narrower professional task requires the concentration and reflection of everyone in the group. The answers are written down by each participant. Then the coordinator reviews all the answers and presents any differences to the participants. At the coordination meeting, the coordinator asks questions to provide justifications for the preferences expressed and to investigate the causes of differences, with an aim to bring the views of the participants closer. For example, the questions for the lower bound determinations are as follow: Why is x_{min} the most preferred evaluation object? How would the change of x_{min} affect the local alternatives' values? What do we want to achieve: greater or lesser differentiation of alternatives?

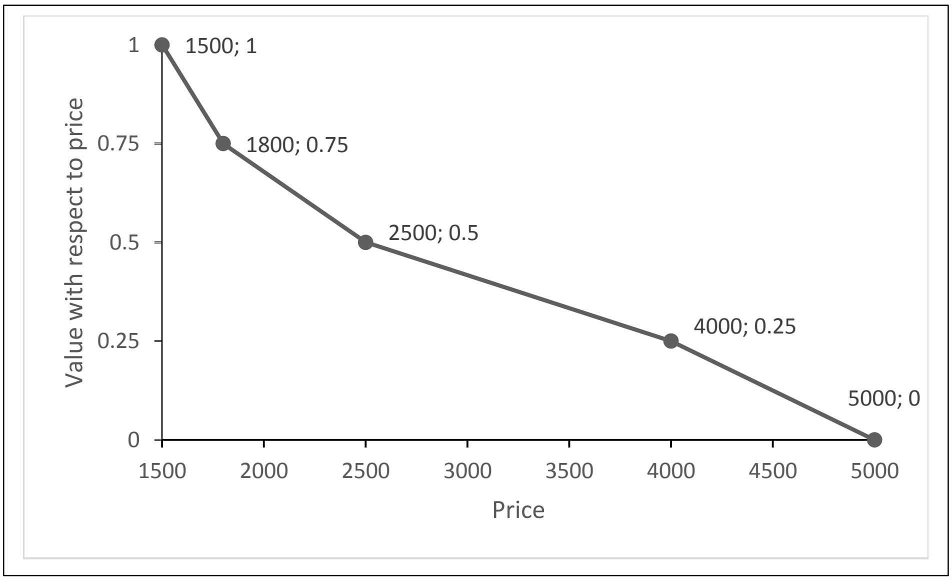

Figure 2: Piecewise linear value function for price.

The obtained decreasing piecewise linear function with respect to price is presented in Figure 2. The local alternatives' values obtained are as follows: v_{23}(Alternative 2) = 0.634, v_{23}(Alternative 1) = 0.5, v_{23}(Alternative 3) = 0.333 and are lower than if they were obtained with monotonic linear decreasing function. The aggregate alternatives' values obtained with an additive model are as follows: v(Alternative 3) = 0.634, v(Alternative 2) = 0.413 and v(Alternative 1) = 0.389.

4 CONCLUSION

In the framework procedure for MCDM, we explored the possibilities of measuring alternatives' values and within this, recommended the original procedure that includes the quantitative and qualitative methods – the creative problem-solving – methods. The described procedure based on the creative problem-solving method, i.e., the six questions technique can be well used in group preference elicitation in the step of measuring local alternatives' values.

In addition, other possibilities of group preference elicitation in the step of measuring alternatives' values can be further explored in detail in the framework procedure for MCDM. Within this, the original procedure can be completed with other quantitative and qualitative methods, with an emphasis to several creative problem-solving methods for problem definition.

Acknowledgement

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A MULTICRITERIA APPROACH FOR THE ANALYSIS OF BIOMEDICAL RESEARCH NETWORKS

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Abstract: This paper aims to present a multicriteria model for studying how to mobilize knowledge for science and innovation. We propose the use of a multi-criteria approach to model the interaction processes of a biomedical network with relevant and diverse actors. The main goal is to identify the mechanisms of scientific collaboration that contribute to greater network cohesion, and how much they should be encouraged to coordinate actor diversity in this research network. The specific setting for our proposal is the biomedical research context. This context allows us to address the multiple dimensions of actor heterogeneity, and the analysis of processes that contribute to bridging translational gaps between knowledge generation and application. The results seek to discuss the benefits of some linkages between different actors in a biomedical network, as well as, identifying and analyzing the type of activities that are particularly conducive to the application of knowledge, in diverse networks.

Keywords: Analytic Network Process, biomedical research, network collaboration, knowledge mobilization, scientific collaboration, translational results.

1 INTRODUCTION

This paper aims to investigate how scientific research networks operate to deliver both scientific discoveries and applicable results. Pursuant to this, a biomedical research group within the biomedical research networking centres in Spain (CIBER network) is analysed.

There are two motivations for this research. First, the role of diverse networks. Social network research [1,2] frequently calls for the formation of research networks embracing multiple stakeholders and actors with distinct cognitions and perspectives, as essential to successfully generate knowledge with higher scientific and societal impact.

Second, we consider the case of biomedicine context, translational research initiatives have become a policy priority as a pathway to facilitating a progression from basic scientific knowledge to patient benefit [3].

Indeed, the aim is the understanding about interaction processes. We are trying to understand the specific type of coordination mechanism in research networks with highly diverse partners.

Against this background we put forward one research question: **What types of activities in research networks are particularly conducive to the application of knowledge?** The idea is to investigate how the scientific collaborative network of a research group operates to deliver both scientific discoveries and applicable results.

The specific setting for our proposal is the biomedical research context. This context allows us to address the multiple dimensions of actor heterogeneity, and the analysis of processes that contribute to bridging translational gaps between knowledge generation and application.

We focus on a research group participating in the Biomedical Research Networking Centres, also known as CIBERs, which is an initiative launched by the Spanish Government in 2007 to foster collaboration between research groups working on similar pathologies [4]. This group is working on rare diseases.

The key criteria for the selection of the case were based on a research network characterized by a high degree of diversity of actors in terms of professional background and a high degree of institutional diversity (policy makers, patients, among others).

2 METHODOLOGICAL PROPOSAL

We propose the use of the Analytic Network Process (ANP) [5] to model this research group, and its interaction processes with relevant and diverse actors, as a research network. These interaction processes will be grouped in components corresponding to different groups of actors.

ANP will be used to analyse the influences that exist among these processes of interaction within and between each group considered in the study. This will allow complementarities to be identified between interaction processes that foster cohesion among network participants. This influence analysis will identify the mechanisms of scientific collaboration that contribute to greater network cohesion, and how much they should be encouraged to coordinate actor diversity in research networks.

The ANP model comprises four main stages (Figure 1). (i) Selection of decision criteria (network elements) and their grouping into components, and analysis of the influences among the elements and components of the network. (ii) The network elements will be derived from semi-structured interviews conducted in a previous phase of the research methodology. The interviews based on the research phases will provide information on the interaction processes that respondents (researchers and stakeholders) identified as relevant for strengthening cohesion in translational research collaborations. The participation of experts with varying expertise in biomedical research is essential for all stages of the ANP method. We use all the researchers and stakeholders involved in processes of interaction that contribute to network cohesion. These stakeholders will include physicians, patient groups, and representatives of companies or other organizations participating in the project. (iii) For the influence analysis among the elements of the network, we will prepare a questionnaire comparing pairs of interaction processes with dependency relations. This questionnaire will be administered face-to-face to experts selected after analysing the case study interviews. The experts will be asked about the interdependence relationships among all the network elements, and to respond to the pairwise comparisons of interaction processes in order to assess the degree of influence of each interaction process on some other process in the context of knowledge generation performance. Finally, (iv) all the calculations and analysis will be developed through the use of Superdecisions Software.

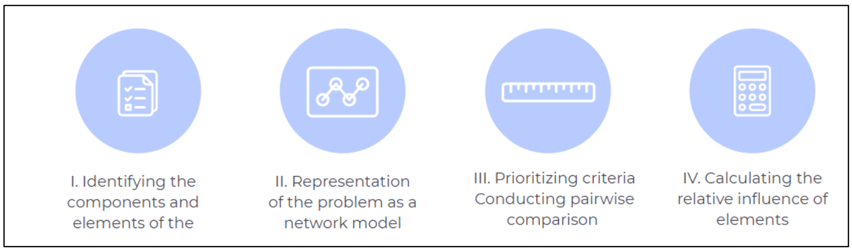


Figure 1 : Methodological proposal. Source: The authors

3 RESULTS

3.1 Identifying the components and elements of the networks

It was necessary to make sure that these elements could be grouped, that they were relevant, not redundant, easy to understand for different actors, and adapted to the case.

In this case those elements constitute two lists: collaboration activities and research results. Both lists came from a literature survey [6][7] and mainly from an iteration process of interviews with the head of a group in the field of rare diseases and that meets the criteria mentioned (see Tab.1).

Table 1: Collaboration activities and research results

I. Collaboration activities with basic researchers, clinicians, health professionals and computer engineers	1. Meetings with basic researchers to open new lines of research and generation of ideas. 2. Design and writing of research projects with basic researchers 3. Meetings with clinical researchers to open new lines of research and generation of ideas. 4. Meetings with health professionals (doctors, nurses, psychologists) to generate new collaboration proposals and assess the group's capacity in a new field of study. 5. Meetings with computer engineers for the design of new research projects. 6. Collaboration with Engineers (analysis of genomic data) to carry out dissemination activities and exploitation of results (publication in conferences and scientific journals). 7. Data collection and analysis with ENT specialists, ophthalmologists, neurologists… (general practitioners) to test initial hypotheses. 8. Participation of clinical researchers (ENT specialists, ophthalmologists, neurologists…) in the design of clinical trials. 9. Introduction of new tests in neonatal screening with ENT specialists, ophthalmologists, neurologists… (general practitioners). 10. Proposals for new algorithms for genomic data analysis by engineers 11. Collaboration with basic researchers to carry out activities to disseminate and exploit results (talks for patients; organization of congresses and conferences, publication of scientific articles) 12. Collaboration with clinical researchers to carry out dissemination activities and exploitation of results (talks for patients; organization of congresses and conferences, publication of papers) 13. Collaboration with health professionals for the organization of conferences, communications to congresses or case reports.
II. Collaboration activities with Spin-offs and Big Pharma	14. Meetings with Spin-offs to generate concrete collaboration proposals based on their expertise. 15. Meetings with Big Pharma to generate concrete collaboration proposals based on our expertise. 16. Collaboration with Spin-offs as partners in ongoing research projects. 17. Collaboration with Spin-offs for patents and products with the possibility of intellectual exploitation 18. Collaboration agreements with Big Pharma to test the efficacy of kits; collaboration through the loan of equipment.
	19. Collaboration with Big Pharma in outreach activities (white papers on diseases, specific courses for healthcare personnel).

III. Collaboration activities with Policy Makers	20. Regular meetings with Public Health to propose a neonatal screening study for a specific disease. 21. Collaboration with the General Research Direction for the preparation of the RIS3 (Research and Innovation Specialized Smart Strategy) scientific strategy to promote research in rare diseases aligned with national and international research strategies. 22. Collaboration with policymakers for the development of clinical guidelines 23. Collaboration with policymakers for the Creation of the Alliance for rare diseases of the Valencian Community (CV) (dedicated to their research). 24. Collaboration with policymakers in the Rare Diseases Information Service of the CV and in the Report on the situation of Clinical Genetics in the CV.
IV. Collaboration activities with patients, families and associations	25. Collaboration with patients, relatives and Patient Associations for testing (testing, data collection, questionnaires ...). 26. Meetings with patients, relatives, patient associations and foundations for genetic counseling, consultation of doubts. 27. Collaboration with the associations of (Asociación Retina-CV; Asocide (Spanish deaf-blind); ASEM (muscular diseases); FUNDAME (Spinal muscular atrophy); AVAEH (Huntington's disease); and FEDER (Spanish Federation of rare diseases that brings together more than 200 associations) for the dissemination of knowledge on rare diseases and financial support. 28. Collaboration with social workers in contact with patients (collecting patient needs, surveys and quality of life documents, recruiting patients for experiments and organizing information days) 29. Collaboration with interpreters for translation between deaf and deaf-blind people and the research team in experimental tests and in informative conferences and talks.
V. Economic-administrative collaboration activities	5.1. Support of the technicians of the economic area in the justification of the economic report of projects and agreements 5.2. Support of technicians of the legal area in the realization of agreements 5.3. Support from human resources technicians in hiring (technicians, predocs, postdocs, etc.) 5.4. Support of the Technicians of the scientific area in calls for projects (dissemination of the call, bases, deadlines ...) 5.5. Collaboration with policymakers in the stabilization plan for CV researchers 5.6. Request for funding from Public Administrations for research projects; research staff, and communication and dissemination of results. 5.7. Meeting and communications with the General Research Direction to request research infrastructures through FEDER Funds. 5.8. Support from the press area for the dissemination of research results
VI. Translational Results	R1. Consultations with patients and / or relatives R2. Institutional participation of the group in relevant actions and specific committees (rare diseases) R3. Participation in the development of the National Genomic Medicine Plan R4. Guidelines developed by the group for professionals and patients R5. Design or execution of clinical trials in preclinical phases, I and II for drug repositioning R6. New applications for orphan drugs designation and / or new orphan designations obtained R7. New applications and / or obtaining of patents, protocols, procedures R8. Technology transfer agreements R9. Scientific publications in prestigious journals R10. Actions to promote a culture of scientific dissemination (interviews in the media ...) R11. Active official records

3.2 Representation of the problem as a network model (influence matrix)

The next stage is to draw the problem as a network model. In this stage, we try to identify some influence among elements. We use a matrix in which row element influences column element. Then, those influences are presented as a network (Figure 2).

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
A1	0	0	1	0	1	0	1	0	1	1	0
A2	0	0	0	0	0	0	1	0	1	1	1
A3	1	0	1	0	1	0	1	0	1	0	0
A4	1	0	0	1	0	0	0	0	1	0	1
A5	0	0	1	0	0	0	1	0	1	0	0
A6	0	0	0	0	0	0	0	0	1	1	0
A7	1	0	1	1	1	0	0	0	1	0	1
A8	1	0	0	1	1	0	0	0	1	0	1
A9	1	0	0	0	1	0	1	0	1	0	0
A10	0	0	0	0	0	0	1	1	1	0	0
A11	0	0	0	0	0	0	0	0	1	1	0
A12	0	0	0	0	0	0	0	0	1	1	0
A13	1	1	0	0	0	0	0	0	1	1	0
A14	0	0	0	0	1	1	1	1	0	0	0
A15	0	0	0	0	1	1	1	1	1	0	0
A16	0	0	0	0	1	1	1	1	1	0	1
A17	0	0	0	0	1	0	1	1	0	0	0
A18	0	0	0	0	1	1	1	1	0	0	0
A19	0	0	0	0	0	0	0	0	0	1	0
A20	0	0	1	0	0	0	0	0	0	0	0
A21	0	1	1	0	0	0	0	0	0	1	1
A22	0	0	0	1	0	0	0	0	0	0	0
A23	0	1	1	0	0	0	0	0	0	0	1
A24	0	1	1	0	0	0	0	0	0	0	1
A25	1	0	0	0	1	0	0	0	0	0	0

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
A26	1	1	0	0	0	0	0	0	0	1	0
A27	1	1	0	0	0	0	0	0	0	1	0
A28	1	0	0	0	0	0	0	0	0	1	0
A29	1	0	0	1	0	0	0	0	0	1	0
A5.1	0	0	1	0	1	0	0	1	0	0	0
A5.2	0	0	0	0	1	1	1	1	0	0	0
A5.3	0	0	0	0	1	0	0	1	0	0	0
A5.4	0	0	0	0	0	0	0	1	0	0	0
A5.5	0	1	0	0	0	0	0	0	0	0	0
A5.6	0	1	0	0	0	0	0	0	1	0	0
A5.7	0	1	1	0	0	0	0	0	0	0	0
A5.8	0	0	0	0	0	0	0	0	1	1	0
R1	0	0	0	0	0	0	0	0	0	0	0
R2	0	0	1	0	0	0	0	0	0	0	0
R3	0	1	0	0	0	0	0	0	0	0	0
R4	1	0	0	0	0	0	0	0	0	0	0
R5	0	0	0	0	0	1	0	0	0	0	0
R6	0	0	0	0	0	0	0	0	0	0	0
R7	0	0	0	0	0	0	0	1	0	0	0
R8	0	0	0	0	1	0	0	0	0	0	0
R9	0	0	0	0	0	0	0	0	0	0	0
R10	0	0	0	0	0	0	0	0	0	0	0
R11	1	0	0	0	0	0	0	0	0	0	0

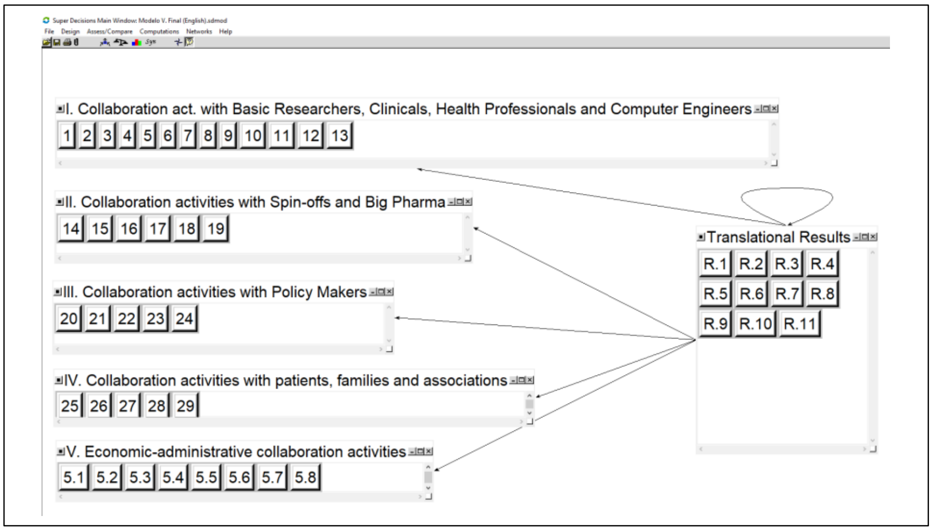
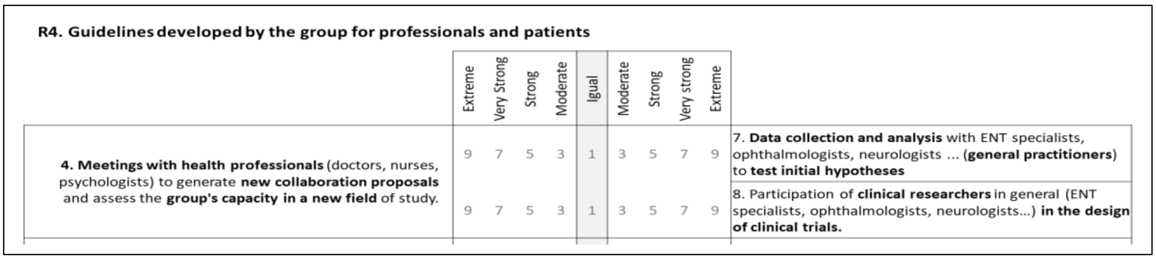


Figure 2: ANP Superdecisions model. Source : Surperdecisions Software©

3.3 Prioritizing the elements – Conducting the pairwise comparisons

Once the model is ready, we design the ANP questionnaire based on pairwise comparisons. As we can see in figure 3, the idea is to compare the influence that two activities exert on one result answering the question: Which element contributes more to obtaining R4? And how much?


R4. Guidelines developed by the group for professionals and patients

	Extreme	Very Strong	Strong	Moderate	Igual	Moderate	Strong	Very strong	Extreme	
4. Meetings with health professionals (doctors, nurses, psychologists) to generate **new collaboration proposals** and assess the **group's capacity in a new field** of study.	9	7	5	3	1	3	5	7	9	7. **Data collection and analysis** with ENT specialists, ophthalmologists, neurologists ... (**general practitioners**) to **test initial hypotheses**
	9	7	5	3	1	3	5	7	9	8. Participation of **clinical researchers** in general (ENT specialists, ophthalmologists, neurologists...) **in the design of clinical trials.**

Figure 3: Example of ANP questionnaire

3.4 Calculating the relative influence of elements

Once we have all the pairwise comparisons, we will get the weights or the influence, in terms of a percentage of each collaboration activity on each result. The results will be analysed in order to obtain not only the relative influence of each activity but also we will identify those activities that may contribute the most to achieving each result.

4 POTENTIAL CONCLUSIONS

So far, we are collecting the questionnaires, but the results seek to discuss the benefits of some linkages between different actors in a biomedical network and how they can usefully address current and future research for this particular group. Also, we want to assess coordination mechanisms that foster cohesion among network participants.
We will explore to what extent certain networking mobilization activities and resources allow research groups to involve actors with different levels of cognitive and institutional diversity.

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COMPARISON OF BEST-WORST METHOD AND ANALYTIC HIERARCHY PROCESS

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Abstract: Best-worst method (BWM) is a recent multi-criteria decision method based on pairwise comparisons, similar to the analytic hierarchy process (AHP). Its main advantage is the smaller number of pairwise comparisons required. Using data from the literature, we compared the results of these two methods. First, we compared the consistency of the comparisons, which shows that AHP comparisons can be more consistent. We also questioned the logic of the input-based consistency ratio in BWM. Then, we compared the individual and group weights obtained by AHP and two models of BWM with the measure of total deviation. The results show that in most cases AHP weights were better evaluated.

Keywords: Multi-criteria decision making, Best-Worst method, Analytic hierarchy process, Consistency, Group decision making, DPSIR model

1 INTRODUCTION

Multi-criteria decision making using many well-known methods is an important part of decision theory. In the class with discrete solutions, one of the most commonly used methods is the analytic hierarchy process (AHP) (Saaty, 1980), with pairwise comparisons of objects as the core of the method. The main drawback of the AHP is the quadratic increase of the pairwise comparisons with respect to the number of compared objects. If the number of required evaluations is too high, their consistency may become a problem. To overcome this drawback, Rezaei (2015) introduced the best – worst method (BWM), which requires fewer comparisons. For n objects, it requires $2n$-3 comparisons, while AHP requires $n(n$-1)/2 comparisons. The authors claim that BWM produces highly consistent comparisons that lead to results with a high degree of reliability (Ahmad et al., 2017).

The aim of this study is to compare the consistency of BWM and AHP comparisons and weights for one decision maker and aggregate results for a group of decision makers.

2 METHODS

2.1 Analytic hierarchy process

Let n be the number of elements compared and m be the number of decision makers (DMs). In AHP, the standard 1-9 scale (Saaty, 1980) is used to evaluate pairwise comparisons of elements at the same hierarchical level, which are collected in pairwise comparison matrices (PCMs) $A^{(k)} = \left(a_{ij}^k\right)_{n\times n}$, $k=1,\dots,m$. The weights $\left(w_1, w_2, \dots, w_n\right)$ can be derived from PCM A by the logarithmic least square method

$$w_i = \frac{\sqrt[n]{\prod_{j=1}^{n} a_{ij}}}{\sum_{i=1}^{n}\left(\sqrt[n]{\prod_{j=1}^{n} a_{ij}}\right)} \tag{1}$$

The group weights can be derived by the arithmetic mean of the individual weights.

PCM A is consistent if $a_{ik}a_{kj} = a_{ij}$, for all i, j, k. The level of inconsistency is measured by the consistency ratio $CR_A = \frac{CI_A}{RI_n}$, a quotient of the consistency index $CI_A = \frac{\lambda_{A,\max} - n}{n-1}$ and the random index RI_n. PCM A with $CR_A < 0.1$ is considered acceptably consistent.

2.2 Best-worst method

BWM can be summarized in five steps (Rezaei, 2015). Step 1-2: Select the best (most important) (B) and worst (least important) (W) elements from the set of n evaluated elements. Step 3-4: Determine the preferences of the best element over all other elements using the 1-9 scale and collect the results in the best-to-others vector $(a_{B1}, a_{B2}, ..., a_{Bn})$. Determine the preferences of all other elements over the worst one using the 1-9 scale and collect the results in the others-to-worst vector $(a_{1W}, a_{2W}, ..., a_{nW})$. Step 5: Determine the weights by solving the optimization model.

There are several known models in BWM for deriving weights. We selected two of them, the equivalent form of the original model (Model 1) and the linear form (Rezaei, 2016) (Model 2).

Model 1

$$\begin{aligned} &\min \xi \\ &\text{s.t. } \left| \frac{w_B}{w_j} - a_{Bj} \right| \le \xi, \text{ for all } j \\ &\left| \frac{w_j}{w_W} - a_{jW} \right| \le \xi, \text{ for all } j \\ &\sum_j w_j = 1, \; w_j \ge 0, \text{ for all } j \end{aligned}$$

Model 2

$$\begin{aligned} &\min \xi^L \\ &\text{s.t. } \left| w_B - a_{Bj} w_j \right| \le \xi^L, \text{ for all } j \\ &\left| w_j - a_{jW} w_W \right| \le \xi^L, \text{ for all } j \\ &\sum_j w_j = 1, \; w_j \ge 0, \text{ for all } j \end{aligned} \tag{2}$$

When the number of elements is more than three and the comparison system is inconsistent, Model 2 may have multiple optimal solutions. Based on the optimal objective value ξ^* of Model 2, minimum and maximum weights can be derived from models (3), respectively.

$$\begin{aligned} &\min \; w_j \\ &\text{s.t. } \left| \frac{w_B}{w_j} - a_{Bj} \right| \le \xi^*, \text{ for all } j \\ &\left| \frac{w_j}{w_W} - a_{jW} \right| \le \xi^*, \text{ for all } j \\ &\sum_j w_j = 1, \; w_j \ge 0, \text{ for all } j \end{aligned} \qquad \begin{aligned} &\max \; w_j \\ &\text{s.t. } \left| \frac{w_B}{w_j} - a_{Bj} \right| \le \xi^*, \text{ for all } j \\ &\left| \frac{w_j}{w_W} - a_{jW} \right| \le \xi^*, \text{ for all } j \\ &\sum_j w_j = 1, \; w_j \ge 0, \text{ for all } j \end{aligned} \tag{3}$$

One way is to choose the average of minimum and maximum optimal weights obtained from models (3) as the representative optimal weights (Rezaei et al., 2015)

$$w_j^* = \frac{w_j^{\min *} + w_j^{\max *}}{2} \tag{4}$$

The group weights can be derived by taking the arithmetic mean of the individual weights.

The consistency of BWM pairwise comparison system is defined as $a_{Bj}a_{jW} = a_{BW}$, for all j. Consistency ratio (CR) is proposed as a measure of inconsistency (Liang et al., 2020). For

Model 1 output-based CR is defined as $CR^0 = \frac{\xi^*}{\xi_{\max}}$, where ξ^* is the optimal objective value of Model 1 and $\xi_{\max}$ is the maximal possible ξ with values 1.00 for $n=3$, 1.63 for $n=4$ and 2.30 for $n=5$. For Model 2 output-based CR is defined as $CR^L = \xi^{*L}$, where ξ^{*L} is the optimal objective value of Model 2. Input-based CR^I depends only on pairwise comparisons and not on the selected model for deriving weights.

$$CR^I = \max_j CR_j^I, \text{ where } CR_j^I = \begin{cases} \frac{\left|a_{Bj}a_{jW} - a_{BW}\right|}{a_{BW}^2 - a_{BW}} & a_{BW} > 1 \\ 0, & a_{BW} = 1 \end{cases} \tag{5}$$

Table 1 presents thresholds of CR for different number of criteria and different maximum value used in the pairwise comparison system. For the cases when a_{BW} equals 1 or 2 and for n=2, the threshold is zero. For CR^L the threshold for acceptable consistency is not defined yet.

Table 1: Thresholds for Model 1 output-based and input-based CR for different maximum pairwise comparison a_{BW} and number of compared elements n

	CR^O, Model 1, BWM			CR^I, BWM		
a_{BW} / n	3	4	5	3	4	5
3	0.2087	0.2087	0.2087	0.1667	0.1667	0.1667
4	0.1581	0.2352	0.2738	0.1121	0.1529	0.1898
5	0.2111	0.2848	0.3019	0.1354	0.1994	0.2306
6	0.2164	0.2922	0.3565	0.1330	0.1990	0.2643
7	0.2090	0.3313	0.3734	0.1294	0.2457	0.2819
8	0.2267	0.3409	0.4029	0.1309	0.2521	0.2958
9	0.2122	0.3653	0.4055	0.1359	0.2681	0.3062

2.3 Comparison of weights

To compare the results of AHP and BWM, the measure of total deviation (TD) is one of the possibilities. It measures the Euclidean distance between the ratios of the weights and the corresponding pairwise comparison

$$TD = \sum_i \sum_j \left(a_{ij} - \tfrac{w_i}{w_j}\right)^2 \tag{6}$$

Smaller values of TD indicate that the weight ratios are closer to the pairwise comparisons and therefore more desirable. To enable the comparison between AHP and BWM, adjusted TD should be used (Rezaei, 2015), which is TD divided by the total number of pairwise comparisons, which is n^2 for AHP and $2n-1$ for BWM. Although we have two vectors with n components in BWM, a_{BW} appears in both vectors, therefore there are 2n-1 different pairwise comparisons.

3 CASE STUDY

The DPSIR framework was a basis of the selected model for forest management planning (Šmidovnik & Grošelj, 2021). DPSIR (*drivers (D), pressures (P), states (S), impacts (I), responses (R)*) is a casual framework for describing the interactions between society and the environment, the influence of humans on the environment and vice versa (Tscherning et al., 2012). It was developed by European Environment Agency. The model was created for the assessment of urban and suburban forests. Different forest functions such as timber production, research and climate function were chosen as driving forces. Recreation of people, insects, testing or research, and natural disasters were chosen as pressures. Growing stock, percentage of forest cover and number of tree species were used to describe the states. The model considered the impacts on climate change, wildlife, researches, recreation, and owners (economic view). The model included economic, ecological, and social responses.

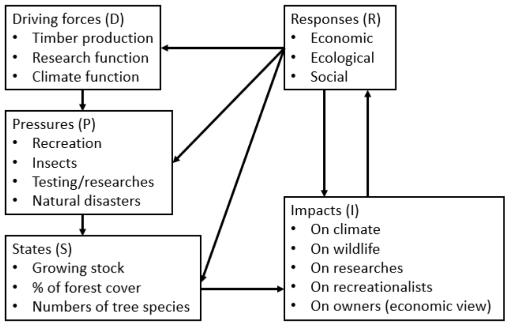

Figure 1: DPSIR framework of the forest management model

Three selected forest management experts evaluated criteria of five DPSIR components for the research forest of the Department of Forestry and Renewable Forest Resources, Biotechnical Faculty, University of Ljubljana. They used the AHP method. For the BWM, the best and worst criteria and scores were selected from the AHP PCMs. The consistency ratios were calculated and individual weights were derived by AHP and BWM, Models 1 and 2. Individual weights were aggregated into group weights by arithmetic mean. Input-based consistency ratios were calculated. Individual and group weights were calculated by Model 1 and Model 2, with associated output-based consistency ratios. The adjusted TD was used to compare individual weights. To compare the group weights of AHP and BWM, TD was calculated as the Euclidean distance between the ratios of the group weights and the corresponding individual pairwise comparisons. Then, the average of the TD adjusted for AHP and BWM was used.

4 RESULTS AND DISCUSSION

Table 2 shows the CR of the AHP pairwise comparisons, the output-based CR for Models 1 and 2, and input-based CR. The last part of the Table 2 shows a_{BW} that influences the BWM CR thresholds. Values in bold are not acceptably consistent. Since the threshold for acceptable consistency of CR^L is not yet defined, there are no values in bold.

Table 2: CR of three DMs of AHP pairwise comparisons, output-based for Models 1 and 2 and input-based. Values in bold are not acceptably consistent. Maximum pairwise comparisons a_{BW} .

	CR_A, AHP			CR^O, Model 1, BWM			CR^L, Model 2, BWM			CR^I, BWM			a_{BW}		
DM	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
D	0.004	**0.141**	0.077	0.172	**1.576**	**0.807**	0.025	0.189	0.125	0.050	**0.250**	**0.417**	5	9	4
P	0.029	0.094	0.025	0.145	**0.967**	**0.329**	0.063	0.171	0.073	0.167	0.250	0.133	3	9	6
R	0.019	0.077	0.000	**0.500**	**1.127**	0.140	0.077	0.133	0.000	0.167	**0.179**	0.000	3	8	6
I	0.015	**0.130**	**0.275**	**0.191**	**1.508**	**1.620**	0.056	0.192	0.237	**1.000**	**0.556**	**1.000**	2	9	7
S	0.000	0.038	0.010	**0.006**	**0.678**	**0.193**	0.000	0.097	0.042	0.000	0.097	0.083	2	9	4

The results show that DM2 used the highest scores (8 or 9) to express preference for the best criterion over the worst, while DM3 used medium scores (4-7) and DM1 used smaller scores (1-3). This is reflected in the consistency of the comparisons, with DM2 being the most inconsistent. When comparing methods, AHP has more acceptably consistent comparisons than BWM. This contradicts the statement that one of the advantages of BWM is that a smaller number of pairwise comparisons leads to higher consistency (Rezaei, 2015). There are also concerns about whether the definition of input-based CR is logical. For example, for Drivers CR of AHP and both output-based BWM CR indicate that DM2 is less consistent than DM3. However, input-based CR indicates that DM3 is less consistent than DM2. The main problem is a_{BW}, which appears in the denominator of CR^I. DM2 has $a_{BW} = 9$, which causes the fraction CR^I to be much smaller than that of DM3 with $a_{BW} = 4$. A similar result can be found for Responses and Impacts for DM1 and DM2.

Table 3 shows the individual weights for AHP and BWM Models 1 and 2. The results show that there are some significant differences between AHP weights and BWM weights and also between BWM Models 1 and 2. Weights where the differences between at least two models are greater than 0.05 are marked in bold. The main differences are for DM2, who made the most inconsistent pairwise comparisons. TD indicates that only for DM2 in Model 1 BWM gives a better result. Otherwise, the AHP weights are better because they better reflect the initial pairwise comparisons.

Table 3: Weights, derived by AHP, Model 1 BWM and Model 2 BWM, and TD

		AHP			Model 1			Model 2		
		DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3
D	Timber production	0.648	0.642	0.268	0.646	0.557	0.274	0.650	0.663	0.250
	Research function	0.122	0.309	0.614	0.125	0.391	0.601	0.125	0.284	0.625
	Climate function	0.230	0.049	0.117	0.229	0.053	0.125	0.225	0.053	0.125
	TD	0.016	2.703	0.286	0.018	**1.490**	0.391	0.018	5.273	0.450
P	Recreation	0.150	0.038	0.062	0.138	0.049	0.061	0.125	0.048	0.061
	Insects	0.283	0.574	0.387	0.309	0.515	0.400	0.313	0.599	0.390
	Testing/researches	0.200	0.071	0.260	0.171	0.075	0.272	0.188	0.096	0.232
	Natural disasters	0.367	0.318	0.291	0.382	0.363	0.268	0.375	0.257	0.317
	TD	0.037	1.889	0.067	0.040	**1.538**	0.183	0.077	4.354	0.456
R	Economic	0.387	0.653	0.600	0.370	0.609	0.594	0.385	0.667	0.600
	Ecological	0.443	0.285	0.300	0.436	0.325	0.306	0.462	0.267	0.300
	Social	0.169	0.062	0.100	0.180	0.067	0.100	0.154	0.067	0.100
	TD	0.030	0.967	0.000	0.075	**0.761**	0.002	0.049	1.650	0.000
I	On climate	0.246	0.028	0.516	0.249	0.043	0.523	0.278	0.043	0.593
	On wildlife	0.219	0.142	0.187	0.189	0.138	0.160	0.167	0.110	0.119
	On researches	0.123	0.192	0.163	0.148	0.209	0.160	0.111	0.155	0.119
	On recreationalists	0.123	0.052	0.069	0.125	0.110	0.086	0.167	0.110	0.119
	On owners	0.289	0.586	0.065	0.296	0.519	0.048	0.278	0.581	0.051
	TD	0.038	6.097	10.434	0.070	**5.586**	16.233	0.188	6.556	16.889
S	Growing stock	0.400	0.589	0.458	0.400	0.538	0.476	0.400	0.597	0.458
	% of forest cover	0.400	0.054	0.416	0.399	0.056	0.399	0.400	0.056	0.417
	Nr. of tree species	0.200	0.357	0.126	0.200	0.407	0.125	0.200	0.347	0.125
	TD	0.000	0.634	0.027	0.000	0.275	0.022	0.000	1.241	0.046

Table 4 presents group weights and group TD. The results show that AHP was evaluated significantly better than BWM models for all DPSIR components.

5 CONCLUSIONS

We compared two multi-criteria decision making methods based on pairwise comparisons. While AHP is a well-known method from 1980, BWM is a new method from 2015.

Table 4: Group weights and group TD

		AHP	Model 1	Model 2
D	Timber production	0.520	0.460	0.521
	Research function	0.348	0.363	0.345
	Climate function	0.132	0.141	0.134
	group TD	3.658	6.284	6.354
P	Recreation	0.083	0.093	0.078
	Insects	0.415	0.413	0.434
	Researches	0.177	0.172	0.172
	Natural disasters	0.325	0.322	0.316
	group TD	1.726	4.632	3.690
R	Economic	0.547	0.490	0.552
	Ecological	0.343	0.348	0.337
	Social	0.110	0.130	0.111
	group TD	1.125	2.124	2.063
I	On climate	0.263	0.295	0.305
	On wildlife	0.183	0.163	0.132
	On researches	0.159	0.195	0.128
	On recreationalists	0.081	0.106	0.132
	On owners	0.314	0.297	0.303
	group TD	6.796	22.320	14.841
S	Growing stock	0.482	0.469	0.485
	% of forest cover	0.290	0.228	0.291
	Nr. of tree species	0.228	0.266	0.224
	group TD	4.298	7.612	7.671

Rezaei (2015) claims that BWM has several advantages over AHP. While we agree that the main advantage of BWM is the reduced number of pairwise comparisons required, we cannot agree that this leads to highly reliable and more consistent comparisons. The results of our case study show that this need not be the case.

The drawback of our study is that we took pairwise comparisons from the AHP for the BWM. It can be argued that DMs may make different evaluations when they first select the best and the worst criterion and then make pairwise comparisons. However, both methods are very subjective and the same DM may have different preferences when comparing the same elements again. In the future, more research should address the reliability of weights in BWM. The problem of consistency in BWM should also be studied more thoroughly.

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MULTI-CRITERIA DECISION MAKING METHODS COMPARISON ON A CASE OF POWER PLANT PROCUREMENT

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Abstract: Significant amounts of taxpayers' money are spent on government procurement every year. Therefore, governments should conduct them efficiently and with high standards of conduct to ensure high quality of service delivery and to safeguard the public interest. With the use of multi-criteria decision making methods, decision makers would be able to decompose complex decision (i.e. public procurement problem) into smaller sub-problems, weigh up criteria, evaluate and rank received bids (alternatives) and finally select the most suitable one and thus make decision (i.e. public procurement process) more transparent, efficient and comprehensible. In this paper, a comparison of different multi-criteria decision making methods is presented on a synthetic case of power plant procurement.

Keywords: decision making, multiple criteria decision analysis, decision methods, economical procurement, power plant

1 INTRODUCTION

Public procurement or public contract is a term that mean a set of actions carried out by the contracting authorities with the aim of economical procurement of goods, services and work while considering the fundamental principles of public procurement [12]. In 2014, the Directive 2014/24/EU on public procurements was introduced and since then the concept of MEAT[1] is used, which takes into consideration aspects other than the lowest price [28]. Award criterion lowest price is very questionable as it can happen, that public procurement is awarded to a bidder whose goods can have bad specification and poor quality of delivery (e.g. [22], [23]) and may also seriously damage financial health, reputation and have undesirable and unexpected side effects [21]. MEAT has to be assessed on the basis of price or cost, using cost-effectiveness approach or the best prices-quality ratio [13]. Due to a low adaptability to administrative culture, unfamiliarity with the purchasing operation during the preliminary stage, difficulty selecting experience evaluation committee members and the quality of the evaluation committee and inappropriate evaluation methods, many scholars have criticised the MEAT [16]. According to [2] the usage of the MEAT can also lead to favouring a specific bidder when assigning a high weight to a criterion which only that bidder can fully satisfy. This method is often characterized by subjective choices which have a tendency of enabling corrupt behaviour.

Essentially, evaluation of public procurements and thus selecting the most appropriate bidder is public multi-criteria decision making (MCDM) problem, which requires that the selection is made from the set of alternatives (potential bidders) in accordance with the evaluation of their inherent attributes (quantitative and qualitative) [25]. Many decision methods have been developed by scientists in the field of decision theory to solve decision problems. The choice depends on multiple factors, like users' skills and knowledge, preference and assumption of the decision maker(s) or desired level of accuracy [11]. Applicability of MCDM methods in the case of public procurement is further complicated by the need of public procurement official to comply with basic principles of public procurement like transparency,

[1] The Most Economically Advantageous Tender

integrity, economy, openness, fairness competition and accountability [15]. As such, selecting the most suitable MCDM method is a decision problem itself. In this context, the aim of the work is to analyse five MCDM methods (AHP[2] [26], PROMETHEE[3] [3], TODA[4] [19], WSM[5] [14] and WPM[6] [4]) on a synthetic case of selecting the best location for power plant. We selected this synthetic case as there are many cases or intentions of power plant procurements all over the world (e.g. [1], [5], [8], [20], [24]). The use of the MCDM method could also prevent unsuccessful projects [6] and reduce development costs [9], as the selection of the most suitable bidder would be more comprehensible, efficient and transparent (which could also reduce the possibility of corruption).

2 METHODOLOGY

The methodological framework consists of few steps, 1) use of a case study, 2) development of a decision support model for each multi-criteria decision making method, 3) evaluate the case study for two scenarios and 4) use of Fibonacci scale to score evaluation results for both scenarios.

Consumption of electricity in Europe is constantly increasing, and therefor there is a need for new hydro electrical power plant. According to use case [17], six national projects (alternatives) have been proposed (Italy, Belgium, Germany, Sweden, Austria and France). There are six criteria by which those alternatives are assessed: 1) manpower, power (10 MW), construction cost (10 EUR), operation cost (10 EUR), number of villages to evacuate and 6) safety level. Power and safety level are positive criteria, so the alternative with the highest value will be the best, while manpower, construction cost, operation cost and number of villages to evacuate are negative criteria, so the alternative with the lowest value will be the best. Preference functions and thresholds for criteria are: 1) manpower (U-shape, q=10), 2) power (V-shape, p=30), 3) cost (Linear, q=50, p=500), 4) operation host (Level, q=1, p=6), 5) number of villages to evacuate (Usual) and 6) safety (Gaussian, s=5). Threshold “q” represents the largest difference that is considered as negligible, “p” represents the smallest difference that corresponds to a full undisputable preference and “s” defines the position of inflexion point of the preference curve.

In the 1st scenario (s1), all criteria will have the same weight as all criteria are equally important, while in the 2nd weights will be calculated with the AHP method, as the construction cost and operation cost are extremely more important against other criteria and thus have higher weight and higher impact on the final score. In both scenario, the sum of weights is 100 %.

Table 1: Alternatives values for each criterion

Criteria	***Min/ Max***	***Alternatives***						***Weights (s1)***	***Weights (s2)***
		Italy	*Belgium*	*Germany*	*Sweden*	*Austria*	*France*		
Manpower	Min	80	65	83	40	52	94	16,67 %	4,55 %
Power	Max	90	58	60	80	72	96	16,67 %	4,55 %
Construction cost)	Min	600	200	400	1000	600	700	16,67 %	40,91 %
Operation cost	Min	5,4	9,7	7,2	7,5	2,0	3,6	16,67 %	40,91 %
Number of villages to evacuate	Min	8	1	4	7	3	5	16,67 %	4,55 %
Safety level	Max	5	1	7	10	8	6	16,67 %	4,55 %

[2] Analytic Hierarchy Process
[3] Preference Ranking Organization METHod for Enrichment of Evaluation
[4] Trade Off Decision Analysis
[5] Weighted Sum Model
[6] Weighted Product Model

The preparation of the multi-criteria decision model is based on the methodology of multi-attribute decision making, which enables us to differentiate between various alternatives (in our case countries) according to six criteria. According to [30], available MCDM methods can be categorized into three schools: 1) Value measurement models (e.g. WSM, AHP), 2) Goal, aspiration and reference level models (e.g., TOPSIS) and 3) Outranking models (e.g. PROMETHEE). We will compare methods from first school with outranking method PROMETHEE.

According to [29], the WSM is probably the most commonly used approach, especially in single dimensional problems. In single-dimensional cases, where all the units are the same, the WSM can be used without difficulty. As we have multi-dimensional problem (different units), the additive assumption is violated. WPM is very similar to WSM, the main difference is that instead of addition in the model there is multiplication. WPM is sometimes called dimensionless analysis because its structure eliminates any units of measure and thus can be used in single- and multi-dimensional MCDM. The main advantage over the WSM is that instead of actual values it can use relative ones.

In [26] was stated that the AHP is a general theory of measurement and is used to derive ration scales from both discrete and continuous paired comparisons. These comparisons can be taken from actual measurement or from a fundamental scale which reflects the relative strength of preferences and filings. The AHP method is an approach to MCDM, where elements are hierarchically structured. The distribution of goals, criteria, attributes and stakeholders serves two purposes, to provide a comprehensive view of the complex relationship of the situation and to help the decision-maker to assess whether the criteria at the same hierarchic level are equally important [27].

The least known method is TODA. According to [19], TODA emerged as an alternative to AHP and has a simpler decision-making process, that avoids the complex procedure to verify the consistency of preferences. It is based on three principles of analytical thinking and enables decision maker to: 1) construct a hierarchy and decompose problems into sub-problems for easier understanding and evaluation, 2) establish priorities using a Trade-off matrix with objective function and 3) observe absolute logical consistency that is induced by the process of establishing priorities. AHP uses complex calculation to obtain consistency index while TODA assures consistency through the comparison pivot.

In [18] was said that the PROMETHEE method offers decision-makers two types of values: partial values (positive and negative flow) of alternatives and the total value (the sum of positive and negative flow) of alternative which will be used in this case study. PROMETHEE ranking shows us the most suitable alternative according to a compromise between evaluation criteria, desires and priorities and also it enables us to choose different alternatives depending on the specific restrictions (e.g. the size of the budget).

As methods WSM and WPM are the most basic methods available, they will be used as a baseline scenario, AHP will be used as it is one of the most used method, and TODA will be used as it is an alternative to the AHP with a simpler decision-making process. PROMETHEE will be used as it shows positive and negative flows of each alternative, where the alternative with higher flow is preferred, if the flows of two alternatives are almost the same.

As we expect that different MCDM methods will give different results, we will use a Fibonacci scale for final ranking of alternatives. Fibonacci series was invented in about 1200 and starts with 1, 1, 2, 3, 5, 8, 21, 34, … [10]. We can see, that the sequence of numbers can go infinitely. It begins with two 1s, followed by 2 (sum of 1+1), followed by 3 (sum of 1+2), followed by 5 (sum of 2+3). Each time, the adding of previous two numbers gives us the next number. The best alternative will get 13 points, 2nd alternative 8 points, 3rd alternative 5 points, 4th alternative 3 points, 5th alternative 2 points and the last alternative 1 point.

3 RESULTS

In this chapter, results of the assessments for both scenario are presented. First, we present the results for the 1st scenario and then the 2nd scenario.

Table 2: Results for 1st scenario

Alternatives	***Ranking***				
	AHP	***PROMETHEE***	***TODA***	***WSM***	***WPM***
Italy	5.	6.	6.	6.	6.
Belgium	2.	2.	4.	1.	3.
Germany	6.	5.	3.	5.	4.
Sweden	3.	3.	5.	3.	5.
Austria	1.	1.	1.	2.	1.
France	4.	4.	2.	4.	2.

Table 2 shows the ranking of alternatives according to different MCDM methods. All MCDM methods except WSM ranked Austria as the best and all MCDM methods except AHP ranked Italy as the worst. Other four alternatives are ranked mostly from 2nd to 5th place.

Table 3: Results for 2nd scenario

Alternatives	***Ranking***				
	AHP	***PROMETHEE***	***TODA***	***WSM***	***WPM***
Italy	5.	5.	5.	5.	5.
Belgium	2.	4.	4.	2.	3.
Germany	4.	3.	3.	4.	4.
Sweden	6.	6.	6.	6.	6.
Austria	1.	1.	1.	1.	1.
France	3.	2.	2.	3.	2.

Table 3 the ranking of alternatives according to different MCDM methods is presented. All MCDM methods ranked Austria as the best, all MCDM ranked Italy 5th and also all MCDM methods ranked Sweden as the worst. There is no consensus about the ranking of alternatives from 2nd to 4th place.

As it was shown in Tables 2 and 3, the choice of decision method has impact on the final ranking. Because there is no consensus about final ranking of alternatives between different MCDM methods, Fibonacci series is introduced for both scenarios.

Table 4: Classification of alternatives by all MCDM using the measurement scale for 1st scenario

Alternatives	***AHP***		***PROMETHEE***		***TODA***		***WSM***		***WPM***		***Total***	
	Rank	***Points***	***Rank***	***Points***	***Rank***	***Points***	***Rank***	***Points***	***Rank***	***Points***	***Points***	***Place***
Italy	**5.**	2	**6.**	1	**6.**	1	**6.**	1	**6.**	1	**6**	6.
Belgium	**2.**	8	**2.**	8	**4.**	3	**1.**	13	**3.**	5	**37**	2.
Germany	**6.**	1	**5.**	2	**3.**	5	**5.**	2	**4.**	3	**13**	5.
Sweden	**3.**	5	**3.**	5	**5.**	2	**3.**	5	**5.**	2	**19**	4.
Austria	**1.**	13	**1.**	13	**1.**	13	**2.**	8	**1.**	13	**60**	1.
France	**4.**	3	**4.**	3	**2.**	8	**4.**	3	**2.**	8	**25**	3.

Table 4 shows the final ranking of alternatives after using Fibonacci series. The best alternative is Austria, 2nd Belgium, 3rd France, 4th Sweden, 5th Germany and the last is Italy. Final ranking is different than final rankings of all used MCDM methods.

Table 5: Classification of alternatives by all MCDM using the measurement scale for 2nd scenario

Alternatives	***AHP***		***PROMETHEE***		***TODA***		***WSM***		***WPM***		***Total***	
	Rank	***Points***	***Rank***	***Points***	***Rank***	***Points***	***Rank***	***Points***	***Rank***	***Points***	***Points***	***Place***
Italy	**5.**	2	**5.**	2	**5.**	2	**5.**	2	**5.**	2	**10**	5.
Belgium	**2.**	8	**4.**	3	**4.**	3	**2.**	8	**3.**	5	**27**	3.
Germany	**4.**	3	**3.**	5	**3.**	5	**4.**	3	**4.**	3	**19**	4.
Sweden	**6.**	1	**6.**	1	**6.**	1	**6.**	1	**6.**	1	**5**	6.
Austria	**1.**	13	**1.**	13	**1.**	13	**1.**	13	**1.**	13	**65**	1.
France	**3.**	5	**2.**	8	**2.**	8	**3.**	5	**2.**	8	**34**	2.

In Table 5 the classification of alternatives after applying Fibonacci series is shown. The best alternative is Austria, 2nd is France, 3rd Belgium, 4th Germany, 5th Italy and the last Sweden. Final ranking is the same as when using WPM method. Non-linearity of the Fibonacci series helps to distinguish the difference between two alternatives as each number is about 60 % larger than the previous (after the first two as second is 100 % bigger than first) which roughly correspond to Weber's Law of just-noticeable difference, which states that if we can distinguish a 60 % difference in effort between two estimates, we can distinguish that same percentage in difference between other estimates [7].

4 CONCLUSION

This paper presents a comparison of selected MCDM methods on a synthetic case. We can confirm, that final ranking of alternatives depends on choosing MCDM for solving a decision problem. The main limitation is that we compared MCDM methods only on one use case, so in the future we could compare methods on more use cases. We would like to encourage decision makers to use MCDM methods when selecting the most suitable bidder and the usage of many different MCDM methods can only contribute to a better understanding of a problem, but in practice it is not expected that decision makers will use more than one. However, decision maker should select the MCDM method based on his knowledge and familiarity with the MCDM methods, availability of tools (freeware vs licensed), time requirements (pairwise comparison of numerous criteria and alternatives can be very time-consuming) and with the help of the selected MCDM method, they will be able to make more transparent, efficient and comprehensible decision.

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EMERGENCY MEDICAL SYSTEM UNDER CONFLICTING CRITERIA

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Abstract: The optimization of the network of emergency medical service stations is subject to various requirements that should be taken into account when the mathematical models to obtain the optimal service centers deployment are created. Frequently used standard models suffer from a shortcoming of a single optimization criterion, which does not allow to optimize more objectives simultaneously. In this paper, we introduce such an optimization approach, which is able to comply with contradictory demands. Since there are too many feasible solutions with different values of considered objective functions, it is impossible to decide on the best one without any additional comparative rule. Therefore, suggested method produces a Pareto front of solutions. Such a method output enables to put the final decision on a supervising manager board. In addition, common mathematical programming tools can be used to implement and run the method without the necessity of special application development.

Keywords: Location science, Emergency Medical System, conflicting criteria, Pareto front, radial formulation

1 INTRODUCTION

When an Emergency Medical System (EMS) is to be designed, the system founder is often confronted with conflicting objectives raised by public. On one side, the average response time of the system is commonly taken as an important criterion, which reflects utility of the system [1, 2, 15, 16, 19]. Nevertheless, minimal average response time usually causes that a minority of the public is confronted with situation that their response time is far beyond any acceptable limit. This unfairness of the system design can be mitigated by application of another objective, which can be represented by amount of the population situated behind given time limit [7, 11].

This conflict has no mathematical solution unless weights of each objective are given. The final system design can be achieved by negotiation of the system founder and representatives of the concerned public. What can be proposed through operational research tools is the final set of significant non-dominant solutions that can be used as a basis for negotiation.

Within this paper, we focus on a way of obtaining so-called Pareto front of emergency system designs by means of mathematical programming. As far as the mathematical model of the emergency service system design is concerned, we have to mention the long history of the topic, which started with location-allocation formulation of the weighted p-median problem [2, 3, 4], continued with the radial formulation, which enabled considerable reduction of the computational time of exact solving methods [6, 8, 9]. Then, the development of approaches to the emergency medical service system designing incorporating probability of service center availability into the models [5, 17] cannot be bypassed. Besides that, further acceleration of the methods was achieved by a generalization of the radial formulation [12, 18].

Based on the recent approach [6, 9, 18], two procedures can be suggested. The first one is destined for minimizing the average response time subject to restricted number of inhabitants behind a given radius and, vice versa, the second procedure minimizes the number of inhabitants behind the radius subject to limited average response time. Instead of bisection approach used in [10, 13], we suggested a new approach, which is able to determine the Pareto front with given accuracy.

2 RADIAL MODELS FOR EMERGENCY SERVICE SYSTEM DESIGN

The key stone of the further suggested approach can be seen in the radial formulation of two problems, which will be repeatedly solved by an IP-solver to optimality. Each of the problems searches for the optimal deployment of p service centers in a finite set I of possible service center locations and considers the finite set J of system users' locations, where each user location $j \in J$ is populated by b_j inhabitants. The decisions on locating or non-locating a service center at a location $i \in I$ are modelled by a series of binary variables $\{y_i \in \{0, 1\}: i \in I\}$, where the variable y_i takes the value of one, if a center is to be located at the location i and it takes the value of zero otherwise. Objective of the first problem is to minimize the average response time of the system to users' demands for service subject to the condition that the amount of inhabitants behind a radius T from the nearest service center must be less than or equal to B.

The average response time model comprises the queuing system characteristics by taking into account r nearest centers to an individual user and probabilities $q_1, \ldots, q_r$ that the k-th nearest center to a location j is the first available one for servicing a current demand at the location. The range $1, \ldots, r$ will be denoted as R. It is considered that the matrix $\{t_{ij}\}$ contains the travel times t_{ij} from a center location i to a users' location j. It is assumed, that the travel times are given in integer units and the finite set S contains all relevant values from $\{t_{ij}\}$. To describe the situation that the travel time t from a service center location i to the user location j is less than or equal to a radius s, a series of zero-one coefficients e_{ijs} for $i \in I$, $j \in J$, $s \in S$ will be defined by the rule that $e_{ijs} = 1$ if $t \le s$ and $e_{ijs} = 0$ if $t > s$. Similarly to this rule, a series of zero-one coefficients E_{ij} will be defined by the rule that $E_{ij} = 1$ if $t \le T$ and $E_{ij} = 0$ if $t > T$.

To complete the model of individual relations, two series of auxiliary variables must be introduced. The first series consists of binary variables u_{jks} for $j \in J$, $k \in R$, $s \in S$ and the second series consists of binary variables v_j for $j \in J$. The variable u_{jks} will indicate by the unit value that the distance from the user location j to the k-th nearest service center is greater than s. Similarly, the variable v_j will indicate by the unit value that the distance from the user location j to the nearest service center is greater than T.

After these preliminaries, the first problem can be modelled as follows:

$$Minimize \quad \sum_{j \in J} \sum_{k \in R} \sum_{s \in S} b_j q_k u_{jks} \tag{1}$$

$$Subject\ to \quad \sum_{k \in R} u_{jks} + \sum_{i \in I} e_{ijs} y_i \ge r \quad for\ j \in J,\ s \in S \tag{2}$$

$$\sum_{i \in I} y_i = p \tag{3}$$

$$v_j + \sum_{i \in I} E_{ij} y_i \ge 1 \quad for\ j \in J \tag{4}$$

$$\sum_{j \in j} b_j v_j \le B \tag{5}$$

$$u_{jks} \in \{0, 1\} \quad for\ j \in J,\ k \in R,\ s \in S \tag{6}$$

$$v_j \in \{0, 1\} \quad for\ j \in J \tag{7}$$

$$y_i \in \{0, 1\} \quad for\ i \in I \tag{8}$$

The above model (1)-(8) can be explained in the following way. The minimized objective function (1) expresses the total sum of network distances from all users' locations to their nearest available service centers according to the concept of so-called generalized disutility used also in [12, 14, 17]. The first structural constraint (2) expresses the relation between the set of location variables y_i, $i \in I$ and the sum of auxiliary variables u_{jks} over the range R. If no center is located in the radius s, then the sum of auxiliary variables u_{jks} equals to r. If exactly $k \leq r$ centers are located in the radius s, then the sum of variables equals to r-k due to the minimization process, which presses down the values of the variables u_{jks}. If the sum of variables u_{jks} equals to $k<r$, then the variables u_{j1s}, …, $u_{j(r-k)s}$, equal to 0 and the remaining variables equal to 1 due to the used optimization process and decreasing values of q_1, …, q_r. The constraint (3) limits the number of located service centers by p. If there is at least one EMS station located in radius T from the user location j, then the variable v_j can take the value of zero, otherwise it takes the value of one. This relation is expressed by (4). The constraint (5) ensures that no more than B users can be further from the nearest located center than T. The obligatory constraints (6), (7) and (8) keep the definition scope of used variables.

In the second problem, the amount of inhabitants behind a radius T from the nearest service center is minimized subject to the condition that the value of the expression (1) is less than or equal to the given value Q. Using the introduced constants and decision variables, the second problem can be modelled by the following relations.

$$Minimize \quad \sum_{j \in j} b_j v_j \tag{9}$$

$$Subject\ to \quad \sum_{k \in R} u_{jks} + \sum_{i \in I} e_{ijs} y_i \geq r \quad for\ j \in J,\ s \in S \tag{10}$$

$$\sum_{i \in I} y_i = p \tag{11}$$

$$v_j + \sum_{i \in I} E_{ij} y_i \geq 1 \quad for\ j \in J \tag{12}$$

$$\sum_{j \in J} \sum_{k \in R} \sum_{s \in S} b_j q_k u_{jks} \leq Q \tag{13}$$

$$u_{jks} \in \{0, 1\} \quad for\ j \in J,\ k \in R,\ s \in S \tag{14}$$

$$v_j \in \{0, 1\} \quad for\ j \in J \tag{15}$$

$$y_i \in \{0, 1\} \quad for\ i \in I \tag{16}$$

In the remainder of this paper, the optimal solution of each of these two problem will be denoted by $\mathbf{y}$, which stands for $|I|$ dimensional binary vector of components y_i and the optimal objective function value will be denoted by f_1 for the first problem and f_2 for the second one. The solving method for the first problem and given value B will be denoted by *Problem1*(B) and obtaining the optimal solution of the first problem will be intimated by $f_1, \mathbf{y} = Problem1(B)$. Similarly, the optimal solution of the second problem for given value of Q can be obtained by $f_2, \mathbf{y} = Problem2(Q)$.

3 APPROXIMATE DETERMINATION OF THE PARETO FRONT

Let us consider a finite set $\boldsymbol{Y}$ of all feasible solutions $\boldsymbol{y}$ with respect to constraints (2)-(4), (6)-(8) or (10)-(12), (14)-(16) , where objective functions $f_1(\boldsymbol{y})$ and $f_2(\boldsymbol{y})$ are defined by (1) and (9) respectively. We say that a solution $\boldsymbol{y}\in\boldsymbol{Y}$ is a non-dominated solution of $\boldsymbol{Y}$ if every other solution $\boldsymbol{x}\in\boldsymbol{Y}$**,** which satisfies $f_1(\boldsymbol{y}) \neq f_1(\boldsymbol{x})$ or $f_2(\boldsymbol{y}) \neq f_2(\boldsymbol{x})$ satisfies $f_1(\boldsymbol{y}) < f_1(\boldsymbol{x})$ or $f_2(\boldsymbol{y}) < f_2(\boldsymbol{x})$. The sub-set of all non-dominated solutions is called a Pareto front.

Using solving methods *Problem1*(B) and *Problem2*(Q), we suggest an algorithm, which obtains Pareto front with accuracy *Eps1* and *Eps2* concerning domains of the objectives f_1 and f_2 respectively.

Algorithm *ParetoFront*(*Eps1*, *Eps2*)

1. {Determination of the most left member of the Pareto front}
   Do f_2, $\boldsymbol{y}$ = *Problem2*(∞) and then perform f_1, $\boldsymbol{y}$ = *Problem1*(f_2), the resulting solution $\boldsymbol{y}$ corresponds to the most left member, i.e. the solution with minimal value of f_2.
   Initialize *Stop* = f_2.
   {Determination of the most right member of the Pareto front}
   Do f_1, $\boldsymbol{y}$ = *Problem1*(∞) and then perform f_2, $\boldsymbol{y}$ = *Problem2*(f_1 + *Eps1*) and then the resulting solution $\boldsymbol{y}$ corresponds to the most right member, i.e. the solution with minimal value of f_1. Initialize *Start* = f_2.
2. {Repeated search for the next member of the Pareto front}
   While *Start* + *Eps2* > *Stop* do
   Perform f_1, $\boldsymbol{y}$ = *Problem1*(*Start* - *Eps2*).
   Perform f_2, $\boldsymbol{y}$ = *Problem2*(f_1 + *Eps1*).
   {The current $\boldsymbol{y}$ with objective function values [f_1, f_2] corresponds to a new member of the Pareto front approximation.}
   Update *Start* = f_2.

The algorithm can find an approximation of the Pareto front of the solutions of the emergency service system design problem with accuracy depending on the parameters *Eps1* and *Eps2*. Building each member requires performing two optimization processes, *Problem1* and *Problem2*. Both can be implemented in common integer programming environment.

4 NUMERICAL EXPERIMENTS

The numerical experiments reported in this section were worked up to study the characteristics of the individual optimization processes used in the approximate Pareto front search and determine their influence to efficiency of the resulting process.

The experiments were performed with benchmarks derived from real emergency medical service system, which operates on the road network of the self-governing regions of Slovakia. The list of denotations of the used self-governing regions follows: Bratislava (BA), Nitra (NR), Trenčín (TN), Trnava (TT) and Žilina (ZA). The names of the self-governing regions are followed by their abbreviations in brackets. The individual benchmarks were constructed from the real road network, where nodes of the network correspond to the individual dwelling places, which are considered as users' locations with population b_j for $j\in J$. The set I of possible service center locations is identical with the set J.

Processes *Problem1* and *Problem2* were codded in the programming language Mosel and run by the optimization software FICO Xpress 7.3 installed on a PC equipped with the Intel® Core™ i5 – 9300HF CPU@ 2.4 GHz and 16 GB RAM.

As far as the objective function (1) is concerned, it must be noted that previous research reported in [14, 17] showed that three nearest located service centers to each client location are enough to guarantee provision of the service in case of emergency. Therefore, all experiments were performed for r=3. The associated coefficients q_k for $k \in$R were set in percentage such that q_1 = 77.063, q_2 = 16.476 and q_3 = 100 - q_1 - q_2. These values correspond to the results of a simulation model of existing EMS system in Slovakia [14]. The critical radius T used in both problems for evaluating the coefficients E_{ij} was set to the value of 10.

The exact Pareto fronts were obtained from [10, 13], where a bisection approach were applied. The following Table 1 contains the basic characteristics of the used benchmarks and the results of the exact Pareto fronts. The problem sizes are defined by the cardinality of the set I and by the value of p, which expresses the number of centers to be located. The right part of the table is devoted to the exact Pareto front characteristics. The column denoted by *NoS* contains the number of solutions in the Pareto front and the denotation *CT* is used to report the computational time in seconds, within which the exact Pareto front was obtained. Finally, let the symbol *StartEps* denote the value f_2 of the most right member. Analogically, the column denoted by *StopEps* reports the value f_2 of the most left member.

Table 1: Basic characteristics of the used benchmarks and the results of the exact Pareto fronts

Region	$\|I\|$	p	**Exact Pareto front**			
			NoS	*CT*	*StartEps*	*StopEps*
BA	87	14	34	140.86	6061	0
NR	350	27	106	5497.58	6900	557
TN	276	21	98	1331.34	5942	223
TT	249	18	64	1831.31	5563	450
ZA	315	29	97	2127.19	6911	254

The results of suggested algorithm *ParetoFront*(*Eps1*, *Eps2*) discussed in Section 3 are summarized in the following Table 2 and Table 3, which use the same denotations as above. In addition, we use *CTF1* to denote the computational time of the *Problem1* and, similarly, the computational time of the *Problem2* is reported in the column denoted by *CTF2*.

Table 2: Results of numerical experiments with the algorithm *ParetoFront*(*Eps1*, *Eps2*) – part I

Region	***Eps2* = 1**					
	NoS	*CT*	*CTF1*	*CTF2*	*StartEps*	*StopEps*
BA	29	102.84	23.18	79.66	280	0
NR	105	25264.40	2546.31	22717.80	976	557
TN	96	5824.93	809.27	5015.50	567	223
TT	64	4428.66	702.12	3726.45	921	450
ZA	97	10778.00	1333.57	9444.25	728	254
Region	***Eps2* = 2**					
	NoS	*CT*	*CTF1*	*CTF2*	*StartEps*	*StopEps*
BA	26	87.30	20.18	67.12	280	0
NR	88	19171.60	2019.56	17151.90	976	557
TN	85	4815.26	630.25	4184.84	567	223
TT	62	4152.61	645.21	3507.33	921	450
ZA	63	7069.83	750.86	6318.83	728	254

Table 3: Results of numerical experiments with the algorithm *ParetoFront*(*Eps1, Eps2*) – part II

Region	***Eps2* = 4**					
	NoS	*CT*	*CTF1*	*CTF2*	*StartEps*	*StopEps*
BA	24	75.53	14.43	61.08	280	0
NR	58	10978.60	1269.55	9708.96	976	557
TN	59	2741.34	376.12	2365.15	567	223
TT	48	3048.12	472.35	2575.74	921	450
ZA	49	4634.66	542.89	4091.68	728	254
Region	***Eps2* = 8**					
	NoS	*CT*	*CTF1*	*CTF2*	*StartEps*	*StopEps*
BA	17	41.81	10.88	30.92	280	0
NR	43	7453.11	848.96	6604.10	976	557
TN	34	1403.19	212.45	1190.64	567	223
TT	35	1956.69	305.42	1651.23	921	450
ZA	35	2564.21	347.91	2216.21	728	254

The results in Table 2 and Table 3 confirmed that the problems, the objective function of which is constructed as so-called min-sum objective, converge much faster to optimum than the problems, the objective function of which is similar to the min-max objective. In this paper, the first problem (1)-(8) corresponds to the min-sum problem and the second problem (9)-(16) is similar to the min-max problem due to the link-up constraints (12). It can be observed that the computational time of the *Problem2* is approximately in order higher than the computational time of *Problem1*. This feature can be considered to be a serious drawback, which causes that the bisection approach performs faster even though it solves much more times the problem (1)-(8). Nevertheless, from the practical point of view the suggested approach is more convenient and flexible for practical use, where only part of the Pareto front is to be produced and it is often demanded that the solutions must differ in one of the objectives by given value. It can be easily achieved by suitable setting of *Eps1* and *Eps2*.

5 CONCLUSIONS

The research reported in this paper was aimed at Emergency Medical Service and other forms of public service systems, in which two conflicting criteria must be considered when the system is to be optimized or newly designed. The main contribution consists in the algorithm, which produces a Pareto front. These solutions can be provided to the representatives for the final decision-making. Performed computational study has proved that the suggested approach fulfills the requirements as concerns the accuracy and computational time demands. It must be noted that the method performance efficiency is strongly dependent on used objectives and model structure. Based on the results we can conclude that we have constructed a useful tool for effective solving of the problem with conflicting criteria.

Future research in this field could be aimed at other possible algorithms for Pareto front determination or at adjusting the method to save time without losing the solution quality.

Acknowledgement
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ASSESSING FLORISTS' COMPETENCIES USING MULTICRITERIA DECISION METHODOLOGY

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Abstract: Research questions are how to help employers select the right candidate for employment in a florist field and what competencies are important for a florist. The research aims to create an appropriate tool to facilitate candidate selection to meet the employer's needs. We designed a multicriteria decision model according to the DEX methodology. We weighted the criteria according to the importance of how they affect the development of an individual. The operation of the model was demonstrated on four already employed candidates known to the expert team from Slovenia.

Keywords: floristics, competence, decision model, DEX, employability

1 INTRODUCTION

The main research question is how to help employers select a suitable candidate for employment as a florist, because of lack of florists with appropriate competencies. How to design a tool that will take into account the specific needs of the employer for jobs in his company? What competencies are important for a florist to do his job successfully?

Based on many years of experience, for the first-time Slovenian florist experts, in cooperation with experts on decision-making methodologies jointly created a decision model of the competencies that affect the employment of florist candidates.

The florist has knowledge about ornamental plants and their use, the basic design techniques he has upgraded with his innovative ideas and knows the sales strategy. The appropriate candidate has developed soft competencies and the most important are readiness for work, communication, ICT technology, improvisation, adaptability, and knowledge of foreign languages.

We created four different profiles of candidates, depending on their position as florists with different priorities, taking into account the specific needs of employers. Based on these variants, we tested the hypothesis - the assumption that a decision model is a tool that helps the employer to determine the suitability of the candidate for employment. Namely, the employer temporarily hires a new candidate for a probationary period based on documentation that demonstrates his professional and soft competencies. During this probationary period, he analyses his actual professional and soft competencies and at the end of the probationary period, he can use a decision model to determine whether the candidate is suitable to hire him for an indefinite period of time or not.

2 THEORETICAL BASES

Changes in the market and the importance of professional and soft competencies
We live in a time when change is a constant lifestyle. In particular, changes in the labour market are the ones that mark the period of rapid development of technologies and specific conditions in 2019 and 2020 due to the crisis caused by COVID 19. This is recognized by the strategic priorities of the international organization in the field of vocational training and European grants. Erasmus +. They want to increase the flexibility of vocational training programs, keep pace with changes in the labour market, digitalization, increase the accessibility of training and increase the attractiveness of individual professions [1].

As early as 2008, the Lisbon European Council reaffirmed the importance of soft competence for creativity, as this soft competence is a generator of innovation development. As the labour market situation is constantly changing, an initiative has been taken to play an additional important role in improving the employability of candidates, as well as non-formal education [2].

Saje [3] found that any knowledge acquired by the employee at his own request or under the guidance of management is an added value to his work, as he has more knowledge and skills with new competencies that improve the quality of the work process.
At various economic forums, employers emphasized that key competencies are important for future jobs: the ability to solve complex problems, the ability to coordinate with others, negotiation, cognitive flexibility or. emotional intelligence. It is a different way of thinking, the focus is on cooperation, creativity, and interdisciplinarity in both academic types of research and works in the company [4].

Jevšček [5] found that the most important key competencies of process managers are orientation to order, quality, and accuracy, understanding the organization, Focus on excellent results, teamwork and cooperation, initiative, research, team leadership, self-control.

In 2019, digitalization has advanced tremendously and its impact is perceptible in everyday life. Thus, professional forums have become a relevant source of data and one such forum is the World Economic Forum. In a survey of which competencies are most desirable in employability, Petrone [4] found that as many as 57% of managers believe that soft competencies are more important than professional ones. In the first place, they gave creativity, persuasiveness - communication, cooperation, flexibility, teamwork, ICT competencies, analytical thinking, human capital management, user experience design, sales psychology, language skills, social media marketing and market analysis.

To ensure the objectivity and transparency of the process, we decided to use the multi-criteria decision-making methodology DEX, which is often used in related problems related to personnel and competencies [6, 7]. The method supports a systematic approach, allows model building, input, and evaluation of variants. Its special features include various analyses and visualization methods that allow the interpretation of evaluation estimates [8].

3 METHOD

3.1 Competence data collection method

In the research, we first obtained data on competencies that, in the opinion of employers, are important for employment as a florist. Partners of the international floristic organization FlorCert created a survey questionnaire and sent it to employers in Slovenia, Italy, Sweden, Croatia, and also to employers in Finland and Slovakia. For the reliability of the data, we determined the sample size, namely a minimum of 50 employers from one country. Based on the information obtained and many years of our own experience, we jointly created a list of competencies that we entered into the questionnaire and tested their importance in employment [9].

3.2 Model design method

The multi-criteria decision method DEX was used, the properties of which are a hierarchical structure of criteria, qualitative discrete stocks of values , and the presentation of utility functions in the form of simple if-then rules. Such a model allows for transparency of the process, calculation, and interpretation of estimates based on explicit knowledge. The freely available DEXi program was used, which makes it easy to use the mentioned methodology.

In designing the decision model, we divided competencies into knowledge and skills. Soft competencies are defined in detail in the set of abilities, which are then divided into two major groups of soft competencies: work and personality. Given the many years of experience and training of experts who jointly designed the decision model, we have weighted all the competencies in the model accordingly. For each competence, we formed values, which we also described.

4 RESULTS

4.1 Problem identification

The importance of soft competencies is growing during the crisis caused by COVID 19. Some companies, service only with ornamental plants and flowers, were completely closed due to the epidemic. Other florists operating as part of horticulture or agricultural cooperatives operated normally. Thus, diversification occurs during the typification of florists. Therefore, we decided to design 4 types of florists according to the scope of their activity:

- Florist shop A: independent florist; the main industry is making decorations;
- Florist shop B: operates within the horticulture; the main branch is the production of ornamental plants and vegetable seedlings, supplementing the making of decorations: bouquets, wrapping gifts, occasionally wedding and mourning decoration;
- Florist shop C: operates within agricultural cooperatives; the main branch is the marketing of farming material, the sale of vegetable seedlings; occasional wrapping gifts, designing bouquets;
- Florist shop D: operates in cooperation with the funeral home; main branch mourning floristics, occasional bouquets, gift wrapping, wedding decoration.

Given the priority tasks of each type of florist, we had to create a decision model with competencies that the employer will be able to choose for their business needs.

4.2 Identification and description of criteria

In formulating the criteria, we divided the competencies into hard - professional competencies and soft competencies. Professional hard competencies are directly related to professional work: practical floriculture knowledge, which includes practical knowledge of decorations (funeral and wedding decoration and room decoration, making bouquets and decorating gifts) and additional horticultural knowledge about plantations (indoor and outdoor plantations). To the competencies that are directly related to work in the florist and belong to the group of hard - professional competencies, we added other knowledge: professional theoretical knowledge, digital competencies, and knowledge of foreign languages. Soft competencies were included in the group of competencies, which we named abilities or. characteristics of the individual.

The whole group was divided into two subgroups: working abilities or. traits and personality traits or abilities. Extensive research by the World Economic Forum 2019 highlighted soft competencies on the part of employers, which we will focus on in further analysis: communication, flexibility, time efficiency, problem-solving, finding new ideas, responsibility, working under stress, and proactivity. The decision model includes hard competencies in the field of knowledge (12 competencies) and soft competencies (32 competencies). In this paper, we have analyzed the competencies according to the 4 most typical forms of flower shops in Slovenia.

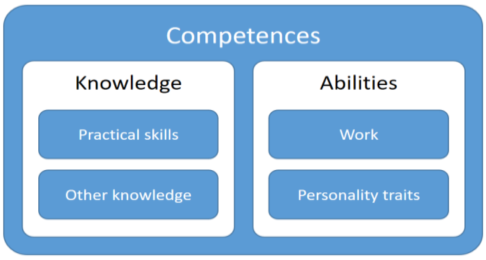

Figure 1: Top two hierarchical levels in the tree of criteria.

Each person is employed in different types of florists and we see that the graphic presentation of competencies is different according to the priorities of individual activities in florists. Employers are satisfied with their employees, as employees have the right professional competencies according to their needs. However, except for person A, other persons would find it difficult to change employers without additional professional training. Despite the reduced professional competencies of making decorations, person B is successful as the type B florist, as the florist who operates within the horticulture, prioritising producing ornamental plants for outdoor planting. Thus, special professional skills, such as arranging graves and external shafts, are those professional competencies that the employer expects and requires from the employee. Florists who operate within agricultural cooperatives are only an additional offer of agricultural cooperatives and are important professional competencies in the field of agriculture. Thus, employed person C, despite poorly demonstrated professional floristic competencies, fully meets the needs of the employer, as professional competencies in the field of agriculture are a priority. Person D has excellent professional competencies in the field of mourning floristics, as she specializes in this field. Namely, flower shop D cooperates with the funeral home and mourning decorations are a priority.

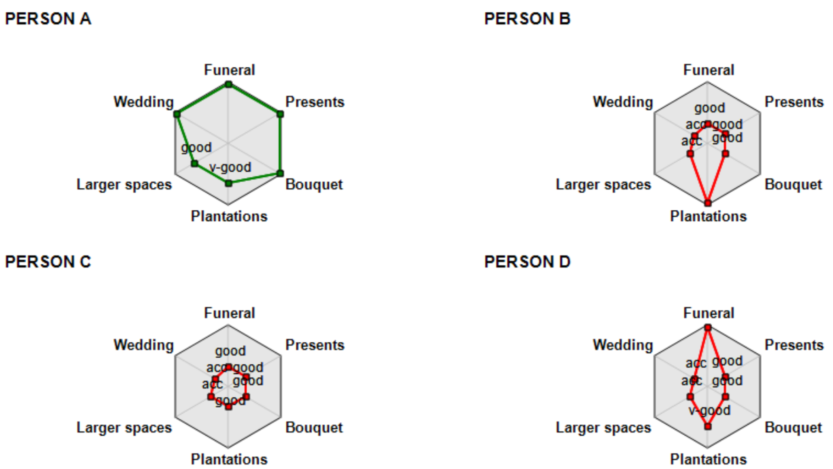

Figure 2: Multicriteria evaluation of variants - florists A, B, C and D: professional competencies.

Based on the results of the World Economic Forum (Petrone, 2018) research, we will analyse the following soft competencies: working with clients (communication, customer relationship), dynamism (flexibility, time efficiency, teamwork), problem-solving, finding new ideas, performing tasks (responsibility, accuracy, independence), work under stress and proactivity (self-initiative, willingness to learn).

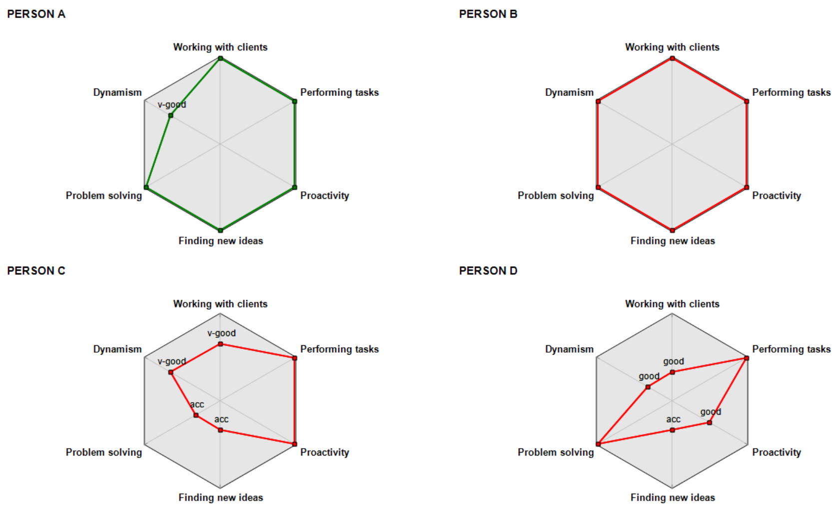

Figure 3: Multicriteria evaluation of variants - florists A, B, C and D: soft competencies.

Persons A and B have expressed all the soft competencies very good or. excellent. Thus, their personality traits are what most employers want. When we analyse in more detail the personality traits of person C, who is employed in an agricultural cooperative, the problem-solving competencies and the search for new ideas are poorer. The job and the tasks it performs within its responsibilities are largely stable and predictable. The employer is satisfied with this person, as the person is dynamic enough, has a good relationship with clients, and fully fulfils the tasks delegated by the management staff. Person D works in a florist working with a funeral home. The vast majority of them already arrange the entire client's order at the funeral home and then hand over the order for making mourning decorations to the florist. Person D must complete the orders in full and the analysis of the graph shows that this person has excellent competencies in performing the tasks. It is also important that at the moment when an unforeseen situation arises regarding the order, this person knows how to solve problems. Decorations must be made in a timely manner and delivered to the chapel in the cemetery, although there may be a problem with the delivery of flowers or delivery. Therefore, the employer is satisfied with this person D because he performs his work diligently and independently solves various unforeseen situations so that the customers are satisfied.

4 DISCUSSION

In designing the DEX decision model, we evaluated the competencies of florists/florists. We formed a list of professional and soft competencies that are important for a smooth operation of florists, based on many years of professional experience and international research [9]. Since we found that in Slovenia there are several different types of florists that have their own specific characteristics, according to their target market and priorities, we analysed the data and concluded that it would make sense to design customized decision models on competencies that would be used by employers in assessing a candidate’s suitability for employment. When we analysed the data of four candidates employed in four different types of florists, we found that professional competencies are much more different than soft competencies. All four candidates perform excellently the tasks delegated to them by the management, and at the same time, given the specifics of their work, they have a good ability to solve problems. An exception is a person who has a routine job in an agricultural cooperative and has a rare situation that is unpredictable and would require him to solve problems. Candidates A and B have very good and excellent soft competencies that employers are looking for in hiring and have more opportunities to change jobs. We found that according to the research on the importance of soft competencies [4] part of the decision model DEX, which contains soft competencies, is also suitable for other areas of employment and this part of the decision model would generally help employers to assess personality traits of new job candidates. Therefore, we will continue our research and adapt it to the needs of the market, because due to COVID 19, the situation on the market has changed a lot and with it the desired soft competencies and knowledge that employers expect from employees.

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COMPARISON OF STUDENT AND EXPERT IDEA ASSESSMENT IN ONLINE BRAINSTORMING SESSION

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Abstract: Despite the abundance of studies on brainstorming, there is a lack of studies conducted with experts. Therefore, the applicability of guidelines based on these studies to expert decision-making groups is questionable. In this paper, we analyse the group decision-making process of expert and lay committees appointed to create a regional development plan. Over 10 sessions, 120 participants generated 1,133 ideas. A novel approach, facilitated by the developed Teamworks tool, is used to obtain data on the behaviour of individuals in group sessions, including how ideas are generated and categorised, and how categories are evaluated and ideas are assessed. Differences were found in the generation and categorization of ideas between experts and laypeople. For general topics, the decisions of laypersons were similar to those of experts, while for specific topics, experts outperformed lay people. However, ad hoc selection of experts may lead to similar behaviour as laypeople. Sessions conducted using the Teamworks methodology proved to be efficient, as on average 66% of the projects included in the final Regional Development Plan were identified during these sessions.

Keywords: electronic brainstorming, group decision support system, expert decision making, regional development plan

1 INTRODUCTION

Brainstorming has been shown to be one of the most positive techniques for creative thinking [1], although it is not without controversy in the research community [2]. Regarding the number of generated ideas, the more is not always better but still, there are other “side effects” of brainstorming such as improving a common problem overview of the group, sharing ideas etc. [2]. To overcome the problems of traditional brainstorming [3], [4], electronic brainstorming (EBS) can be used to generate a wealth of ideas anonymously and with virtual communication [5]. EBS increases the range of ideas generated [1], reduces production blockages [6] and can work with any number of participants. EBS groups are more productive [4], more creative, exhibit slower productivity loss, and provide more original ideas [5]. Another important aspect addressed by EBS is anonymity [1].

Brainstorming and group decision-making processes are commonly used to address various regional development issues [7]–[11]. A regional development plan (RDP) is an important document that defines the strategic guidelines for a region’s priority areas for a given period. Experts from different fields of work come together to agree on common goals and all the activities needed to achieve them. As suggested by United Nations Department of Economic and Social Affairs – Division for Sustainable Development [12], brainstorming techniques can be used when developing sustainable development strategies. However, most research on the brainstorming process and group decision-making has been conducted with students [6], [13]–[15]. Therefore, the applicability of the guidelines to conduct successful brainstorming sessions in groups of experts is questionable. Given this discrepancy, our main objective is to evaluate the possibility of involving students or laypersons in the group decision-making process regarding regional development issues. We therefore compare experts and laypersons in terms of the quality of idea evaluation and behavioural dynamics during an EBS session. To assess the effectiveness of these sessions, we also look at how many of the highest scoring project ideas ended up in the actual version of the RDP.

In this research, a real case study was conducted in a semi-controlled environment supported by a group decision support system (GDSS). Five committees of experts from relevant fields were invited to identify key issues and proposals in the RDP. The RDP was prepared for the Gorenjska region in Slovenia. The five development topics proposed in the RDP are: a) Technological Development, Entrepreneurship and Innovativeness (TDEI); b) Human Resource Development (HRD); c) Tourism (T); d) Environment, Spatial Planning and Infrastructure (ESPI); and e) Farming, Forestry and Countryside Development (CD). To address the issues of lay involvement in the decision-making process, five student committees were also invited to participate in the research.

2 METHODOLOGY

Brainstorming sessions and other types of idea collection found in the literature have mostly involved students, so the generalizability of their results to brainstorming groups in the real world is questionable. We want to find out whether experts are more productive than students in both generating and categorising ideas. Therefore, two hypotheses were formulated:

Hypothesis 1: *Experts generate more ideas than students.*

Hypothesis 2: *Experts categorise more ideas than students.*

Different decision-making approaches show different behaviours of participants and we therefore want to establish the similarities in decision making between experts and students within a GDSS session, where evaluation of ideas and categorisation of ideas are at the core of decision making. Therefore, we hypothesise the following:

Hypothesis 3: *Student assessment of ideas is similar to expert assessment.*

Hypothesis 4: *Student assessment of categories is similar to expert assessment.*

To achieve the research objectives the GDSS tool Teamworks [16] was used. The tool allows EBS, definition of categories, categorization and the assessment of categories and ideas. As shown in Figure 1, the Teamworks system consists of a network of personal computers with a server [11]. The majority of participants in the GDSS session are decision makers, while one or two group members act as content and/or technical managers. The content manager has an in-depth knowledge of the topic under discussion and acts as the leader of the group. The technical manager provides technical support and moderates the session using the server. The content manager may participate in the session as a decision maker.

At the beginning of the GDSS session, the content manager presents the topic to be discussed, while the technical manager presents the methodology. Teamworks uses a specific idea collection mechanism (Figure 1). In addition to the sheets with the different ideas, the decision makers see the main question and the latest ideas on the big screen.

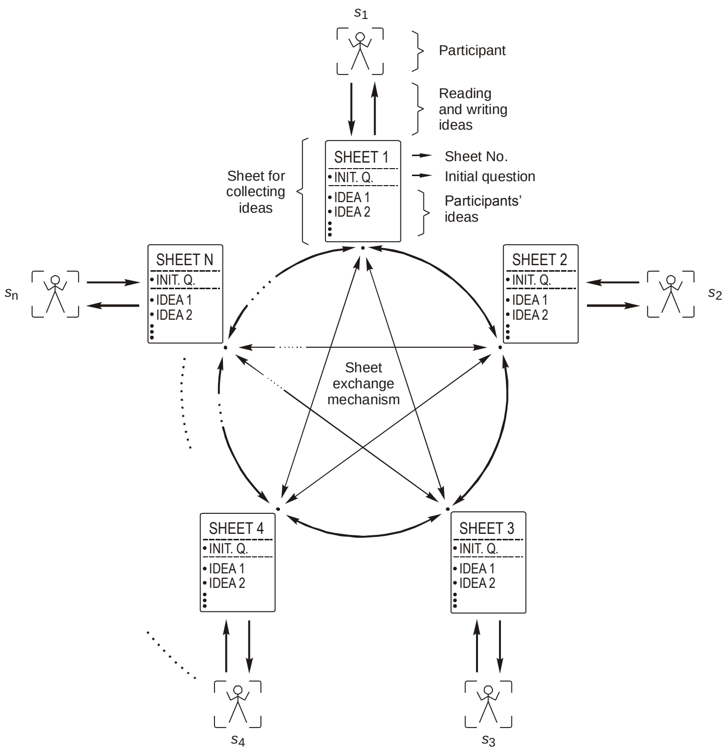

Figure 1: Collecting ideas with sheet exchange mechanism

After 30 minutes of idea generation, the technical manager calls for a break where the content manager identifies the main categories of ideas. The decision makers are then asked to rate the importance of the categories. They categorise the ideas using the drag-and-drop principle. As the process continues, the ideas are ranked in descending order within the categories. The technical manager presents the results on the top ranked ideas, followed by a brief overview of the entire session and its results.

Five expert groups were invited to participate in the GDSS session for the development of the RDP. The expert groups had between 6 and 17 members (TDEI = 6, HRD = 14, T = 12, ESPI = 11, CD = 17). Following the same methodology, five equally sized groups of students discussed the same issues and contributed their own ideas. To examine the similarities in decision making between experts and lay people, the student groups rated the importance of the categories and ideas provided by the expert groups.

Several statistical methods were used to analyse group behaviour. An independent samples t-test was conducted to determine differences between the experts and the students. The correlation between the group decision-making process of the experts and students was analysed using Kendall's Tau-b test. Pearson's correlation coefficient was used to determine statistically significant correlations. All statistical tests were conducted using IBM SPSS Statistics 24 (IBM Corp, 2016).

3 RESULTS

To investigate the differences in productivity between the experts and the students, we tested hypotheses 1 and 2. The number of ideas generated is significantly higher in the expert groups than in the student groups (independent samples t-test, $\mathrm{t}\,(\mathrm{df} = 97.295) = 4.994,\ \mathrm{p} = 0.000 < 0.05$). The average number of ideas collected by the experts was 18.87 ($\mathrm{sd} = 10.341$), while the student groups collected on average only 11.07 ideas ($\mathrm{sd} = 6.278$). The results confirm hypothesis 1, namely that experts generate more ideas than students during the EBS session.

To ensure a meaningful comparison of the categorisation process, both experts and students categorised the ideas generated by the experts. The experts were more productive than the students in categorising the ideas (independent samples $t-test$, $\mathrm{t}\ (\mathrm{df} = 84.555) = 4.501,\ \mathrm{p} = 0.000 < 0.05$). The average number of categorisations performed by the experts was 19.83 $(\mathrm{sd}\ =\ 11.822)$, whereas the student groups only categorised 11.48 ideas on average $(\mathrm{sd} =\ 6.793)$. The results confirm the hypothesis 2: experts categorise more ideas than students.

After idea categorisation, all ideas collected in the expert group were rated on a scale of 1 to 10, with the most favourable idea rated as 10. Figure 2 shows the distribution of the average assessment of the expert committee ideas by the experts and students. The x-axis shows the grade intervals while the y-axis shows the absolute frequency. The majority of the ideas had an average grade of 5.75 to 6.75. It can be observed that the distribution is left-skewed in the case of for the expert committees, while there is no obvious skewness for the student group. The analysis showed that the long left tail is a result of several ideas being beyond the scope of the session topic.

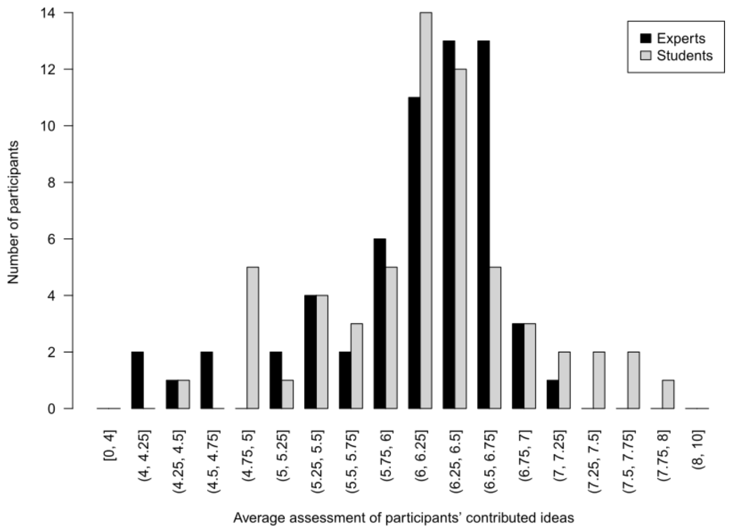

Figure 2: Distribution of the average assessment of ideas contributed by the participants (left: expert committees; right: student committees)

Student groups were given the task of evaluating the 18.83 ideas generated by the expert groups to determine whether non-experts were able to evaluate the strategic ideas proposed by the experts. Participants were asked to rate the ideas within the categories of their committee. In total, the ideas were distributed across 37 categories. In only 35% of these categories (13 categories) were the correlations between student and expert ratings statistically significant $(p < 0.05)$. Of these, 18% had a negative correlation coefficient τ_B. Hypothesis 3, which states that the students' assessment of the ideas is similar to the experts' assessment, is thus rejected.

When comparing the assessment of the importance of the categories by the expert and student groups, the TDEI committee was excluded from the analysis because no categories were defined there. The estimation in the HRD $(\tau_B = 0.857; p = 0.003 < 0.05)$, CD $(\tau_B = 0.667; p = 0.012 < 0.05)$ and ESPI $(\tau_B = 0.626; p = 0.002 < 0.05)$ committees was statistically significantly similar, but not in the T committee $(\tau_B = 0.800; p = 0.05 = 0.05)$.

Hypothesis 4, which states that students' assessment of categories is similar to experts' assessment, can therefore be partially supported.

4 DISCUSSION AND CONCLUSIONS

This research extends previous knowledge on the involvement of laypeople rather than experts in brainstorming sessions. Existing research on brainstorming sessions mostly involves students [13], [17], [18], which might be questionable when dealing with topics that require expertise [19], [20]. We compared the behaviour of experts and students based on their productivity and similarity of ratings. We showed that experts generate more ideas than students and are more efficient than students at categorizing ideas. Thus, in terms of productivity, experts outperform students when it comes to general RDP topics. This could be due to the fact that experts are more familiar with the topics addressed and are more motivated due to their professional vocation. Furthermore, the analysis of the experts' and students' ratings revealed that the ratings are similar in general (for categories), while there is no similarity in the ratings of specific topics (ideas). These findings are consistent with Prior's [21] findings that lay people are experts by virtue of their 'experience' and therefore can be used in general decision-making where complex, in-depth knowledge is not required. The comparison showed that there is potential to involve students in the RDP decision-making process at a general level. After the RDP was confirmed by the Ministry of Economic Development and Technology of the Republic of Slovenia, we examined the success rate of GDSS session results by determining the number of projects confirmed in the RDP. On average, 66% of the projects in the RDP were identified in the GDSS sessions. One should note, that there were several meetings held on regional development but only one in series was conducted by the proposed methodology.

Acknowledgement
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VECTORS OF INDICATORS IN MULTISTAGE BIPOLAR METHOD

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Abstract: Multistage Bipolar Method considered in the paper deals with multistage decision processes. Multistage alternatives are not compared directly to each other, but they are confronted to the stage sets of reference objects – desirable and non-acceptable. In the paper vectors of indicators for multistage alternatives are defined. The aim of the paper is to apply vectors of indicators to search for the final solution. It gives a chance to apply single criterion dynamic programming in the solution process.

Keywords: multistage decision process, multiple criteria decision analysis (MCDA), Multistage Bipolar Method, dynamic programming.

1 INTRODUCTION

The paper is devoted to the Multiobjective Bipolar Method, which is an extension of the classical Bipolar procedure, introduced by Konarzewska- Gubała [1]. The classical Bipolar approach is based on one hand on Electre methodology [3]. and on the other hand on the idea of set confrontation, proposed by Merighi [2].

In the Multistage Bipolar Method we consider stage and multistage alternatives. Stage alternatives are components of multistage alternatives. The multistage alternatives are not compared directly to each other, but (stage) reference objects are used for comparisons. On the basis of these comparisons the position of the stage alternatives in relation to the Bipolar reference system is assigned. At the end multistage alternatives are divided into 6 classes and the final solution is pointed. The method is described in detail in open-access papers [4,5].

It is proved in [5], that the final solution belongs to the class with the lowest number and is non-dominated. In [5] there is also described an effective procedure, based on multiobjective dynamic programming for searching for the final solution.

The aim of this paper is to define vectors of indicators, present some of their properties and apply them in the proposed procedure for searching the final solution.

The paper consists of 6 sections. After introduction in section 1, Multistage Bipolar Method is briefly described in section 2. Vector indicators and their properties are presented in section 3. The proposed algorithm is described in Section 4 and numerically illustrated in Section 5. Some concluding remarks are given in Section 6.

2 MULTISTAGE BIPOLAR PROCEDURE

We consider T-stage decision process, described in detail in [4]. Two kinds of alternatives: stage alternatives $\mathbf{a}_t$ for t = 1,...,T and multistage alternatives $\mathbf{a} = (\mathbf{a}_1,...,\mathbf{a}_T)$ are distinguish. Sets of stage and multistage alternatives are denoted as $\mathbf{A}_t$ and $\mathbf{A}$, respectively. At each stage of the process, two reference sets are defined: the first, containing "good" objects, named $\mathbf{G}_t$, and the second one, containing "bad" objects, named $\mathbf{B}_t$. At each stage, the reference set of good objects is disjoint with the reference set of bad objects. The position of a multistage alternative with respect to the reference sets for the entire process is evaluated on the basis of the positions of the stage alternatives which form this multistage alternative with respect to the stage reference sets. We calculate the values of stage success achievement degree $d_\mathbf{G}^+(\mathbf{a}_t)$ and $d_\mathbf{G}^-(\mathbf{a}_t)$ as well as the values of stage failure avoidance degree $d_\mathbf{B}^+(\mathbf{a}_t)$ and $d_\mathbf{B}^-(\mathbf{a}_t)$. Then for multistage alternatives the multistage success achievement degree values $d_\mathbf{G}^+(\mathbf{a})$ and $d_\mathbf{G}^-(\mathbf{a})$ as well as the multistage failure avoidance degree values $d_{\mathbf{B}}^{+}(\mathbf{a})$ and $d_{\mathbf{B}}^{-}(\mathbf{a})$ are defined. Using this values, the multistage alternatives can be sorted into six classes:

$$\mathbf{A}^1 = \{a\in\mathbf{A}: \quad d_{\mathbf{G}}^{+}(\mathbf{a}) > 0, \quad d_{\mathbf{G}}^{-}(\mathbf{a}) = 0, \quad d_{\mathbf{B}}^{+}(\mathbf{a}) > 0, \quad d_{\mathbf{B}}^{-}(\mathbf{a}) = 0\}.$$
$$\mathbf{A}^2 = \{a\in\mathbf{A}: \quad d_{\mathbf{G}}^{+}(\mathbf{a}) > 0, \quad d_{\mathbf{G}}^{-}(\mathbf{a}) > 0, \quad d_{\mathbf{B}}^{+}(\mathbf{a}) > 0, \quad d_{\mathbf{B}}^{-}(\mathbf{a}) = 0\}.$$
$$\mathbf{A}^3 = \{a\in\mathbf{A}: \quad d_{\mathbf{G}}^{+}(\mathbf{a}) > 0, \quad d_{\mathbf{G}}^{-}(\mathbf{a}) > 0, \quad d_{\mathbf{B}}^{+}(\mathbf{a}) > 0, \quad d_{\mathbf{B}}^{-}(\mathbf{a}) > 0\}.$$
$$\mathbf{A}^4 = \{a\in\mathbf{A}: \quad d_{\mathbf{G}}^{+}(\mathbf{a}) = 0, \quad d_{\mathbf{G}}^{-}(\mathbf{a}) > 0, \quad d_{\mathbf{B}}^{+}(\mathbf{a}) > 0, \quad d_{\mathbf{B}}^{-}(\mathbf{a}) = 0\}.$$
$$\mathbf{A}^5 = \{a\in\mathbf{A}: \quad d_{\mathbf{G}}^{+}(\mathbf{a}) = 0, \quad d_{\mathbf{G}}^{-}(\mathbf{a}) > 0, \quad d_{\mathbf{B}}^{+}(\mathbf{a}) > 0 \quad d_{\mathbf{B}}^{-}(\mathbf{a}) > 0\}$$
$$\mathbf{A}^6 = \{a\in\mathbf{A}: \quad d_{\mathbf{G}}^{+}(\mathbf{a}) = 0, \quad d_{\mathbf{G}}^{-}(\mathbf{a}) > 0, \quad d_{\mathbf{B}}^{+}(\mathbf{a}) = 0, \quad d_{\mathbf{B}}^{-}(\mathbf{a}) > 0\}.$$

If $k < l$, then each multistage alternative from class $\mathbf{A}^k$ is preferred over any multistage alternative from class $\mathbf{A}^l$ [4].

Let $\mathbf{a}^{(i)}$ and $\mathbf{a}^{(j)}$ be two multistage alternatives, ≥ be the relation of domination and

$$d(\mathbf{a}^{(i)}) = d_G^{+}(\mathbf{a}^{(i)}) - d_G^{-}(\mathbf{a}^{(i)}) + d_B^{+}(\mathbf{a}^{(i)}) - d_B^{-}(\mathbf{a}^{(i)}). \tag{1}$$

Within the classes the ordering of the alternatives is defined as follows:

$$\mathbf{a}^{(i)} \text{ is preferred to } \mathbf{a}^{(j)}\text{, iff} \quad d(\mathbf{a}^{(i)}) > d(\mathbf{a}^{(j)}) \tag{2}$$

$$\mathbf{a}^{(i)} \text{ is equivalent to } \mathbf{a}^{(j)}\text{, iff} \quad d(\mathbf{a}^{(i)}) = d(\mathbf{a}^{(j)}) \tag{3}$$

The final solution $\mathbf{a}^{0*}$ is defined as a non-dominated multistage alternative which belongs to the non-empty class $(\mathbf{A}^{0m})^*$ with the lowest index m and satisfies the relationship:

$$d(\mathbf{a}^{0*}) = \min \{d(\mathbf{a}^0): \mathbf{a}^0 \in (\mathbf{A}^{0m})^* \tag{4}$$

3 STAGE AND MULTISTAGE VECTORS OF INDICATORS

In the further considerations we apply well known real function

$$\operatorname{sgn}(x) = \begin{cases} 1 \text{ for } x > 0 \\ 0 \text{ for } x = 0 \\ -1 \text{ for } x < 0 \end{cases} \tag{5}$$

3.1 One-stage vectors of indicators

For any stage alternative $\mathbf{a}_t$ we consider vector

$$\mathbf{d}(\mathbf{a}_t) = [d_{\mathbf{G}}^{+}(\mathbf{a}_t), d_{\mathbf{G}}^{-}(\mathbf{a}_t), d_B^{+}(\mathbf{a}_t), d_B^{-}(\mathbf{a}_t)] \tag{6}$$

and apply signum function to its components. We obtain

$$\sigma_{1t}(\mathbf{a}_t) = \operatorname{sgn} d_{\mathbf{G}}^{+}(\mathbf{a}_t), \quad \sigma_{2t}(\mathbf{a}_t) = \operatorname{sgn} d_{\mathbf{G}}^{-}(\mathbf{a}_t), \quad \sigma_{3t}(\mathbf{a}_t) = \operatorname{sgn} d_{\mathbf{B}}^{+}(\mathbf{a}_t), \quad \sigma_{4t}(\mathbf{a}_t) = \operatorname{sgn} d_{\mathbf{B}}^{-}(\mathbf{a}_t) \tag{7}$$

and

$$\boldsymbol{\sigma}_t(\mathbf{a}_t) = [\sigma_{1t}(\mathbf{a}_t), \sigma_{2t}(\mathbf{a}_t), \sigma_{3t}(\mathbf{a}_t), \sigma_{4t}(\mathbf{a}_t)] \tag{8}$$

As $\mathbf{d}(\mathbf{a}_t) \geq 0$, vector $\sigma_t(\mathbf{a}_t)$ is a zero-one vector. According to the assumptions [4, 5] it holds:

$$\sigma_{1t}(\mathbf{a}_t) + \sigma_{2t}(\mathbf{a}_t) = 1 \quad \text{and} \quad \sigma_{3t}(\mathbf{a}_t) + \sigma_{4t}(\mathbf{a}_t) = 1 \tag{9}$$

Let $\mathbf{I}(1)$ be the set of all one stage potential vectors of indicators. Set $\mathbf{I}(1)$ is presented in Table 1.

Table 1: Set of one stage potential vectors of indicators for $T = 1$

No of vector	Components of $\boldsymbol{\sigma}_t$				Comments	Class
	σ_{1t}	σ_{2t}	σ_{3t}	σ_{4t}		
1	0	1	0	1		$\mathbf{A}^6$
2	0	1	1	0		$\mathbf{A}^4$
3	1	0	0	1	overgood and underbad	x
4	1	0	1	0		$\mathbf{A}^1$

Vector no 3 is excluded because it describes stage alternative which is simultaneously overgood (better than the set of stage good objects $\mathbf{G}_t$) and underbad (worse than the set of bad objects). According to multistage Bipolar assumptions [4, 5] such situation cannot occur.

3.2 Multistage vectors of indicators

Let $\mathbf{a} = (\mathbf{a}_1,...,\mathbf{a}_T)$ be a multistage realization of the considered process. We define:

$$\boldsymbol{\sigma}(\mathbf{a}) = \sum_{t=1}^{T} \boldsymbol{\sigma}_t(\mathbf{a}_t) \tag{10}$$

Vector $\boldsymbol{\sigma}(\mathbf{a})$ has four components:

$$\boldsymbol{\sigma}(\mathbf{a}) = [\sigma_1(\mathbf{a}), \sigma_2(\mathbf{a}), \sigma_3(\mathbf{a}), \sigma_4(\mathbf{a})] \tag{11}$$

Let $\mathbf{I}(T)$ be the set of all potential, multistage vectors of indicators.

We define a *pointer function* in the following way:

$$\delta(\mathbf{a}) = [\sigma_1(\mathbf{a}) - \sigma_2(\mathbf{a}) + \sigma_3(\mathbf{a}) - \sigma_4(\mathbf{a})] \tag{12}$$

As before, we would like to associate potential, multistage vectors of indicators $\mathbf{I}(T)$ with classes $\mathbf{A}^1$ – $\mathbf{A}^6$ considered in Multistage Bipolar Method. Let $i, j = 1,...,T$-1.

Class $\mathbf{A}^1$ (definition of classes are taken from [4])
At each stage, all the stage alternatives outrank all the stage sets $\mathbf{G}_t$ and $\mathbf{B}_t$. We have:

$$\boldsymbol{\sigma}(\mathbf{a}) = [T, 0, T, 0] \quad \text{and} \quad \delta(\mathbf{a}) = 2T \tag{13}$$

Class $\mathbf{A}^2$.
At some stages, the stage alternatives outrank the stage sets $\mathbf{G}_t$, but at one stage at least, $\mathbf{G}_t$ outranks a stage alternative from the given multistage alternative. At each stage, the stage alternatives outrank $\mathbf{B}_t$. We have:

$$\sigma(\mathbf{a}) = [T\text{-}i, i, T, 0] \quad \text{and} \quad \delta(\mathbf{a}) \in \{2,..., 2T\text{-}2\} \tag{14}$$

Class $\mathbf{A}^3$.
At some stages, stage alternatives outrank the stage good sets $\mathbf{G}_t$, while at other stages, $\mathbf{G}_t$ outranks the stage alternatives. On the other hand, at some stages, stage alternatives outrank the stage bad sets $\mathbf{B}_t$, while at other stages, $\mathbf{B}_t$ outranks the stage alternatives. We have:

$$\sigma(a) = [T\text{-}i, i, T\text{-}j, j] \quad \text{and} \quad \delta(a) \in \{-2T+4,...,2T-4\} \tag{15}$$

Class $\mathbf{A}^4$.
At all stages, all the stage alternatives are outranked by $\mathbf{G}_t$. At the same time, at all stages, the stage alternatives outrank $\mathbf{B}_t$. We have:

$$\sigma(a) = [0, T, T, 0] \quad \text{and} \quad \delta(a) \in \{-2T\text{-}2, ...,-2\} \tag{16}$$

Class $\mathbf{A}^5$
All the stage alternatives are outranked by $\mathbf{G}_t$. At the same time, among the stage alternatives there are some that outrank $\mathbf{B}_t$ as well as some that are outranked by these sets. We have:

$$\sigma(a) = [0, T, T\text{-}j, j] \quad \text{and} \quad \delta(a) = 0 \tag{17}$$

Class $\mathbf{A}^6$

All the stage alternatives are outranked by $\mathbf{G}_t$. At the same time, these stage alternatives are outranked, in all stages, by $\mathbf{B}_t$. We have:

$$\sigma(a) = [0, T, 0, T] \quad \text{and} \quad \delta(a) = -2T. \tag{18}$$

For all T values $\delta(\mathbf{a})$ are odd numbers and $\delta(\mathbf{a}) \in \{-2T, -2T+2, ..., 2T-2, 2T\}$. The results of the considerations presented above are summarized in Table 2.

Table 2: Components of multistage, potential vectors of indicators and values of pointer functions

Class	Components of vectors of indicators				Values of $\delta(\mathbf{a})$
	1	2	3	4	
$\mathbf{A}^1$	T	0	T	0	$2T$
$\mathbf{A}^2$	$T-i$	i	T	0	$\{2,..., 2T-2\}$
$\mathbf{A}^3$	$T-i$	i	$T-j0$	j	$\{-2T+4,...,2T-4\}$
$\mathbf{A}^4$	0	T	T	0	0
$\mathbf{A}^5$	0	T	$T-j$	j	$\{-2T-2, ...,-2$
$\mathbf{A}^6$	0	T	0	T	$-2T$

We will present sets $\mathbf{I}(T)$ for T = 2, 3 and 4.

Two stage process

We consider any two stage process. We will apply lexicographic ordering for the components of vectors of indicators (table 3). Vectors no 4, 7 and 8 are excluded because they describe alternatives which are in some stages overgood and underbad simultaneously.

Table 3: Set of potential vectors of indicators and values of pointer function for T = 2.

Vector no.	Components of vectors of indicators				$\delta(\mathbf{a})$	Comments	Class
	1	2	3	4			
1	0	-2	0	-2	-4		$\mathbf{A}^6$
2	0	-2	1	-1	0		$\mathbf{A}^5$
3	0	-2	2	0	0		$\mathbf{A}^4$
4	1	-1	0	-2	x	overgood and underbad	x
5	1	-1	1	-1	0		$\mathbf{A}^4$
6	1	-1	2	0	0		$\mathbf{A}^4$
7	2	0	0	-2	x	overgood and underbad	x
8	2	0	1	-1	x	overgood and underbad	x
9	2	0	2	0	4		$\mathbf{A}^1$

Three stage process

The set of potential vectors of indicators for any three stage process is shown in table 4.

Table 4: Set of potential vector indicators and values of pointer function for T = 3.

Class	Components of vectos of indicators				$\delta(\mathring{a})$	Class	Components of vectors of indicators				$\delta(\mathring{a})$
	1	2	3	4			1	2	3	4	
$\mathbf{A}^1$	3	0	3	0	6		1	-2	1	-2	-2
$\mathbf{A}^2$	2	-1	3	0	4	$\mathbf{A}^4$	0	-3	3	0	0
	1	-2	3	0	2	$\mathbf{A}^5$	0	-3	2	-1	-2
$\mathbf{A}^3$	2	-1	2	-1	2		0	-3	1	-2	-4
	2	-1	1	-2	0	$\mathbf{A}^6$	0	-3	0	-3	-6
	1	-2	2	-1	0						

Four stage process

The set of potential vectors of indicators for any four stage process is shown in table 5.

Table 5: Set of potential vectors of indicators and values of pointer function for $T = 4$.

Class	Components of vector indicators				$\delta(\mathbf{\mathring{a}})$	Class	Components of vector indicators				$\delta(\mathbf{\mathring{a}})$
	1	2	3	4			1	2	3	4	
$\mathbf{A}^1$	4	0	4	0	8	$\mathbf{A}^3$	1	-3	2	-2	-2
$\mathbf{A}^2$	3	-1	4	0	6		1	-3	1	-3	-4
	2	-2	4	0	4	$\mathbf{A}^4$	0	-4	4	0	0
	1	-3	4	0	2	$\mathbf{A}^5$	0	-4	3	-1	-2
$\mathbf{A}^3$	3	-1	3	-1	4		0	-4	2	-2	-4
	2	-2	3	-1	2		0	-4	1	-3	-6
	2	-2	2	-2	0	$\mathbf{A}^6$	0	-4	0	-4	-8
	1	– 3	3	-1	0						

4 ALGORITHM

Applying properties of vectors of indicators, we propose an algorithm for searching the final solution in the Multistage Bipolar Method.

Algorithm 1

Step 1.We consider T-stage process. The set of potential vector indicators $\mathbf{I}(T)$ is generated.

Step 2. For each t=1,...,T we find sets $\{\sigma(\mathbf{a}_t)\colon \mathbf{a}_t \in \mathbf{A}_t\}$.

Step 3.Applying single criterion dynamic programming algorithm we find value

$$\delta o = \max \{\delta(\sigma(a))\colon a \in A)\}. \tag{19}$$

Step 4. We identify the potential vector of indicators $\mathbf{i}^0 \in \mathbf{I}(T)$ such, that $\delta(\mathbf{i}^0) = \delta^o$, which belongs to the class of the lowest number m.

Step 5. We find the set of multistage realizations $\mathbf{A}^{0m}$ such, that

$$A0m = \{a0 \in A\colon \delta(a0) = \delta o\} \wedge \sigma(a0) = i0\} \tag{20}$$

Step 6. From $\mathbf{A}^{0m}$ we choose the set of non-dominated realizations $(\mathbf{A}^{0m})^*$. and find the final solution $\mathbf{a}^{0*}$ which fulfills formula (4).

5 NUMERICAL ILLUSTRATION

We consider a three-stage decision process, shown in Fig. 1.

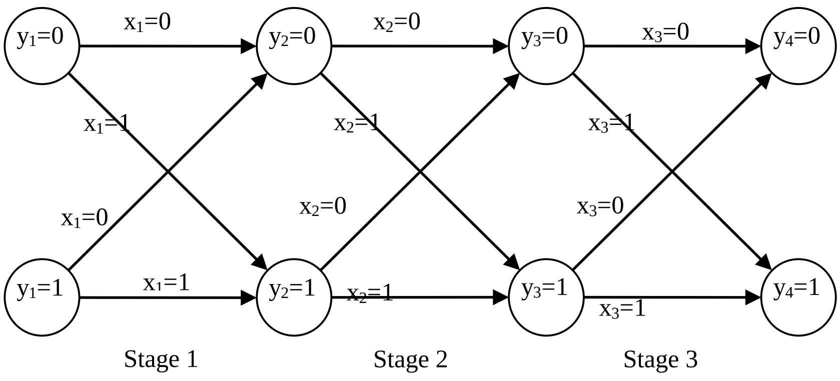

Figure 1: The graph of the exemplary process

There are two states at each stage of the process and two decisions in each state. At each stage we have four stage alternatives and we consider two reference sets at each stage: $\mathbf{G}_t$ and $\mathbf{B}_t$. The values of stage indicators and vector indicators are given in table 6. The structure of the process together with values $\delta(\mathbf{a}_t)$ is shown in Fig. 1.The full description of the process in question and the numerical data can be found in [4]

Table 6 Set of vector indicators and values of pointer function for $T = 4$.

Stage	$\mathbf{A}_t$	$d_G^+(\mathbf{a}_t)$	$d_G^-(\mathbf{a}_t)$	$d_B^+(\mathbf{a}_t)$	$d_B^-(\mathbf{a}_t)$	$\sigma_{1t}(\mathbf{a}_t)$	$\sigma_{2t}(\mathbf{a}_t)$	$\sigma_{3t}(\mathbf{a}_t)$	$\sigma_{1t}^-(\mathbf{a}_t)$
t=1	$\mathbf{a}_1^{(0)}$	0	0.88	0.63	0	0	1	1	0
	$\mathbf{a}_1^{(1)}$	0.65	0	0.77	0	1	0	1	0
	$\mathbf{a}_1^{(2)}$	0	0.75	0	0.64	0	1	0	1
	$\mathbf{a}_1^{(3)}$	0	0.52	0.52	0	0	1	1	0
t=2	$\mathbf{a}_2^{(0)}$	0	0.88	0.63	0	0	1	1	0
	$\mathbf{a}_2^{(1)}$	0	1	0	1	0	1	0	1
	$\mathbf{a}_2^{(2)}$	0.51	0	0.77	0	1	0	1	0
	$\mathbf{a}_2^{(3)}$	0	0.72	0	0.63	0	1	0	1
t=3	$\mathbf{a}_3^{(0)}$	0.77	0	0.59	0	1	0	1	0
	$\mathbf{a}_3^{(1)}$	0	0. 61	0	0.73	0	1	0	1
	$\mathbf{a}_3^{(2)}$	0	0.75	0	0.77	0	1	0	1
	$\mathbf{a}_3^{(3)}$	0	0.75	0.75	0	0	1	1	0

Applying Algorithm 1 we obtain:

Step 1. The set of potential vectors of indicators for T=3 is given in Table 4.

Step 2. Vectors belonging to $\{\sigma(\mathbf{a}_t)\colon \mathbf{a}_t \in \mathbf{A}_t\}$ for t=1, 2 and 3 are shown in Fig. 1.

Step 3. Applying the single criterion dynamic programming method we find, that $\delta^o = 6$.

Step 4. We identify the only vector $\mathbf{i}^0 = [3, 0, 3, 0]$, $\mathbf{i}^0 \in \mathbf{I}^1$.

Step 5. Set $\mathbf{A}^{01}$ consists of one multistage realization $\mathbf{a}^{0*} = (a_1^{0*}, a_2^{0}*, a_3^{0}*) = (0,1; 1,0: 0,0)$.

Step 6. Realization $\mathbf{a}^{0*}$ is the final solution.

6 CONCLUSIONS

Properties of vectors of indicators described in the paper gives the opportunity to formulate Algorithm 1. Proposed approach, based on single criterion dynamic programming seems to be simpler then the approach for finding final solution., described in [5], based on multiobjective dynamic programming.

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ANALYZING THE CONCORDANCE OF PRINCIPALS' PREFERENCE REPRESENTATION BY AGENTS WITH DIFFERENT DECISION-MAKING PROFILES USING GENERALIZED FUZZY APPROACH

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Abstract: The paper aims to analyze how accurately the agents of various decision-making profiles can represent their principals' preferences in representative negotiations. The agents are grouped according to (1) the way they interpret the imprecise preference information provided by principals, (2) the way they construct the scoring systems, and (3) various decision-making profiles they represent. The notion of a generalized fuzzy scoring system is applied to find the representation of the principal's preferences by a group of agents with a homogenous decision-making style. For empirical verification of the proposed model, the dataset of the prenegotiation in-class experiment is used.

Keywords: preference analysis, decision-making style, fuzzy scoring system, representative negotiation, negotiation support

1 INTRODUCTION

The critical element of negotiation analysis is the negotiation template and its rating system that reflects the structure of the negotiation problem and the negotiator's preferences over its elements. Based on the scoring systems, individual or joint support may be offered to the negotiators, e.g., by electronic support systems [4, 8]. In representative negotiations, where the agents negotiate on behalf of their principals [1], determining accurate scoring systems seems particularly vital. Usually, principals have no analytical skills to impart their preference information precisely. In such cases, verbal descriptions of preferences may be supported by various visualization techniques [6]. Among many, circles or pie charts are used [12]. Using circles to represent the preferences seems to be quite convenient and cognitively easy for principals. However, it may raise interpretational problems as the circles are two-dimensional. It is also linked with uncertainty and imprecision since pies, if sketched out, are not based on the precise measurement of the preference. Otherwise, the principal would be able to impart them directly to the agent using numbers [9, 12].

Therefore a vital question arises of how the agents may interpret the preference information provided by means of such visualization and use it to determine the scoring systems for their principals. This may be related to the cognitive capabilities of agents, i.e., the way they process information and use a mix of reflective and intuitive styles. Due to their cognitive limitations, people vary in their ability to process information [2, 11]; therefore, they may be categorized according to their decision-making styles that describe precisely how the human mind operates using information and making decisions.

The goal of this paper is to empirically verify how the information processing style may affect the way the agents interpret the preference information provided to them by the principals and how it affects the concordance of the scoring systems built based on such information. The notion of a generalized fuzzy scoring system is used to represent the principal's preferences by agents of a particular cognitive style. In such an approach, the fuzzy numbers aggregate individual scoring systems of agents within a group of homogenous cognitive styles. In our study, we use the dataset of prenegotiation experiment that required the participants to play the role of agents in typical business negotiation that we adopted from the Inspire electronic negotiation system [4]. The General Decision-Making Style (GDMS) instrument [10] is applied to determine the decision-making styles of agents.

The paper consists of four following sections. In section 2, we define the negotiation template and scoring system procedure. Section 3 describes the experimental setup, while in section 4, the results are presented. We finished with conclusions.

2 NEGOTIATION TEMPLATE AND THE SCORING SYSTEM

2.1 Individual scoring systems

The negotiation template (for details see [13]) is an ordered pair $\mathbb{T} = (\mathcal{F}, \mathcal{X})$, where $\mathcal{F} = (f_i)_{i=1}^{n}$ is a sequence of negotiation issues f_i, $\mathcal{X} = (X_i)_{i=1}^{n}$ is a sequence of options lists X_i related for issue f_i, $X_i = \left(x_{i,j}\right)_{j=1}^{m_i}$ is a the sequence of options for issue f_i. The set $\mathbb{P}$ of feasible negotiation offers $\overline{P}_p$ is defined as

$$\mathbb{P} = X_1 \times X_2 \times \ldots \times X_n \ni \overline{P}_p = \left(x_{1(p)}, \ldots, x_{n(p)}\right) \tag{1}$$

where $x_{i(p)} \in X_i$ denotes an option of issue i used to build the package p, $p = 1, \ldots, \text{card}\, \mathbb{P}$.

Assuming the preferences are additive, the scoring system is an ordered pair $\mathbb{S} = (\mathcal{W}, \mathcal{S})$ where $\mathcal{W} = \left(v_{i,0}\right)_{i=1}^{n}$ is a sequence of issues' importance (weights) and $\mathcal{S} = (S_i)_{i=1}^{n}$ is a sequence of lists of option scores $S_i = \left(v_{i,j}\right)_{j=1}^{m_i}$. The negotiation package from template $\mathbb{T}$ can be evaluated based on the scoring system $\mathbb{S}$ with the use scoring function

$$F\left(\overline{P}_p\right) = \sum_{i=1}^{n} v_{i,0} v_{i(p)}, \tag{2}$$

where $v_{i(p)} \in S_i$ denotes the score of $x_{i(p)}$.

In this paper, we will assume that the principal may use circles $\mathcal{C}(R)$ of various radii R to visualize their preferences over the template $\mathbb{T}$. The more important issue f_i is (or the better option $x_{i,j}$), the larger the size of the circle it represents.

When building the scoring systems $\mathbb{S}$ an agent assesses circle sizes by value $V_{i,j} \in \mathbb{R}_0^+$ $(i = 1, \ldots, n; j = 0, \ldots, m_i)$. Further, she standardizes her assessments so that they can be used to determine the value of negotiation offers according to (2). The issue importance is standardized in the following way

$$\forall_{i=1,2,\ldots,n}\; v_{i,0} = \frac{V_{i,0}}{\sum_{q=1}^{n} V_{q,0}}. \tag{3}$$

The standardized description of preferences between predefined options can be performed using linear Max-Min (1) and linear Max (2) scaling in the following way:

$$\forall_{i=1,2,\ldots,n}\,\forall_{j=1,2,\ldots,m_i}: v_{i,j}^{(1)} = \frac{V_{i,j} - \min\{V_{i,q}: q=1,2,\ldots,n_i\}}{\max\{V_{i,q}: q=1,2,\ldots,n_i\} - \min\{V_{i,q}: q=1,2,\ldots,n_i\}} \quad (4)$$

$$\forall_{i=1,2,\ldots,n}\,\forall_{j=1,2,\ldots,m_i}: v_{i,j}^{(2)} = \frac{V_{i,j}}{\max\{V_{i,q}: q=1,2,\ldots,n_i\}} \quad (5)$$

The absolute utilities (standardized and weighted) $U^s(x_{i,j}) = u_{i,j}^{(s)}$ for any option $x_{i,j}$ are obtained in the following way:

$$\forall_{s=1,2}\forall_{i=1,2,\ldots,n}\forall_{j=1,2,\ldots,m_i}: \; u_{i,j}^{(s)} = v_{i,0} \cdot v_{i,j}^{(s)} \quad (6)$$

where $v_{i,j}^{(s)}$ is normalized relative utility obtained by method s.

2.2 Representing the scoring systems of a group of agents

In our approach, the series of absolute utilities determined from formula (6) are used to build the fuzzy scoring systems $\langle \mathbb{P}, F \rangle$ representing a group of agents. By Q we denote the group of agents for which the absolute utilities are represented by the sequence $\mathcal{U}_{i,j}^{(Q)} = (u_{i,j,k}^{(Q)})_{k=1}^{|Q|}$. Trapezoidal fuzzy numbers $Tr(a,b,c,d)$ depending on the sequence $\mathcal{U}_{i,j}^{(Q)}$ will constitute the group scoring system. For group Q we can determine absolute utilities as function $U^{(Q)}: \bigcup_{i=1}^{n} X_i \longrightarrow \mathbb{F}_{Tr}$ given by the identity

$$U^{(Q)}(x_{i,j}) = Tr\left(\check{u}_{i,j}^{(Q)}, \bar{u}_{i,j}^{(Q)}, \bar{\bar{u}}_{i,j}^{(Q)}, \hat{u}_{i,j}^{(Q)}\right) \quad (7)$$

where: $\check{u}_{i,j}^{(Q)} = \min\left\{y: y \in \mathcal{U}_{i,j}^{(Q)}\right\}$, $\bar{u}_{i,j}^{(Q)} = \min\left\{y: \frac{\text{card}\left\{z: z \le y, z \in \mathcal{U}_{i,j}^{(Q)}\right\}}{\text{card } Q} \ge \frac{1}{3}, y \in \mathcal{U}_{i,j}^{(Q)}\right\}$,

$\bar{\bar{u}}_{i,j}^{(Q)} = \max\left\{y: \frac{\text{card}\left\{z: z \ge y, z \in \mathcal{U}_{i,j}^{(Q)}\right\}}{\text{card } Q} \ge \frac{1}{3}, y \in \mathcal{U}_{i,j}^{(Q)}\right\}$, $\hat{u}_{i,j}^{(Q)} = \max\left\{y: y \in \mathcal{U}_{i,j}^{(Q)}\right\}$.

Now, the negotiation package $\bar{P}_p \in \mathbb{P}$ is represented in the following way

$$\begin{aligned} F^{(Q)}(\bar{P}_p) &= \bigoplus_{i=1}^{n} Tr\left(\check{u}_{i,j(p)}^{(Q)}, \bar{u}_{i,j(p)}^{(Q)}, \bar{\bar{u}}_{i,j(p)}^{(Q)}, \hat{u}_{i,j(p)}^{(Q)}\right) = \\ &= Tr\left(\textstyle\sum_{i=1}^{n} \check{u}_{i,j(p)}^{(Q)}, \sum_{i=1}^{n} \bar{u}_{i,j(p)}^{(Q)}, \sum_{i=1}^{n} \bar{\bar{u}}_{i,j(p)}^{(Q)}, \sum_{i=1}^{n} \hat{u}_{i,j(p)}^{(Q)}\right). \end{aligned} \quad (8)$$

With a generalized fuzzy scoring system defined for a group Q of agents with a similar profile, we may determine how accurately such a group represents the principal's preferences.

3 PRENEGOTIATION EXPERIMENT

We organized a prenegotiation experiment to analyze the differences in the representation of the scoring systems by agents of various profiles. A negotiation case from Inspire negotiation system [4] was used, in which agents of a musician (Fado) and a broadcasting company (Mosico) discuss the terms of a potential contract. The negotiation template consisted of four issues and lists of predefined options (see Table 1) that allow building 240 various packages.

The preference information of principals was provided to the agents by means of a short verbal description accompanied by the visualization, in which circles are used (see Fig. 1).

Table 1: Negotiation template in Inspire negotiation

Negotiations issues	***Lists of feasible options***
Number of promotional concerts (per year)	5; 6; 7 or 8 concerts
Number of new songs introduced and performed each year	11; 12; 13; 14 or 15 songs
Royalties for CDs (in percent)	1.5; 2; 2.5 or 3 %
Contract signing bonus (in dollars)	$125 000; $150 000 or $200 000

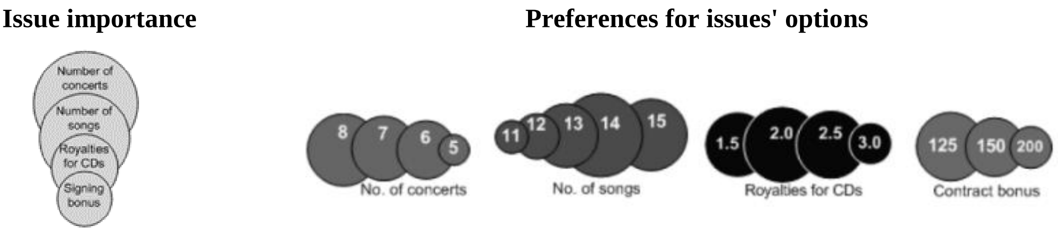

Figure 1: Visualization of principal's preferences for Mosico agents.

Based on this information, the participants, all representing the Mosico party, were asked to provide the quantitative representation of the priorities, i.e., the circle sizes $V_{i,j}$, to construct the scoring system. Additionally, they filled the General Decision-Making Style Inventory. Our analytics consisted of the five following steps:

- Step 1. Determining the participants' decision-making profiles using GDMS [10] and factor analysis [5].
- Step 2. Verifying scores $V_{i,j}$ declared by the agents and differences in their normalization.
- Step 3. Building the clusters of homogenous agents.
- Step 4. Determining the fuzzy scoring systems for clusters.
- Step 5. Comparing rankings of packages from each cluster with the principal's ranking. To compare fuzzy negotiation offers, the similarity measures proposed by Chen [3], Hsieh and Chen [14], Wei and Chen [14], and Ponnialagan, Selvaraj, and Velu [7] were used.

The principal's scoring system required for Step 5 was built using directly the radii of circles presented to agents (see Fig. 1). When determining the relative utilities of issues and options for principal, the original radii $R_{i,j}$ replace the scores $V_{i,j}$ in eq. (3)- (5) respectively.

The experiment was conducted in the form of an in-class survey. The participants were the bachelor and master students of four Polish universities. We received 141 completed questionnaires; 83 were filled by males (~59%), while 41% by females.

4 RESULTS

In step 1, the agent's decision-making profiles were determined using GDMS, which allows describing the decision-making style using five modes: Rational (R) – which describes analytic, systematic information processing; Intuitive (I) – strong reliance on emotions, gut feelings, and intuition; Spontaneous (S) – desire to finish the decision process as quick as possible; Dependent (D) – search for advice and consulting; Avoidant (A) – attempts to avoid or delay the decision. The combined exploratory and confirmatory factor analysis was used (E/CFA) to determine the participants' styles [5]. The reduced 17-item model with five factors revealed a satisfactory fit with χ^2_M/df_M equal to 1.33, RMSEA = 0.048, CFI = 0.966, and the Bollen-Stine bootstrap (required for non-normal data) with p = 0.197.

In step 2, we verified the agents' scores standardization mode. We found that some of the agents (28%) had assigned the least preferred option with a score of 0, implicitly using the standardization procedure described by formula (4). This is an important finding because when the perception of circles is to be determined (according to eq. (7)), these zeroes cannot be compared to non-zero circles drawn by the principals to avoid false-negative conclusions. Thus the results will be analyzed separately for two groups of agents: Q1 (38 agents) - for which the standardizing formula (4) will be used, and Q2 (103 agents) - where formula (5) will be applied.

In Step 3, the clusters of agents with homogenous decision-making styles were built using k-means clustering. In each resulting cluster, the subgroups Q1 and Q2 were distinguished. This made the subclusters too small to provide any reliable statistical comparison. Luckily, it occurred that both groups Q1 and Q2, differ significantly in terms of the decision-making style characteristics. It confirms the relationship between how the agents perform the preference analysis (representing the relative importance of negotiation template elements) and the agents' behavioural characteristics. In Table 2, the average values of factors representing each decision-making style for each group of agents are shown.

Table 2: Average Values of Decision-Making Style's for Agents' Groups

Group	***Decision-making style***				
	D	S	A	I	R
Q1	3.299	1.188	2.340	3.013	1.871
Q2	3.191	1.428	2.287	3.419	1.745
p^*	0.287	0.015	0.838	0.003	0.077

* significance determined by means of Mann-Whitney test

The differences between agents from groups Q1 and Q2 are significant with respect to three major GDMS styles. The agents from Q1 occurred less spontaneous, less intuitive, and more rational than those from Q2, and the differences were statistically significant. The differences for dependent and avoidant styles are insignificant, yet those modes are considered as regulatory only. These results seem plausible, as the agents from Q1 performed more advanced analysis by standardizing the circle sizes and providing their relative importance by means of eq. (4) than their colleagues from Q1. Such analysis requires more analytic skills (higher rationality mode and lower spontaneous one) and restricted reliance on intuition.

In Step 4, the fuzzy scoring systems were determined for both groups of agents, Q1 and Q2, respectively, consisting of absolute option ratings (Eq. (8)).

Finally, in step 5, the package rankings for principal and Q1 and Q2 agents were compared. The Tau Kendall coefficients between principal's ranking and fuzzy ranking (resulting from different comparison formulas) for 240 packages comprising the set of feasible offers $\mathbb{P}$ are presented in Table 3. All results show a high and statistically significant ($p<0.01$) correlation between agents' and principals' ranking, higher for group Q1.

Table 3. Tau Kendall between principal's ranking and fuzzy ranking

	Tau Kendal			
Group	Chen	Hsieh &Chen	Wei&Chen	Ponnialagan et al
Q1	0.906	0.908	0.844	0.904
Q2	0.832	0.837	0.790	0.848

5 CONCLUSIONS

The results obtained show that the negotiators with higher rational modes and lower intuitive and spontaneous ones behave differently while representing the preferences of their principals.

They process the preference information in a different way (Q1) than the highly spontaneous and intuitive agents (Q2), being aware of its further use in the scoring system (a need for standardization and use of standardized scores in the classic additive scoring formula). Furthermore, Q1 agents were also able to produce the scoring systems that result in a very similar representation of offer rankings to those derived from the principal's own scoring system. Their similarity was higher no matter which ranking comparison approach was implemented, showing that they perform better in representing their principal's preferences than highly spontaneous, intuitive and less rational colleagues. Simultaneously, using a fuzzy generalized approach allowed us to resign from the classic aggregation of differences of preference representation within clusters (as averaging) and convey a whole spectrum of representation typical for this group of agents.

Our results confirm that agents vary in the representation of principals' preferences. Hence, there is a need for developing the decision support tools to help agents with various profiles to improve the adequacy of their decision analysis and preference elicitation to assure good representation of their preferences in negotiation.

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Session 7:
Theory of Games

COOPERATIVE INTERVAL GAMES AND SELECTIONS REVISITED

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Abstract: Cooperative interval games are a generalisation of classical cooperative (transferable utility) games in which every coalition (group of players) gets assigned some closed real interval. This models uncertainty about the reward which coalition gets for cooperating together.

This paper extends the current knowledge of cooperative interval games and their selections (possible outcomes) by tackling the following two problems.

First, we provide a Shapley-like characterisation of selection convex interval games. This is a class of games in which every possible outcome is a convex game.

Second, we investigate the so called *core coincidence problem.* Core, being one of the most well-known stability concepts in cooperative game theory, can be generalised in two natural ways to interval games. We compare these two variants, varying in terms of their resulting uncertainty, and provide several large classes and important examples of interval games for which these two definitions coincide. Finally, we provide also negative examples in terms of classes for which these definitions do not coincide.

Keywords: cooperative games, interval game, interval, selections, convexity, core, solution concepts

1 INTRODUCTION AND PRELIMINARIES

Uncertainty and inaccurate information are an everyday issue in real-world situations and thus subsequently also in operations research, economics, and game theory. It is crucial to be able to make decisions even when the exact data is not available and only bounds on them are known.

In classical cooperative game theory, every group of players (*coalition*) knows the precise reward for their cooperation. On the other hand, in cooperative interval games, only the worst and the best possible outcome is known. Such situations can be naturally modelled with intervals encapsulating these extremal outcomes. Cooperative (transferable utility) games under interval uncertainty were first considered by Branzei, Dimitrov, and Tijs in 2003 to study bankruptcy situations [7] and later further extensively studied by Alparslan Gök in her PhD thesis [1] and in series of follow-up papers (see the references section of [6]).

We note that there are several other models incorporating a different level of uncertainty, namely fuzzy cooperative games [8, 11], multi-choice games [8], fuzzy interval games [10], games under bubbly uncertainty [13], ellipsoidal games [17], and games based on grey numbers [12]. Compared to the aforementioned models of cooperative games, cooperative interval games provide a simple model which tends to be easier to analyse and it is suitable for situations where we do not have any other assumptions on data we have. There are already a few applications of this model, e.g. to airport problems [3], bankruptcy situations [7], or network design [9].

This paper continues in the line of research started in [5]. Our main focus is on selections (Definition 1.4), that is on possible outcomes of interval games.

Interval analysis. An interval X is a set $X \coloneqq [\underline{X}, \overline{X}] = \{x \in \mathbb{R} : \underline{X} \leq x \leq \overline{X}\}$ with $\underline{X}$ being the lower bound and $\overline{X}$ being the upper bound of the interval. The length of an interval X ($|X|$) is defined as $|\overline{X} - \underline{X}|$. For every two intervals X, Y, $X + Y \coloneqq [\underline{X} + \underline{Y}, \overline{X} + \overline{Y}]$. We say that an interval J is weakly better than interval I ($I \preceq J$) if $\underline{I} \leq \underline{J}$ and $\overline{I} \leq \overline{J}$.

Classical cooperative games. Let us briefly recall two basic notions of classical cooperative games needed for our paper.

Definition 1.1 *A* cooperative game *is an ordered pair* (N, v) *where* N *is a finite set of players (usually* $\{1, 2, \ldots, n\}$*) and* $v : 2^N \to \mathbb{R}$ *is the characteristic function of the cooperative game. We assume that* $v(\emptyset) = 0$*. The set of all cooperative games on* N *is denoted by* G^N*.*

Definition 1.2 *A cooperative game* (N, v) *is* convex *if for every* $S, T \subseteq N$*,* $v(T) + v(S) \leq v(S \cup T) + v(S \cap T)$*.*

Cooperative interval games. We are now ready to formally extend cooperative games to intervals.

Definition 1.3 *A* cooperative interval game *is an ordered pair* (N, w) *where* N *is a finite set of players (usually* $\{1, 2, \ldots, n\}$*) and* $w : 2^N \to \mathbb{IR}$ *is the characteristic function of the cooperative game. We further assume that* $w(\emptyset) = [0, 0]$*. The set of all interval cooperative games on a player set* N *is denoted by* IG^N*.*

The associated *length game* of $(N, w) \in \mathrm{IG}^N$ is the game $(N, |w|)$ with $|w|(S) := \overline{w}(S) - \underline{w}(S)$, $\forall S \in 2^N$. And *lower border game* is defined as $\underline{w}(S) := \underline{w(S)}$ for every $S \in 2^N$. We call a game $(N, w) \in \mathrm{IG}^N$ *degenerated* if its length game satisfies $\overline{|w|(S)} = 0$ for every $S \in 2^N$. A *non-degenerated game* is a game that is not degenerated.

The fundamental notion of this paper is *selection.*

Definition 1.4 *A game* $(N, v) \in G^N$ *is a* selection *of* $(N, w) \in \mathrm{IG}^N$ *if for every* $S \in 2^N$*, we have* $v(S) \in w(S)$*. The set of all selections of* (N, w) *is denoted by* $\mathrm{Sel}(w)$*.*

2 SELECTION CONVEX INTERVAL GAMES

There are two ways how to generalise convex games into interval setting: *convex interval games* [4] (denoted CIG) and *selection convex interval games* (introduced in [5] and denoted SeCIG). We shall focus here in this section on the latter.

Definition 2.1 *An interval game* (N, v) *is* selection convex *if all its selections are convex games. The class of such games on a player set* N *is denoted by* SeCIG^N*.*

The main result of this section is a characterisation of selection convex interval games analogous to a classical result of Shapley on convex games [16] and to Theorem 3.1 of [4] on convex interval games.

Theorem 2.2 *For every interval game* (N, w)*, the following assertions are equivalent.*

1. *The game* (N, w) *is a selection convex interval game.*
2. *For every nonempty* $S, T \in 2^N$ *such that* $S \cap T \neq T$*, and* $S \cap T \neq S$*,*
$$\overline{w}(S) + \overline{w}(T) \leq \underline{w}(S \cup T) + \underline{w}(S \cap T).$$
3. *For every coalition* $U_1, U_2, U \in 2^N$*, such that* $U_1 \subsetneq U_2 \subseteq N \setminus U$*, and* U *is nonempty,*
$$\overline{w}(U_1 \cup U) - \underline{w}(U_1) \leq \underline{w}(U_2 \cup U) - \overline{w}(U_2).$$
4. *For every coalition* $T_1, T_2 \in 2^N$ *and for every* $i \in N$ *such that* $T_1 \subsetneq T_2 \subseteq N \setminus \{i\}$*,*
$$\overline{w}(T_1 \cup \{i\}) - \underline{w}(T_1) \leq \underline{w}(T_2 \cup \{i\}) - \overline{w}(T_2).$$

Proof. (1) $\leftrightarrow$ (2) : This part is proved as Theorem 2 in [5].

(2) $\to$ (3) : Suppose for a contradiction that there exist $U_1, U_2, U \in 2^N$, U nonempty, such that $U_1 \subsetneq U_2 \subseteq N \setminus U$, and $\overline{w}(U_1 \cup U) - \underline{w}(U_1) > \underline{w}(U_2 \cup U) - \overline{w}(U_2)$.

Set $S := U_1 \cup U$, and $T := U_2$. Both S and T are nonempty sets and they are incomparable. Furthermore:

$$\begin{aligned} \overline{w}(U_1 \cup U) - \underline{w}(U_1) &> \underline{w}(U_2 \cup U) - \overline{w}(U_2), \\ \overline{w}(S) - \underline{w}(U_1) &> \underline{w}(T \cup U) - \overline{w}(T), \\ \overline{w}(S) + \overline{w}(T) &> \underline{w}(T \cup U) + \underline{w}(U_1), \\ \overline{w}(S) + \overline{w}(T) &> \underline{w}(S \cup T) + \underline{w}(S \cap T). \end{aligned}$$

This is, however, a contradiction.

(3) $\to$ (4) : Straightforward. Take $U_1 := T_1, U_2 := T_2, U := \{i\}$.

(4) $\to$ (3) : Suppose that (4) holds and (3) does not. Take U that violates (3) of minimal cardinality. If $|U| = 1$, we get a contradiction. If $|U| > 1$, we can construct U', with $|U'| = |U| - 1$, such that it violates (3) as well. This contradicts the minimality of U.

(3) $\to$ (2) : For a contradiction, take S and T that violate (2). Define $U := S \setminus T$; this must be nonempty since S and T are nonempty and incomparable. Define $U_1 := S \cap T$ and $U_2 := T$. As for the conditions on U_1 and U_2, we see that $U_1 \subsetneq U_2$, since U is nonempty and $(S \cap T) \subseteq T$. Now:

$$\begin{aligned} \overline{w}(S \cup U) - \overline{w}(T) &> \underline{w}(S \cup T) + \underline{w}(S \cap T) \\ \overline{w}(U_1 \cup U) + \overline{w}(T) &> \underline{w}(U_1 \cup U \cup T) + \underline{w}(U_1) \\ \overline{w}(U_1 \cup U) - \underline{w}(U_1) &> \underline{w}(U_2 \cup U) - \overline{w}(U_2) \end{aligned}$$

The last equation leads to a contradiction, concluding the proof. $\square$

3 CORE COINCIDENCE PROBLEM

Core is one of the most studied solution concepts in classical cooperative game theory. See [15, 14] for comprehensive information about core. We shall first define two generalisations of core for interval games and then investigate their relation.

Definition 3.1 *The* interval selection core *(shortly* selection core*) of* $(N, w) \in \mathrm{IG}^N$ *is defined as* $\mathcal{SC}(w) := \bigcup_{v \in \mathrm{Sel}(w)} C(v)$.

In an analogous way to classical games, we have a notion for games with nonempty selection core for all selections. We say that an interval game is called *strongly balanced* if every selection of this game has a nonempty core. The set of all strongly balanced games on a player set N is denoted by BIG^N.

Definition 3.2 *The* interval core *of* $(N, w) \in \mathrm{IG}^N$ *is defined as*

$$\mathcal{C}(w) := \Big\{(I_1, I_2, \ldots, I_N) \in \mathcal{I}(w) \mid \sum_{i \in N} I_i = w(N) \text{ and } \sum_{i \in S} I_i \succeq w(S),\ \forall S \in 2^N \setminus \{\emptyset\}\Big\}.$$

In Alparslan Gök's PhD thesis [1] and in later paper [2], the following question is raised:

> *"A difficult topic might be to analyze under which conditions the set of payoff vectors generated by the interval core of a cooperative interval game coincides with the core of the game in terms of selections of the interval game."*

The main thing to notice is that while the interval core gives us a set of interval vectors, selection core gives us a set of real-numbered vectors. Thus they both provide a different degree of uncertainty. To be able to compare them, we need to assign to a set of interval vectors a set of real vectors generated by these interval vectors. That is exactly the purpose of the following function — gen.

Definition 3.3 *The function* gen: $2^{\mathbb{IR}^N} \to 2^{\mathbb{R}^N}$ *maps to every set of interval vectors a set of its selections. It is defined as* $\mathrm{gen}(S) := \bigcup_{s \in S} \big\{(x_1, x_2, \ldots, x_n) \mid x_i \in s_i, \forall i \in N\big\}$.

The *core coincidence problem* can be then formulated in the following way. What are the necessary and sufficient conditions so that an interval game (N, w) satisfies $\mathrm{gen}(\mathcal{C}(w)) = \mathcal{SC}(w)$?

For the sake of brevity, we define the following property.

Definition 3.4 *Let (N, w) be a cooperative interval game. We call the game* core-coincident *if* $\mathrm{gen}(\mathcal{C}(w)) = \mathcal{SC}(w)$. *Also, we say that a class of interval games is* core-coincident *if all games in this class are core-coincident.*

The results in this section can be seen as a step towards a complete classification of core-coincident games. We divide the rest of the section to positive and negative results.

3.1 Positive results

We start with two simple propositions. The proof of the following one easily follows from [5, Theorem 7].

Proposition 3.5 *Every cooperative interval game with empty selection core is core-coincident.*

Proposition 3.6 *Every degenerated cooperative interval game is core-coincident.*

Proof. It is enough to observe that definitions of selection core (Definition 3.1) and interval core (Definition 3.2) coincide for degenerate games. □

For our next result, we shall need the following, slightly technical theorem from [5].

Theorem 3.7 *[5] For every interval game (N, w), we have $\mathrm{gen}(\mathcal{C}(w)) = \mathcal{SC}(w)$ if and only if for every $x \in \mathcal{SC}(w)$, there exist nonnegative vectors $l^{(x)}$ and $u^{(x)}$ such that*

$$x(N) - l^{(x)}(N) = \underline{w}(N), \tag{1}$$

$$x(N) + u^{(x)}(N) = \overline{w}(N), \tag{2}$$

$$x(S) - l^{(x)}(S) \geq \underline{w}(S),\ \forall S \in 2^N, \tag{3}$$

$$x(S) + u^{(x)}(S) \geq \overline{w}(S),\ \forall S \in 2^N. \tag{4}$$

We are now ready to provide an example showing that there are infinitely many core-coincident non-degenerated games with a nonempty player set.

Theorem 3.8 *There are infinitely many non-degenerated core-coincident interval games.*

Proof. Define a game (N, w) with at least two players as $w(S) := 1/|S|$, if $S \neq N$, and further $w(N) := [|N|, |N| + b], b > 0, b \in \mathbb{R}$.

Clearly, $\mathcal{C}(w)$ consists exactly of the vectors x such that $x(N) \in w(N)$, and $x_i \geq 1, \forall i \in N$.

Let us take any such vector x. Define $l_i^{(x)} := x(i) - 1$, and $u_1^{(x)} := x(1) + \overline{w}(N) - x(N)$, and $u_i^{(x)} := x(i)$, for every $i \in N, i \neq 1$. It is now straightforward to check that all the inequalities of Theorem 3.7 hold and, therefore, this game is core-coincident. □

3.2 Negative results

Theorem 3.9 *Let (N, w) be an interval game defined as:*

$$u(S) \coloneqq \begin{cases} \overline{w}(S), & \text{if } S = N, \\ \underline{w}(S), & \text{if } S \neq N. \end{cases}$$

If it has a nonempty core and $C(\overline{w}) \neq \emptyset$, then (N, w) is not core-coincident.

Proof. We define an excess function as $e(x, S) \coloneqq (\sum_{i \in S} x_i) - w(S)$ for $S \subseteq N$ and $x \in \mathbb{R}^N$.

If for every $x \in C(u)$ and for every player $i \in N$, there is a coalition $S \in 2^N \setminus N, i \in S$ such that $e(x, S) = 0$, then we claim that the core of the upper border game $\overline{w}$ of w is empty.

To see this, observe that $C(\overline{w}) \subseteq C(u)$. However, if every $x \in C(u)$ has the aforementioned property, then by Theorem 3.7 none of those vectors can be in $C(\overline{w})$, a contradiction with $C(\overline{w}) \neq \emptyset$.

The other option is that there exists a vector $y \in C(u)$ and a player $j \in N$ such that for every $S \in 2^N \setminus N, j \in S$, $e(x, S) > 0$. We define $m \coloneqq \min_{S \in 2^N \setminus N, j \in S} e(x, S)$, and let M be the set on which this minimum is attained. We pick an arbitrary player $j' \in N \setminus M$. Such player must necessarily exist. We then construct a new vector $y' \in \mathbb{R}^N$:

$$y'_k \coloneqq \begin{cases} \underline{y_k} - m, & \text{if } k = j, \\ \underline{y_k} + m, & \text{if } k = j', \\ \underline{y_k}, & \text{otherwise.} \end{cases}$$

It can be observed that $y' \in C(u)$ and by a similar argument as in the previous case, y' does not satisfy the mixed system of inequalities of Theorem 3.7. This finishes the proof. □

The theorem has several interesting corollaries. We pinpoint the following two.

Proposition 3.10 *Every interval game $(N, w) \in \mathrm{BIG}^N$ with $|w|(S) > 0$ for every $S \in 2^N$ is not core-coincident.*

Proposition 3.11 *Let N be a player set and $|N| \geq 2$. Then the classes SeCIG^N and CIG^N are not core-coincident. Furthermore, every game in $\mathrm{SeCIG}^N \cup \mathrm{CIG}^N$ with every interval non-degenerated is not core-coincident either.*

Proof. A basic result on classical convex games by Shapley [16] says that every convex game has a nonempty core. This implies that selection convex games are strongly balanced.

In [4], it is proved that an interval game is convex interval game if and only if its lower border game and its length game are convex. This completes the proof. □

The preceding proposition has in fact even broader impact. (For the definitions of the following classes, consult introductory sections of [5].) We know that $\mathrm{SeCIG}^N \subseteq \mathrm{SeSIG}^N \subseteq \mathrm{SeMIG}^N$. Hence we immediately obtain that all these sets are not core-coincident as well for nontrivial player sets. Also, $\mathrm{CIG}^N \subseteq \mathrm{SIG}^N$ and thus, superadditive interval games are not core-coincident either.

From this we conclude that selection core and interval core behave very differently on many important and widely used classes with nontrivial uncertainty. To further develop theory and solve problems regarding both versions of cores remains as an important task for future.

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FROM THE INTERACTIVE PROGRAMMING TO A NEW DECISION RULE FOR UNCERTAIN ONE-CRITERION PROBLEMS

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Abstract: The interactive programming based on aspiration levels is a well-known approach applied to multi-criteria decision making under certainty (M-DMC). Nevertheless, recently, some evident analogies between M-DMC and scenario-based one-criterion decision making under uncertainty (1-DMU) have been revealed in the literature. These similarities give the possibility to adjust the interactive programming to an entirely new area. The goal of the paper is to create a novel procedure for uncertain problems on the basis of the interactive programming ideas. The new decision rule may be helpful when solving problems under uncertainty with partially known probabilities.

Keywords: one-criterion optimization, multi-criteria optimization, decision making, certainty and uncertainty, interactive programming, scenario planning, aspiration level, analogies.

1 INTRODUCTION

The goal of the paper is to create a novel procedure for uncertain problems on the basis of the interactive programming ideas. The interactive programming (IP) is one of the approaches applied to multi-criteria decision making under certainty (M-DMC). This type of optimization is related to the situation where the decision maker (DM) assesses particular alternatives (options, courses of action, decision variants) on the basis of more than one criterion. Criteria are usually conflicting. The IP is successfully used in the discrete and continuous version of M-DMC, but it in this paper we only investigate the first case.

So far, the interactive programming was used in multi-criteria problems: initially - under certainty [6], [10] and later – under uncertainty [11], [14] as well. However, it is worth emphasizing that thanks to some evident analogies (recently revealed in the literature [2], [3]) occurring between multi-criteria decision making with deterministic parameters (M-DMC) and scenario-based one-criterion decision making under uncertainty (1-DMU) there is a possibility to extend the applications range of IP, i.e. to adjust the interactive programming to uncertain optimization with one criterion. The IP in M-DMC consists in analysing objectives iteratively according to a pre-established order while the IP in 1-DMU will mean an iterative scenarios analysis where the sequence of considered scenarios is supposed to be defined as well. Such a concept differs significantly from existing decision rules designed for 1-DMU, but the novel idea opens new opportunities especially in the case of uncertain problems with partially known probabilities. The main advantage of the suggested approach is its flexibility.

The paper is organized as follows. Section 2 describes the original version of the interactive programming. Section 3 presents the analogies between M-DMC and scenario-based 1-DMU. Section 4 contains a description of the IP for scenario-based uncertain 1-criterion optimization. We focus on the interactive programming referring to aspiration levels. Section 5 uses an example to show how the novel approach may be applied to indicate the optimal pure strategy. Conclusions concerning the suggested procedure are gathered in the last section.

2 INTERACTIVE PROGRAMMING BASED ON ASPIRATION LEVELS

The interactive programming is regarded as a multi-criteria reduction technique [7], which means that it does not compute the entire set of optimal compromises, but instead interactively explores the Pareto set. One of the main advantages of interactive methods is the reduced computational effort, especially in the presence of many criteria, since it is not affected significantly by the dimension of the Pareto set. »In an interactive multiobjective optimization method, the DM specifies preferences progressively during the solution process to guide the search towards his/her preferred regions. (...) Only one or a small set of solutions which the DM is interested in is found. Thus the computational complexity is reduced and the DM does not need to compare many non-dominated solutions simultaneously.« [13]. Neverthelles, it is worth stressing that this aforementioned characteristic signifies that in the case of the IP approaches applied to the discrete version of M-DMC the generation of a ranking consisting of all the decision variants is impossible.

There are numerous varieties of interactive programming techniques designed for multiple objective decision making [10]. Therefore we examine only one IP algorithm in the paper. Shin and Ravindran [9] have divided IP methods into following groups: feasible region reduction methods, feasible direction methods, criterion weight space methods, trade-off cutting plane methods, Lagrange multiplier methods, visual interactive methods using aspiration levels, branch-and-bound methods, but within the last 30 years other approaches have been developed. They are discussed for instance in [5], [7] and [13]. In the article we investigate the concept related to the feasible region reduction. Additionally, Ravindran [8] distinguishes diverse interaction styles used in IP, such as the binary pairwise comparison, vector comparison, precise local trade-off ratio, interval trade-off ratio, but in this paper we concentrate on IP based on so-called aspiration levels. This tool has three essential advantages [6]:

- »It does not require any consistency of the DM's judgement,
- It reflects the wish of the DM very well,
- It plays the role of probe better than the weight for objective functions.«

The discrete IP algorithm explored here consists of the following steps:

1. Define the set of options $A=\{A_1,\ldots,A_j,\ldots,A_n\}$.
2. Define the set of criteria $C=\{C_1,\ldots,C_k,\ldots,C_p\}$.
3. Generate the payoff matrix.
4. Choose the first criterion to be analyzed (l=1).
5. Normalize the initial values connected with the first criterion (l=1).
6. Select the decision variants satisfying the first objective according to the normalized aspiration level declared by the DM (AL_1).
7. Move to criterion l=2 (subsequent elements of the objective sequence are established iteratively by the DM), normalize its values only for the reduced set of options (A^1) and select alternatives fulfilling AL_2. Follow the same procedure for criteria $l=3,\ldots,p-1$.
8. Select from the current reduced set of alternatives (i.e. A^{p-1}) the option (or set of options) performing the best criterion $l=p$. That is the compromise solution.

As we can observe, there is no need to normalize all the data in step 5 since after each iteration the set of possible alternatives changes and when it changes, maximum and minimum values within a given criterion may vary as well. Of course, the normalization is only required if the objectives are expressed in different units and scales. Note that if each initial value is transformed into a performance degree, it means that the aspiration levels also must be normalized.

3 ANALOGIES BETWEEN M-DMC AND 1-DMU

The structure of M-DMC is extremely similar to the structure of the scenario-based 1-DMU. This observation has been made for the first time by the author of this article and her conclusions have been formulated in [2], [3]. M-DMC is related to cases where the DM assesses particular alternatives in terms of many criteria (at least two). „Under certainty" signifies that the parameters of the problem are supposed to be known. The second area is connected with situations in which the DM evaluates a given option in terms of one objective function, but, for instance due to numerous unknown future factors, the parameters of the problem are not deterministic. Instead of that a set of potential scenarios is available. These scenarios may be defined by experts, decision makers or by a person who is simultaneously an expert and a DM. There are diverse uncertainty levels (uncertainty with known probabilities, uncertainty with partially known probabilities, uncertainty with unknown probabilities, uncertainty with unknown scenarios) [1], [12], but in this research we focus on uncertainty with partially known probabilities.

For both issues (M-DMC and 1-DMU), assuming that the discrete version is investigated, a payoff matrix can be generated (see Tab. 1-2): n – number of alternatives, p – number of criteria, $b_{k,j}$ – performance of criterion C_k if option A_j is selected, m – number of scenarios, $a_{i,j}$ – payoff obtained if option A_j is selected and scenario S_i occurs. Payoffs may represent efficiencies, profits, revenues, profitability, sale volumes etc.

Table 1: Payoff matrix for M-DMC

Criteria	***Alternatives***				
	A_1	$\cdots$	A_j	$\cdots$	A_n
C_1	$b_{1,1}$	$\cdots$	$b_{1,j}$	$\cdots$	$b_{1,n}$
$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\ddots$	$\vdots$
C_k	$b_{k,1}$	$\cdots$	$b_{k,j}$	$\cdots$	$b_{k,n}$
$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\ddots$	$\vdots$
C_p	$b_{p,1}$	$\cdots$	$b_{p,j}$	$\cdots$	$b_{p,n}$

Table 2: Payoff matrix for 1-DMU

Scenarios	***Alternatives***				
	A_1	$\cdots$	A_j	$\cdots$	A_n
S_1	$a_{1,1}$	$\cdots$	$a_{1,j}$	$\cdots$	$a_{1,n}$
$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\ddots$	$\vdots$
S_i	$a_{i,1}$	$\cdots$	$a_{i,j}$	$\cdots$	$a_{i,n}$
$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\ddots$	$\vdots$
S_m	$a_{m,1}$	$\cdots$	$a_{m,j}$	$\cdots$	$a_{m,n}$

When analysing both matrices we discover two main differences. First, within 1-DMU, if A_j is chosen, the final outcome ($a_{i,j}$) is single and depends on the real scenario which will occur. Within M-DMC, if A_j is selected, there are p final payoffs, i.e. $b_{1,j}$, …, $b_{k,j}$, …, $b_{p,j}$, since alternatives are evaluated in terms of p essential objectives. Second, in the case of M-DMC initial values usually have to be normalized as they represent the performance of different criteria. In 1-DMU the problem is related to one objective. Therefore the normalization is redundant.

Nevertheless, similarities between both tables are more visible - payoff matrices are extremely similar. In both cases there is a set of potential variants and the set of objectives in M-DMC can correspond to the set of scenarios in 1-DMU. Other analogies are given in [4].

4 INTERACTIVE DECISION RULE FOR 1-DMU

The observed analogy gives us the opportunity to adjust the interactive programming to a totally new area, i.e. to scenario-based one-criterion optimization under uncertainty with partially known probabilities. This uncertainty degree is differently described in the literature.

Usually it is connected with a decision situation where the probability is given as interval values (instead of punctual ones) or where the DM is able to order scenarios from the most to the least probable.

Note that the methodology will be similar, but the interpretation is going to be different. The Interactive Decision Rule (IDR) for one-criterion uncertain problems may consist of the following steps:

1. Define the set of options $A=\{A_1,\ldots,A_j,\ldots,A_n\}$.
2. Define the set of scenarios $S=\{S_1,\ldots,S_i,\ldots,S_m\}$.
3. Generate the payoff matrix.
4. Choose the scenario with the highest subjective chance of occurrence (l=1).
5. Select the decision variants satisfying the aspiration level declared for the aforementioned scenario by the DM (AL_1).
6. Move to scenario l=2 (subsequent elements of the scenario sequence are established iteratively by the DM), and select alternatives fulfilling AL_2 from set A^1. Follow the same procedure for scenarios $l=3,\ldots,m-1$.
7. Select from the current reduced set of alternatives (i.e. A^{m-1}) the option (or set of options) with the best payoff value within scenario $l=m$. That is the optimal pure strategy.

Let us briefly discuss the features of IDR.

First, when analysing the structure of the suggested algorithm, indeed, we can notice that the normalization step is not required, because the data representing payoff are connected with only one objective.

Second, within M-DMC, the order of criteria is determined by the subjective objective importance, while within 1-DMU with partially known probabilities the order of scenarios depends on their subjective chance of occurrence which is closely linked to the DM’s attitude towards risk, i.e. his or her state of mind and soul.

Third, in IDR the aspiration level has got a different interpretation than is the case of the original interactive programming. In M-DMC parameters AL are used to declare the decision maker’s requirements. He or she expects at least this level within a considered criterion. On the other hand, in 1-DMU diverse parameters AL are applied for particular scenarios since the payoff ranges related to each scenario may be diverse. Additionally, some scenarios can offer really unfavourable results and that is why in such cases the DM’s expectations should be lower. Of course, sometimes, if the payoff ranges are similar, parameters AL_i may be the same for each scenario since all the results are related to the same objective.

Fourth, in the last step a “pure strategy” is mentioned. Pure strategies are connected with situations where the DM selects and executes only one option. Their opposite are “mixed strategies”, i.e. combinations of several options. Mixed strategies are especially common in portfolio construction and cultivation of different plants.

5 EXAMPLE

Now, let us investigate a simple illustrative example in order to analyse the essence of the suggested procedure. We assume that the managing director of a company is searching an attractive location for a social event which is going to be held on a 20 April 202X (five potential places, step 1). The company tends to choose the place according to the number of participants which is a maximized criterion, but this number depends on diverse circumstances. That is why the company considers four possible scenarios (step 2). They are quite different since numerous diverse factors have been taken into account. Necessary data concerning the expected number of participants are given in Tab.3 (step 3). The degree of uncertainty is rather high as the social event will be held in six months and such events haven’t been organized by the firm before, so the managing director is only able to order the scenarios from the most to the least probable, but his opinion merely relies on subjective predictions.

Table 3: Payoff matrix (example)

Scenarios	***Alternatives***				
	A_1	***A_2***	***A_3***	***A_4***	***A_5***
S_1	5000	2000	4000	1000	6000
S_2	1500	1500	2000	1500	1000
S_3	10000	8000	11000	4000	9000
S_4	500	1000	0	1000	0

The decision maker sets the following scenario order: (S_2, S_1, S_4, S_3), which means that the scenario with the highest chance of occurrence is S_2 (step 4). The aspiration level (declared subjectively by the managing director) for the first considered scenario is equal to $AL_1(S_2)=1200$, which means that set $A^1=\{A_1, A_2, A_3, A_4\}$, step 5. Within step 6 we perform the same procedure for scenarios S_1 and S_4. The DM has noticed that the payoff range connected with scenario S_1 is larger and higher than it was for scenario S_2. Therefore, he will be satisfied with a number of participants equal to at least $AL_2(S_1)=2000$. This condition is not met by alternative A_4, thus $A^2=\{A_1, A_2, A_3\}$. Scenario S_4 is really unfavourable, so the managing director, in this case, would be satisfied with 400 participants: $AL_3(S_4)=400$, which entails another reduction of the set of alternatives: $A^3=\{A_1, A_2\}$. Now, we can move to step 7 since scenario S_3 is the last to consider. Within set A^3 location A_1 is related to a larger number of participants (10000>8000) than location A_2. Therefore the managing director should select the first location (A_1) – this is the optimal pure strategy recommended by IDR.

As a curiosity we can compare the IDR solutions with existing classical decision rules recommendations. The basics of these procedures are explained for instance in [3]. For the Bayes rule A_1 and A_3 are the best. For the Wald rule – A_2 and A_4. According to the max-max rule A_3 should be chosen. The Hurwicz rule indicates: A_3 for high and mid optimism coefficient values; A_1 for low values of this parameter; A_2 and A_4 for extreme pessimists. The Savage rule suggests A_1. Solutions are diverse, but as a matter of fact it is a normal phenomenon, because each decision rule is designed for different types of decision makers.

Note that IDR is a procedure developed for one-shot decisions, i.e. for decisions performed only once. If the DM considers executing one of the analysed alternatives in the future, it is advised to follow the procedure one more time, because the decision maker's attitude towards the problem could change.

6 CONCLUSIONS

The goal of the paper was to adjust the original version of the interactive programming initially designed for multi-criteria decision making under certainty to a totally new domain, i.e. 1-criterion decision making under uncertainty. The novel interactive decision rule (IDR) is technically very similar to the initial version, but the interpretation of particular steps is often different. Within the original interactive programming criteria are ordered according to their importance while within the suggested approach the scenario sequence is established on the basis of the subjective chance of occurrence.

Note that the comparison between the proposed procedure and classical decision rules is not possible since each method is based on different assumptions resulting from different DM's preferences and state of soul/mind.

It is also worth emphasizing that sometimes the interactive programming for multiple criteria problems is used under the assumption that all the aspiration levels are declared at the beginning of the decision making process. Such a possibility also exists in the case of 1-criterion uncertain problems, but we ought to be aware of the fact that under such circumstances the solved problem may be a problem with an empty feasible region. That is why it is recommended to estimate the aspiration levels sequentially in both analogical techniques.

IDR has some essential advantages. First, it does not require the payoff normalization. Second, it can be applied by any kind of decision maker (optimism, pessimist, moderate) since each DM is allowed to set the scenario sequence individually. Third, it does not require the use of precise probabilities. Fourth, it gives the possibility to sequentially analyse scenarios while classical decision rules assume that the whole information on the DM's preferences is declared at the beginning of the decision making process. Thus, IDR is definitely more flexible.

In an extended paper it would be desirable to verify the possibilities to adjust the initial multiple-criteria interactive programming to 1-criterion decision making under uncertainty for optimal mixed strategies searching as well as to multi-criteria decision making under uncertainty. Of course, approaches for the second proposed area are already described in the literature [11], [14], but the author's intention is to maintain the interactive character for scenarios, not for criteria.

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THE DYADIC ANALYSIS OF THE IMPACT OF CONFLICT-HANDLING STYLE ON NEGOTIATION OUTCOMES IN SOFTWARE SUPPORTED NEGOTIATIONS

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Abstract: This research aims to analyze the cause-effect relationships between the behavioral characteristics of participants of electronic negotiation experiments and the results they obtained. The core of the behavioral characteristics is built by means of the parameters describing the conflict-handling mode defined by the Thomas-Killman Instrument. As part of the study, the concepts of negotiation and conflict resolution style were first defined. Then, based on the data collected in the Inspire electronic negotiation system, a quantitative analysis was carried out using the Actor-Partner Interdependence Model. Finally, the clustering analysis was used to derive general conclusions regarding the most efficient mixes of styles of both parties that may assure them the highest possible outcomes,

Keywords: electronic negotiation, Thomas-Kilmann Inventory, conflict-handling style, Actor-Partner Interdependence Model

1 INTRODUCTION

The negotiation and negotiation analysis theory univocally underlines the impact of many behavioral and formal elements of the negotiation on its conduct and results [7, 15]. Among the former, the conflict-handling style is perceived to play a critically important role in affecting the negotiators' behavior, a strategy they use (including the concession strategy), a way they communicate their needs and positions, etc. [10, 14, 15]. However, the recent development of information technology makes more and more negotiations, mainly those related to contracting in the supply chain management, be moved to the Web. There, the negotiations are supported by purposely designed and tailored electronic negotiation systems (eNS) [5]. However, the use of such systems may question the impact of some behavioral characteristics of negotiators on the negotiation process. For instance, non-verbal communication becomes meaningless if eNS allows only for exchanging written messages and no video communication is possible. Similarly, the impact of conflict-handling styles may be diminished or even quashed. Therefore it seems vital to study the effects of behavioral issues on electronic negotiations.

Some earlier studies have focused on analyzing the presence of conflict-handling characteristics in electronic negotiations. Zaremba and Kersten analyzed the conflict style subjectively perceived by negotiators and their counterparts and its impact on their outcomes and differences in outcomes [17]. However, their analysis was asymmetric, i.e., no simultaneous impact of these characteristics describing both negotiators was included in the analytic model. What is more, the style was defined subjectively and directly by the negotiators, with a single-item questionnaire, which could affect their results significantly. In another study, Brzostowski and Wachowicz [2] focused on building a comprehensive mechanism for identifying the negotiator's profile in eNS that hybridizes the speech act theory, communication styles, and bargaining styles. They emphasize the meaning of the bargaining styles in electronic negotiations; however, they do not conduct any empirical analysis to show its true impact neither on the negotiation process nor on the electronic negotiation results. Roszkowska, Kersten, and Wachowicz [13] analyzed the impact of various motivational systems (including social motivation, which addresses the conflict handling style) on the accuracy of prenegotiation preference elicitation in eNS to determine the scoring systems necessary for reliable decision support in negotiations. Again, the authors' approach is asymmetric as the focus is the individual scoring system and its discordance with the true preferences of the negotiators or their principals.

Therefore, the purpose of this paper is to empirically verify the causal relationship between the conflict-handling style and the results obtained in electronic negotiation. We analyze the data from the series of bilateral negotiation experiments conducted in Inspire electronic negotiation system [6]. In our analysis, we operationalize the conflict-handling style using the Thomas-Kilmann Conflict Mode Instrument (TKI) [8]. An impact of conflict-handling styles defined this way on the negotiation outcome would be analyzed using the symmetric approach through the Actor-Partner Interdependence Model (APIM) [3]. This would allow measuring how the elements of the style of the negotiator and her counterpart simultaneously affect the negotiator's outcome as well as the outcome of her counterpart.

In section 2, the concept of the Thomas-Kilmann Inventory and the principles of the APIM model will be described, respectively. Section 3 is focused on the experimental setup. The results of our experiments are discussed in Section 4. We conclude with a short summary.

2 METHODOLOGY

2.1 Conflict handling style

From the viewpoint of experimental economics and - in our study - negotiation analysis, the key important issue is to find a reliable way of identifying conflict-handling style for a particular decision-maker or negotiator as a potential predictor. Various psychometric tools have been developed to measure conflict-handling styles base on the respondents' self-reported questionnaires [4, 8, 12]. Among them, the Thomas-Kilmann Conflict Mode Instrument [8] was developed, which seems to be one of the most frequently used tests examining the style of conflict resolution. Unlike many other psychological tests (e.g. the Emotional Intelligence Test [11]), it is generally available and does not require any formal training in psychology.

Based on the approach proposed in TKI, the conflict handling style can be defined as a set of methods, rules of conduct and behaviour belonging to every human being, the aim of which is resolving the conflict as quickly as possible to obtain specific benefits. TKI is designed in the form of a questionnaire consisting of 30 questions, each consisting of a pair of sentences describing particular behaviour in a conflict situation. Each sentence indicates behaviour from one of five possible modes: avoiding; accommodating; compromising; competitive; and collaborating. The scoring rule adds the answers of respondents within each mode, and hence the profile is built as a vector of quantitative scores reflecting the intensity of each mode in a general conflict-handling style.

2.2 Dyadic analysis using Actor-Partner Interdependence Model

The Actor-Partner Interdependence Model [3] focuses on two main components - actor effect and partner effect. In the APIM, the actor effect aggregate allows describing the cause-and-effect relationships between the behaviour of the examined person and the decisions it makes. The value of the partner effect coefficient, in turn, is to define the influence that the other party's attitude to a given social phenomenon (e.g. a negotiating partner) has on the behaviour of the examined person.

In Fig. 1, the APIM-based model is presented.

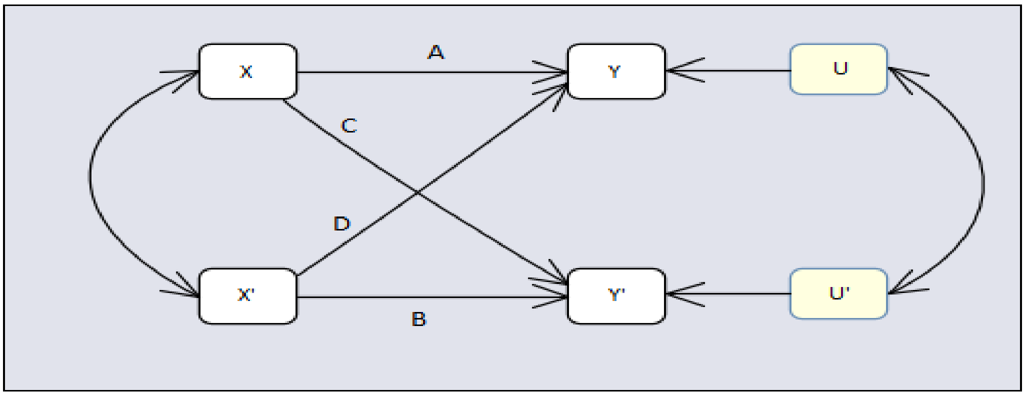

Figure 1: The actor–partner interdependence model (APIM)

The blocks Y and Y' represent the values of the examined features (e.g. the rating of the agreement concluded by negotiators), while the vectors of explanatory variables (e.g. the Thomas-Kilmann test characteristics) are marked with the values of X and X'. The single-ended arrows indicate cause-and-effect relationships occurring in the analyzed phenomenon. The actor effect is measured by the potential relationships identified as A and B, while the partner effect – by C and D. The APIM models also contain a random term component represented as blocks U and U'. An important element of APIM is also the correlations between the explanatory's and explained variables. The measurement of the existing correlations makes it possible to determine whether one of the analyzed variables significantly affects the values of another, and thus, during modeling, additional dependencies should be taken into account.

3 EXPERIMENTAL SETUP

All the analyses described below are based on data collected in the Inspire system [6], in which a series of bilateral negotiation experiments were carried out in 2014-2016. Participants were students playing the role of agents representing the interests of their principals in the negotiations between a musician (Ms. Sonata) and an entertaining company (World Music). Before starting negotiations, each participant got acquainted with the case description and determined the rating system used by the system to provide the decision support to the parties and evaluate each negotiation offer that could be exchanged while bargaining.

Before conducting the proper part of the statistical analyses, the collected data was pre-processed. Based on a detailed verification of the assumptions underlying the negotiations conducted by the agents representing Ms. Sonata and the World Music, the following three criteria were distinguished, the occurrence of which meant that a given data record should not be used in the analysis:

- Misinterpretation of the principal's expectations (e.g., recognition that the lowest amount of the bonus is the most favorable for Ms. Sonata);
- Data gaps (e.g., user did not complete a conflict resolution style survey);
- Outliers in the rating system constructed (e.g., assigning a weight of 0.8 to the issue, which most participants evaluated as 0.6).

It is also worth mentioning that all the analyses described in the following study concern only those negotiators for whom the negotiation experiment ended with an agreement. The analysis of differences between the conflict resolution style of people who ended the experiment with an agreement or the lack of a final agreement exceeds the substantive scope of this document. Finally, after carrying out the necessary data selection, the final set of observations consisted of 566 records.

The participants of the analyzed negotiation experiments were mainly the students from three countries: Poland, China/Taiwan and Austria. The criterion for selecting individual participants for the research sample was participation in academic negotiation courses. Although such an approach implies the risk of potential non-representativeness of the research sample, it should be noted that many discoveries in the field of social psychology were based precisely on research conducted on university students [1].

4 RESULT

According to the assumptions presented in Section 2, the first action that was taken to construct the APIM model was the specification of the following elements:

- aggregates describing the conflict-handling style of both negotiation parties to define the vectors of predictors X and X';
- ratings of agreements achieved by the negotiators (Y and Y').

Having estimated the APIM model, it turned out that the only mode that significantly impacts the negotiators' results (p<0.05) was the ***competitiveness*** of the actors who represented the World Music party. Unfortunately, the existence of an analogous relationship for the representatives of Ms. Sonata was not confirmed (β=1.2, p=0.57). Therefore, it cannot be generally confirmed that there is any actor effect for this element of the negotiation style.

The differences in the statistical significance of the aforementioned causative paths seem to be role-dependent. Such results prove that during a bilateral negotiation experiment, the trait of a competitive person representing the World Music (the contract seller) significantly influences the rating of the negotiated contract. In the case of negotiators representing Ms. Sonata (buyer), the competitive feature does not significantly affect the quality of the negotiated agreement. This suggests that the contextual aspect of the negotiations plays a significant role in shaping the potential influences between the behavioral characteristics of the parties and the results they obtain.

Table 1 summarises the results describing the five most important features and their impact on outcomes in our model.

Table 1: Most important APIM Feature's

Feature	**Impact direction on the rating of**	**β - value**	**Estimate error**	**p-value**
World Music accommodation (X1)	World Music (Y)	-0.60	0.43	0.170
World Music accommodation (X1)	Ms Sonata (X)	-2.23	1.75	0.200
World Music competitive (X2)	World Music (Y)	1.04	0.48	0.029
World Music avoiding (X3)	World Music (Y)	-0.60	0.49	0.220
Ms. Sonata collaboration (X'4)	World Music (Y)	2.15	2.01	0.280

Since the APIM model did not produce many extensive findings, we applied a different dyadic approach to reduce the granularity of the data. The negotiators were divided into relatively homogeneous subgroups, representing specific classes of conflict resolution styles. The criterion for classifying records into individual subgroups was based on a combination of all the characteristics determined by the Thomas - Kilmann test, and the grouping itself was performed using Ward's hierarchical method [16].

As a result, all the negotiators were divided into three homogeneous subgroups. The numerical values shown in Table 2 represent centroids for the clusters' styles. It is worth noting that the distributions of each given characteristic differed significantly from those in other clusters (p<0.05, for Mann-Whitney U test).

Table 2: Average values of the Thomas - Kilmann test characteristics in individual clusters

	Competing	**Collaborating**	**Compromising**	**Avoiding**	**Accomodating**
Cluster I	6.08	6.53 *	7.17 *	6.56 *	3.58 *
Cluster II	5.60 *	5.19 *	5.97 *	6.17 *	6.76 *
Cluster III	6.67 *	6.46 *	7.42 *	4.37 *	5.01 *

Then, to verify whether people belonging to specific clusters achieve better or worse results depending on the partner's conflict-handling style, the average ratings obtained by negotiators for each mix of individual clusters were calculated. The full results of the performed analysis are presented in Table 3. The values (X; Y) in each cell represent the arithmetic mean of the results that the person representing World Music (X) and Ms. Sonata (Y) obtained in a given pair, respectively, and N is the number of pairs assigned to the cluster combination.

Table 3: Average ratings for negotiators representing a given negotiating style

	Ms Sonata Cluster I	**Ms Sonata Cluster II**	**Ms Sonata Cluster III**
World Music cluster I	(79.28;74.41) N = 46	(79.42; 74.19) N = 36	(81.97; 72.61) N = 37
World Music cluster II	(77.07; 72.1) N = 28	(78.83; 68.11) N = 18	(76.18; 78.29) N = 16
World Music cluster III	(77.0; 76.09) N = 42	(75.21; 75.5) N = 33	(75.67; 79.7) N = 27

In order to verify whether the negotiators representing the interests of Ms. Sonata and World Music obtained significantly different results depending on the cluster to which both sides of the experiment were classified, the Mann-Whitney test [9] was also carried out.
The result of the analysis was the detection of the following statistical relationships:

- World Music representatives from cluster I usually obtained higher ratings than negotiators from cluster III, regardless of the partner cluster ($p<0.05$);
- Ratings obtained by representatives of Ms. Sonata from cluster III weakly dominated the results obtained by clusters I and II, regardless of the partner cluster ($p<0.1$). That is, they were not significantly worse if the counterpart revealed the style from cluster I (72.61 vs. 74.41 and 74.19), and significantly better for World Music clusters II and III;
- World Music's representatives obtained, on average, higher ratings than their colleagues negotiating on behalf of Ms. Sonata ($p<0.05$).

5 DISCUSSION AND CONCLUSIONS

The aim of the above study was to verify the cause and effect relationships between the style of conflict-handling and the result of electronic negotiations. Therefore, the preceding chapters of this paper focused on explaining the concept of the style of conflict resolution and the theoretical description of the implemented statistical methods.

The practical part of the document describes the results of the modeling carried out. Although the results obtained from the APIM model are not spectacular, reducing the granularity of data and moving to the cluster-based analysis allowed us to conclude that there is a relationship between the style of conflict resolution and the outcome of negotiations conducted electronically. However, this relationship seems to be weaker than during traditional negotiations [15].

During the analysis, it turned out that the people representing the World Music party achieved, on average, better results than the representatives of Ms. Sonata. Additionally, the representatives of Ms. Sonata characterized by high values of compromising and competing modes, achieved on average better results than the other representatives of Ms. Sonata.

It seems that in order to fully understand the relationships between human behavioral features and the result of electronic negotiations, additional research should be conducted in the future, requiring, among others:

- Collecting a larger set of input data; thanks to which model should be more stable;
- Applying additional algorithms (e.g., random forests or neural networks);
- Extending the set of explanatory variables of additional behavioral and demographic characteristics (e.g., nationality, gender, emotional intelligence).

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Session 8:
Problems Approaching OR

COMPARATIVE ANALYSIS OF DECISION TREE METHODS FROM TWO SCIENTIFIC FIELDS

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Abstract: There are two methods called a decision tree. One belongs to the field of decision making in uncertainty and risks (UR), and the other belongs to the field of data mining (DM). Researchers, practitioners, and students often mix those methods or think that there is only one method. There are several goals of this paper. The first goal is to present the basics of both methods in one place. The presentation is given in the paper by explaining the methods through their elements, procedures, and demonstrations on simple examples. The second goal is to give a comparison of the methods. The comparative analysis is implemented respecting several comparisons criteria and identifying the similarities and differences between the two methods. The third goal is to analyze and demonstrate the possibilities of combining the two methods. Since the UR decision tree can be observed as an extension of the DM decision tree, the natural combination of methods is that outputs of the DM decision tree are inputs for the UR decision tree. The paper contains a short demo example of how to combine those two methods.

Keywords: decision tree, decision making, risk, data mining, machine learning, uncertainty

1 INTRODUCTION

Data analytics is used in the 21st century as a valuable tool for solving problems and assisting in decision making to a competitive strategy. It became one of the essential verticals within organizations due to its potential benefits, including making better decisions [1]. Decision tree methodology is used in both data analytics to develop predictive models in data mining (DM) and decision making as a method for decision making under uncertainty and risks (UR).

A UR decision tree is a visual model consisting of nodes and branches. The basic idea is to describe possible paths representing choices followed by events of different probabilities to occur. The choices are in control of the decision-maker, but events are not. The selection of optimal decisions is based on probabilities and values on decision paths. The DM decision tree is a widely used methodology in data mining to develop classification and prediction models. This method deals with past data and classifies samples into branch-like partitions that develop an inverted tree with a root node, internal nodes, and leaf nodes [2].

Researchers and practitioners often mix those methods. To date, there has been no research critically addressing this issue. We address this gap by providing answers to two questions. The first question is related to identifying the differences between two decision tree approaches. The second question is related to exploring the possibilities for combining the two approaches. In Section 2 and Section 3, both decision tree methods are presented and demonstrated. In Section 4, the methods are compared, and in Section 5, the methods are combined into a single approach demonstrated in the demo example.

2 DECISION TREES IN DECISION MAKING

2.1 Context and purpose

In decision making under risks, the decision-maker must decide on a particular issue at a specific moment, but the consequences of the decision will be visible in the future. When a decision-maker plays a lottery, it has to select numbers they will play, and the result (the success of the decision) will be visible later when the selection of the numbers happens.

A simple example is presented in Table 1. The decision-maker must make a decision: *Should I take an umbrella or not?* The decision is made based on previous information about rain probability. They have two choices, and there are two possible events related to the weather that is not under their control. Of course, here we talk about when the decision-maker must decide for the future, not the current situation (ex. later, when (s)he will go home from work).

Table 1: Decision making problem

	It's raining (70%)	It's not raining (30 %)
Take the umbrella	:-)	:-(
Not to take the umbrella	-(	:-)

In most cases, the decision-making problem under risks is additionally characterized by the fact that none of the alternatives entirely dominates over all others to all events. Here, both options, in one case, bring something good and in some other something wrong.

2.2 Basic terms

Elements of the decision tree in decision making are (i) node of the decision, (ii) node of the event, (iii) alternative, (iv) probability, (v) profit or loss. They are presented in Table 2.

Table 2: Elements of decision-making decision tree

DT element	Label	Definition
The node of the decision	□	The place in the decision tree in which decision-maker has to select one of the alternatives that leave the node.
The node of the events	○	The place in the decision tree in which one of the alternative that leaves the not, but it is not under the decision maker's control which one is going to be.
Alternative	———	Options that are available to the decision maker when he has to make decisions; or events that might occur in some risky situation.
Probabilities	Values above the lines that leave the node of the events	Probabilities that particular alternative leaving the node of events will occur.
Profit/Loss	Values under the lines of alternatives	Income that is achieved if a specific alternative occurs or outcome that should be paid if a specific alternative would occur.

In most cases, we talk about the problems that are somehow related to business and money. Therefore, one of the main elements is profit/loss. Speaking more in general, we can rename this element to *consequences* that is the broader term. In the case of an umbrella dilemma, consequences are expressed by using emoticons, suggesting the decision maker's satisfaction if (s)he selects some alternative, and a specific event occurs.

2.3 Steps of algorithm

The algorithm of the decision tree method will be explained using the example presented in section 2.1. The decision tree for the example is illustrated in Figure 1.

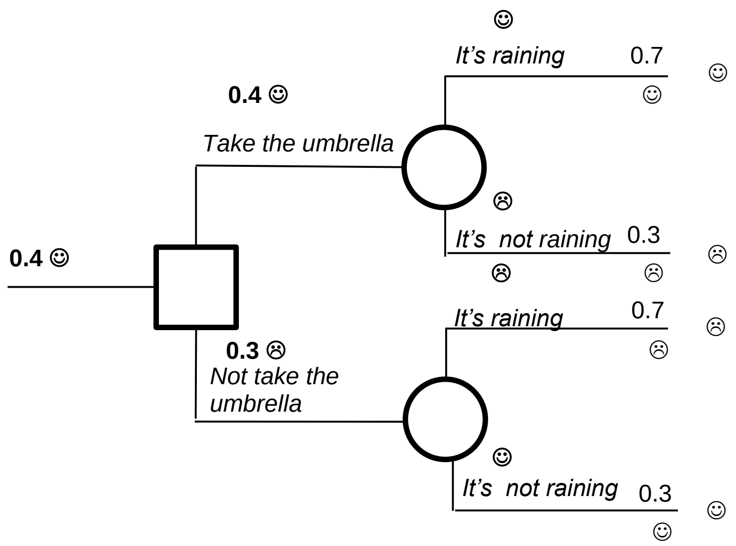

Figure 1: Decision tree in decision making under uncertainty and risk

There are the following steps that need to be performed to provide a decision tree for decision making under risk [3]:

- Development of graphical, logical model, i.e., decision tree with input data: In the first step, the context of the decision-making problem must be drawn using the five basic elements. The tree is drawn from left to right, respecting the timeline of activities. First, we have to draw the decision node about taking the umbrella. Then, we draw the possibilities that may happen in terms of weather conditions – it cannot be vice versa. Additionally, in this step, we insert all the numeric data into the figure and calculate the values of the final nodes (ends of the lines at the right side of the tree, in some software, the final nodes are drawn as triangles, see Figure 3).
- Calculation expected values of a decision based on rollback algorithm: In the second step, we apply rollback algorithm – for each alternative, we calculate the expected value (EV) (bolded values): (1) EV of the finale alternatives are equal to the values of finale nodes (in our case we have four finale alternatives); (2) EV of the alternatives that are placed before (left from) node of the event is calculated using the expected value formula (sum of products of probabilities of each alternative leaving the node of events and expected values of that alternative) (in the case, we have two such cases, ex. EV(*take the umbrella*) = 0.7 ·☺ + 0.3 · ☹ = 0.4 ☺); EV of the alternatives that are placed before (left from) node of the decision are calculated by determining the maximum expected value of alternatives leaving the node of decision (in our case, there is only one such the alternative – in the root of the tree).
- Determining the optimal path in the decision tree: Finally, we make the decision. In our case, the decision is to take the umbrella (respecting higher EV)

3 DECISION TREES IN DATA MINING

The data mining field deals with the discovery of new, valuable knowledge about the problem domain. A decision tree is one of the methods used for prediction and classification. Decision trees or classification trees are usually used for solving classification problems. There are several types of classification tree models. Chi-Squared Automatic Interaction Detection (CHAID) and Classification Trees (CART) are frequently used for solving classification problems [4]. Although the decision trees are usually used for solving classification problems (in which the outcome variable is discrete), they can also be used when the outcome variable is continuous.

3.1 Context and purpose

A data analyst collects data about the past and develops a predictive model to predict future events on new, unseen data. The decision tree is used as a method for graphical representation of the influence of input variables on output variables. The decision tree algorithm solves the classification problem by partitioning the data into "clean" subsets according to the input values. Variables that can achieve the cleanest separation have a significant influence on the output variable. Such variables are placed at the root node of the tree and closer to the root. The resulting model has the tree structure and is used in the prediction of new unlabeled data. Such trees are based on data, not on an expert's decision, and the algorithm obtains the model. There are several algorithms developed depending on types of variables included in past data (e.g., CART, C4.5, ID3,..)

3.2 Basic terms

Decision tree terminology is very much like actual trees except that decision trees are upside down: Roots of decision trees are at the top, and leaves are at the bottom. Each node represents one variable, at the edges of which "child-nodes" are marked for each possible value of an input variable. Node branches form decision rules.

3.3 Steps of algorithm

Table 3 depicts raw training data of class spam and ham emails concerning the suspicious words and images that those emails consist of and the familiarity of the sender. We illustrate decision tree induction with an example using the described dataset.

Table 3: Data mining problem

Suspicious words	Unknown sender	Contains image	Class
True	False	True	Spam
True	True	False	Spam
True	True	False	Spam
False	True	True	Ham
False	False	False	Ham
False	False	False	Ham

There are the following steps that need to be performed to provide a decision tree in data mining:

- For every candidate input variable (*Suspicious words*, *Unknown sender, Contains image*), assess the best way to split the data into two or more subgroups
- Select the best split and divide the data into the subgroups defined by the split.
- For all subgroups, repeat Step 1 (this is the recursive part of the algorithm).
- Continue splitting and splitting until all records after a split belong to the same target variable value until another stop condition is applied.

The determination of best can be made in many ways, but regardless of the metric, they all provide a measure of the purity of the class distribution. Every input variable is a candidate for every split, so the same variable could, in theory, be used for every split in a decision tree. In this paper, we have calculated information gain for each variable to find the best splitting one. Considering the training data mentioned above, the decision tree constructed using this algorithm is depicted in Figure 2.

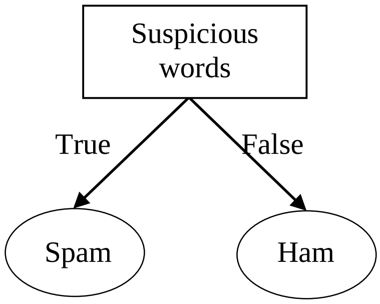

Figure 2: Decision tree in data mining

From Figure 2, the root node is the *Suspicious words*. The tree starts as a single node containing the training samples. Then the splitting criterion, which includes the threshold values check, namely, exception threshold and classification threshold, is applied recursively to grow the tree. Eventually, priority is also assigned for every node based on its level in the tree. Spam and ham (values of class variable) are in the leaf node. IF Suspicious words are *true* THAN Class is Spam is one branch forming decision rule.

4 COMPARISON OF THE METHODS

Decision trees in decision making and decision trees in data mining are compared based on the seven criteria presented in Table 4. Those criteria are method domain, the goal of the method, elements, modeling consequences, inputs, outputs, and memory requirements.

Table 4: Comparison of decision trees

Criteria	**DT in decision making**	**DT in data mining**
Method domain	Uncertainty and risks.	Predictive modeling.
The goal of the method	Make the optimal decision or set of decisions	Predict the future of one aspect
Elements	Nodes of decisions and nodes of events.	Nodes of events.
Modeling consequences	Yes.	No.
Inputs	Decision nodes and alternatives, event nodes and consequences	Two or more independent variables, one dependent variable.
Outputs	Set of decisions.	Predictive model.
Memory requirements	Small requirements.	Medium requirements, except in the case of big data.

DM decision tree develops predictive models intending to predict the future [5]. It is impossible to model consequences in the DM decision tree, whereas the UR decision tree enables this feature. The UR decision tree is based on subjective estimations of experts [6]. The UR decision tree can be considered as an extension of the DM decision tree. The UR decision tree can analyze a much broader context than the DM decision tree, and the DM decision tree can serve as an inputs method for building parts of the UR decision tree.

5 COMBINATION OF THE METHODS – DEMO EXAMPLE

The previous section concluded that the DM decision tree could serve as a method for giving inputs, primarily regarding probabilities for different events. In the following text, we provide an example to demonstrate the idea of combining two decision trees. The example is not real; it describes the context, which is very simplified.

The State considers opening a special department that will deal epidemic of the Virus in the State. The hospital will analyze patients considering two symptoms (B and C), and based on them, it will determine if the patient is positive (A) or negative (not A). However, a specific patient can be proclaimed as positive, even though negative, and vice versa. In Table 5, we have the historical data about the patients considering their symptoms and final results about patients' states (only the part of the historical data is presented, enough to get the idea). The results can be the following: (1) patient is positive, and hospital declared the patient as positive; (2) patient is positive, but the hospital declared the patient as negative; (3) patient is negative, and hospital declared the patient as negative, and (4) the patient is negative, but the hospitals declared them as positive. If the hospital declares the patient as positive, the patient goes into quarantine, and since the person is not productive, we can find this situation a loss for the State -2000 (*A*). If the hospital declares the patient negative, and the patient is negative, there is no loss (*not A*). Finally, if the hospital declares the patient negative, but the patient is positive, the State faces the loss estimated to -6000 (the false negative person will infect other persons, *not A*, *but A*). If the State does not open the department (and announces some restrictive measures), it will face a loss of 5000 per capita. On the other hand, establishing the department will cost 1000 per capita.

The question is: Is it affordable for the State to open the department or not?

To answer the question, we will combine two decision trees methods:

- DM decision tree will focus only on one aspect: it will be used to analyze the hospitals' success, respecting the historical data about the patients and hospital's decisions. From the historical data about the patients' states and the hospital's success, the DM decision tree will generate the rules presented in Table 6.
- UR decision tree will model the whole problem, including both aspects here: the decision to open the department (include all costs) and the success of the hospital's work. In addition, the aggregation of both aspects is now possible.

Table 5: Historical data (part)

B	C	Results
1	1	A
0	1	not A
1	1	not A
1	1	A
1	1	A
1	0	A
0	0	not A, but A
1	0	A
0	1	not A, but A
1	0	not A, but A

Table 6: Rules (DM decision tree)

	p	A	not A	not A, but A
B and C	0,4	0,5	0,25	0,25
B and not C	0,2	0,4	0,1	0,5
not B and C	0,2	0,4	0,5	0,1
not B and not C	0,2	0,1	0,7	0,2

The final decision tree is presented in Figure 3. By using the UR decision tree, we can (1) decide on the covid department opening; (2) make some other decision if the costs are too high (e.g., total lockdown). The combination of the methods will allow us to track the situation and adjust to the current situation. Additionally, in problem can include more decisions, and the UR decision tree will allow modeling all those aspects. It is also possible that some of the aspects include additional DM decision tree analysis of totally new data. Ex. We can expand the example by adding aspects about deciding on compulsory vaccination and its influence on patients. While the whole problem can be analyzed by the UR decision tree, modeling all four aspects, inputs for the department's success and vaccination success can be gathered by the DM decision tree.

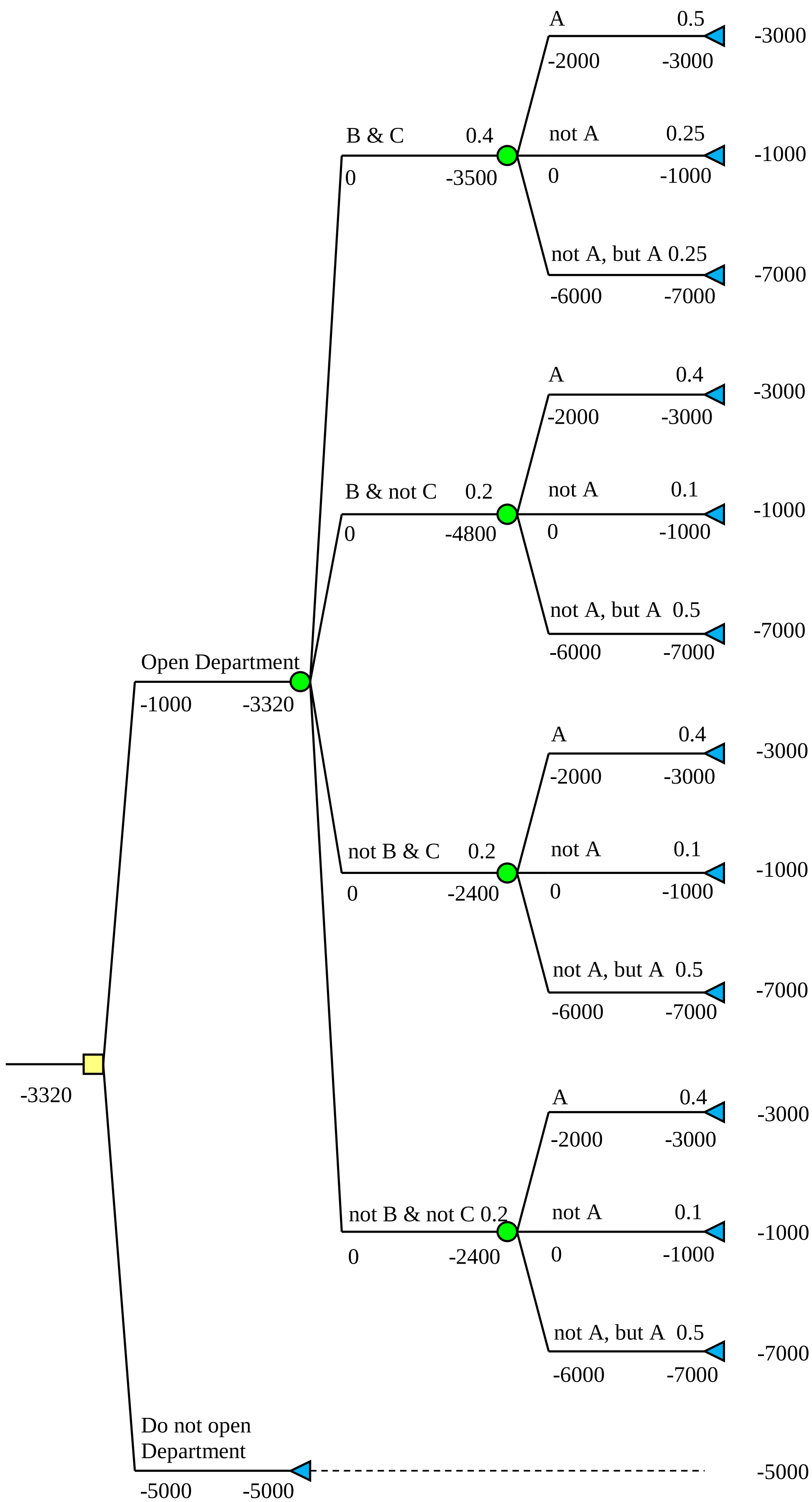

Figure 3: UR decision tree (TreePlan Student Licence)

The advantages of the proposed approach are:

- It combines the development of models by applying data mining techniques and supplements the model through decision-making decision trees.
- Instead of recognizing the probabilities for the UR decision trees, probabilities are generated by applying DM decision tree algorithms and presented to decision-makers following explanatory principles.

6 CONCLUSION

Since many practitioners often mix decision trees from two fields, we have provided an in-depth analysis of both approaches and identified differences between them in this paper. Those two methods can be combined: Data mining decision tree can serve as input for a decision tree in decision making when data about the problem domain exists. This approach would eliminate subjectivity and allow modeling consequences simultaneously.

In today's data-driven world, decision making methods enhanced with the application of data mining could provide an essential capability that every organization should strive to. Some of the previous research papers recognized that idea but used different methods for various purposes: e.g., cluster analysis and ANP [7], fuzzy logic, and decision making [8]. Data mining methods such as decision trees could provide support to existing decision-making methods to be efficient and effective on that path. In future research, we will demonstrate the application of the proposed framework to a real-world problem. Additionally, the combination of two methods can be followed by sensitivity analysis that can act as strong risk analysis tool for the problem that is observed: we can observe how the decisions in UR tree is changing depending on the change of the probabilities in the model and define corrective or agressive measures, depending on risk analysis results.

Acknowledgment

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COMPUTATIONAL ANALYSIS OF THE MUSICAL DIVERSITY IN 22 EUROPEAN COUNTRIES

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Abstract: We present the preliminary results from our cross-cultural study in which we use our data comprising 2,184 songs from three genres (folk songs, children's folk songs, and children's songs) from 22 European countries. The very first results have shown dissimilarities in music between countries, despite the fact that music from these countries is often considered to be a 'single corpus of musical style'. Differences were found also between all the three musical genres from the perspective of the use of musical features and dimensions in these genres.

Keywords: musical diversity, IDyOM, European countries.

1 INTRODUCTION

Music is an art of sound and time, a phenomenon, traditionally studied in the arts and humanities. With the rise of computers, from 1950 on, a variety of opportunities for applying artificial intelligence (AI) is seen also in the domain of music, e.g., to explore computational techniques for the simulation of human behaviour, to simulate the processing of music, or to compose music with a (semi)automatic approach. With the increased availability of huge corpora comprising thousands or even millions of musical examples, computers have shown to be particularly efficient in the automatic analysing of music diversity between and within musical cultures. In this paper, we present our preliminary findings of the (dis)similarities in music between European countries. For this task, we have compared the musical cultures from 22 European countries, using our data, comprising 2,184 songs from three different musical genres, folk songs, children's folk songs, and children's songs. We have employed the probabilistic computational model of auditory expectation, Information Dynamics of Music, IDyOM[1], in detail described in [9], which has shown to be a good quantitative model of cultural distance.[2] We tested if and how the three genres between countries differ from the perspective of the use of musical features in musical structure with MANOVA. We conducted K-means and hierarchical cluster analysis, with the purpose to reveal the relations between 22 European countries and their presumable (dis)similarities in musical culture.

2 IDYOM

When applying AI in music, a proper 'communication' has to be established between music and computers, i.e. the sound has to be 'captured', which can be done, for example by symbolic representations of notes or other musical events, or by audio representations of acoustic sound waves. In IDyOM, the musical input is represented symbolically, as the model cannot process dynamic, timbral, or textual changes. After importing musical examples in ** kern or MIDI format, IDyOM, being exposed to a corpus of music, learns incrementally about the musical syntactic structure and its sequential regularities. The likelihood of the appearance of an event in a sequence of events is determined in the form of a *probability distribution*, in which to each

[1]https://github.com/mtpearce/idyom/wiki

[2]In this paper, the term "model" refers to IDyOM as an analytical tool for testing the diversity in music, and to IDyOM as a computational program.

forthcoming event a probability is assigned, based on the preceding musical context and the prior musical knowledge (experience) of the model. The uncertainty of the prediction before the next event is heard is measured with *entropy.* If every continuation of events is equiprobable, entropy will be maximum and the prediction uncertain, and vice versa, if the probability of an event is high, entropy will be low, and the prediction very certain. After the event happens, it can have a high probability (expected event) or low probability (unexpected). The unexpectedness of an event is measured with the *information content* (IC), which is compared to entropy, numerically more stable (in terms of compressibility) [2]. As the problem of the modeling of music can be understood as a 'sequence learning problem', analyzed and modeled are the sequences of events (in our case melodies, containing notes), where each event (a note) can be defined as a finite set of attributes with a value, drawn from some finite alphabet x. Each event in a sequence can be observed in multiple ways, which is in IDyOM enabled with *viewpoints*, a collection of independent views of the musical surface, for modeling the musical features, e.g., pitch or duration of the sound (see more about viewpoints in [9, 7]).

If applying a computational model in analyzing musical sequences and their events, a particular 'grammar' should be used, which is capable to assign structural descriptions to any sequence of symbolic representations of notes or musical events. In the domain of music, in the last 60 years, several grammars (e.g., context-free, finite state, finite context or n-gram grammars, neural networks. . .) have been applied, more or less successful. In the very first studies (approximately from 1950 on), limited success has been achieved by using probabilistic N-grams, mostly due to overfitting. The computation model IDyOM, is based on n-gram models, however, it uses a *variable-order* n-gram model, i.e. it varies the order for each context adaptively during the prediction of forthcoming events. This is enabled by incorporating an interpolated smoothing strategy, which allows that all possible orders contribute to each predicted distribution [5], and by using an escape strategy, admitting distributions including previously-unseen symbols [8].

IDyOM simulates the listener's listening process with two models. The first one, the long term model (LTM) reflects the listener's knowledge about music acquired during the lifetime, the second one, the short term model (STM), reflects the listener's information about the musical structure, acquired in an incremental, dynamic statistical learning during a current listening experience. These two models are in IDyOM combined, to achieve better prediction performance. As the music perception in listeners differs, due to the short-term/long-term exposure to a particular musical culture, and as music varies among musical cultures, due to external/internal impacts on a particular culture (e.g., historical/economical/political and other changes a culture might be exposed to), it is expected, that these differences will be captured in the syntactic musical structure. The study from [11], simulating the listeners enculturation[3] only with LTM models has shown the IDyOM's capability to model these differences.

3 METHODOLOGY

3.1 Data

We have used in this paper our data, comprising 2,184 songs from 22 European countries (see Table 1). For each country, three datasets have been created, covering in total 959 folk songs (hereafter referred to as FS), 736 children's folk songs (hereafter referred to as CFS), and 489 children's songs (hereafter referred to as CS). All the songs are monophonic, thus melodies, consisting of only one melodic line, without accompaniment or other voice parts. A selection of children's folk songs and folk songs have been obtained from the "The Essen Folksong Collection".[4] The selection of Dutch children folk songs and Dutch folk songs have

[3]The degree to which a listener is enculturated in his musical culture

[4]http://kern.ccarh.org/browse?l=essen

been obtained from "The Meertens Tune Collection".[5] Additional children's folk songs and folk songs have been collected from different (song)books, which are accepted and recognized in a particular country as a trustworthy source, provided by the courtesy of national/school libraries from these countries. Children's songs have been collected partially from different schools (educational) textbooks, provided mostly by schools, school's and national libraries, and partial, when necessary, by using official websites from authors of children's music.

Table 1: Number of folk songs (FS), children's folk songs (CFS), and children's songs (CS) from 22 European countries.

Country	FS	CFS	CS	Country	FS	CFS	CS
Bulgaria	23	18	18	Croatia	58	16	16
Denmark	22	15	11	France	131	71	22
Germany	139	124	21	Great Britain	41	38	17
Greece	23	26	19	Hungary	34	27	16
Italy	23	22	12	Latvia	46	23	20
Netherlands	53	58	23	Norway	30	23	20
Poland	24	22	21	Portugal	15	27	15
Romania	23	18	18	Russia	28	21	21
Serbia	24	13	23	Slovenia	71	109	46
Spain	19	54	15	Sweden	30	29	17
Switzerland	75	23	16	Turkey	25	24	17

3.2 Procedure

For all the 2,184 songs, we have used 12 different viewpoints (see Table 2).

Table 2: Description of viewpoints

Viewpoint	Description	Viewpoint	Description
cpitch	chromatic pitch	cpitch-class	octave equivalent pitch class
cpint	chromatic pitch interval in semitones	cpint-size	size of intervals
cpcint	octave equivalent pitch class interval	cpcint-size	absolute value for cpcint
tessitura	pitch range	inscale	"in-key" and "out-key" tones
contour	shape of a melody	newcontour	changes in contour
cpintfip	pitch interval from the first event	cpintfref	pitch interval from the tonic

We calculated accumulated information content (IC) for each viewpoint, which was obtained in few steps: (i) we computed for each song the mean value of the viewpoint across all the events (notes) in the song, (ii) we averaged these mean values of viewpoint across all the songs from the given genre in each of the 22 countries. This way, we obtained a vector of 12 mean IC values, for each country and each genre, altogether 66 vectors. This is the data that was used in the analysis of variance and cluster analysis. We performed a one-way multivariate analysis of variance (MANOVA) to test the hypothesis, that there are one or more mean differences between 22 countries and viewpoints used in three genres (FS, CFS, and CS). These differences were further analysed with a series of ANOVA (for each viewpoint). Finally, we performed a cluster analysis using K-means algorithm and agglomerate hierarchical clustering to see the (dis)similarities between the countries regarding the observed information content.

3.3 Results

A statistically significant MANOVA difference was found in genres between countries on the combined dependent variables (12 viewpoints), $F(24, 104) = 7.553$, $p < 0.0001$, Wilk's $\Lambda =$

[5] http://www.liederenbank.nl/mtc/

0.132. Multiple pairwise comparisons, to determine how the three genres in 22 countries differ from the perspective of the 12 viewpoints, are shown in Table 3. Except for `tessitura` and `cpintfip`, there are significant differences in how the viewpoints are used in all three genres.

Table 3: Significant differences in viewpoints when comparing all the three genres in 22 countries.

Viewpoint	df	Sum Sq	Mean Sq	F value	Sig.
cpitch	2	0.393	0.196	3.716	0.029*
cpitch_class	2	1.729	0.864	6.616	0.002**
tessitura	2	0.023	0.011	0.345	0.709
cpint	2	2.287	0.143	2.851	0.065.
cpint_size	2	0.799	0.399	9.605	$<$ 0.0001***
cpcint	2	1.059	0.529	5.169	0.008**
cpcint_size	2	1.730	0.865	9.363	$<$ 0.001***
contour	2	3.684	1.842	28.271	$<$ 0.0001***
newcontour	2	2.271	1.135	18.959	$<$ 0.0001***
cpintfip	2	0.180	0.090	1.752	0.181
cpintfref	2	1.594	0.797	6.014	0.004**
inscale	2	1.293	0.646	11.381	$<$ 0.0001***

We conducted a cluster analysis on the collected data, the most common non-hierarchical cluster analysis - the k-means algorithm with standard-setting (Euclidean distance). Figure 1 represents each country by a joint vector of 36 viewpoints (12 viewpoints for each genre).

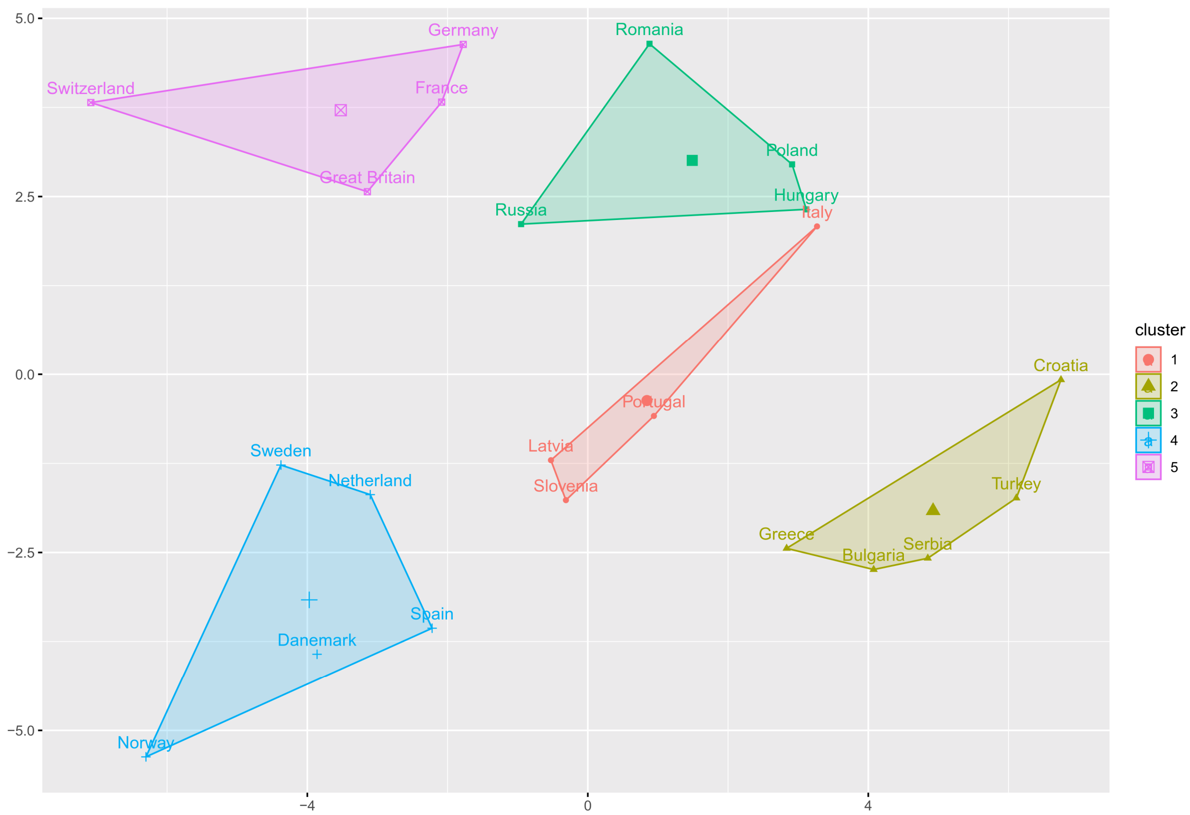

Figure 1: Clusters obtained by using all the three genres (between countries).

We conducted also hierarchical clustering, as with K-means clustering no particular organization or structure within the clusters has been given. We used Euclidean distance as the distance metric d to estimate the pairwise similarity between the 22 countries and Ward's minimum variance method as a linkage method.

In Figure 2, we can see the step-by-step merging bottom-up process, where merging levels correspond to the measure of dissimilarity between two groups (countries). The dendrogram has been obtained by using 22 countries and conjoining three genres (FS, CFS, and CS). The vertical dotted lines are depicting the most salient clusters in this dendrogram. At the top of the dendrogram we can see the partition into two clusters, the first one obtained by merging groups of countries into cluster no. 1, and the second one, by merging clusters no. 2 and 3, and clusters no. 4 and 5 into a big cluster. This partition is plausible reflecting the coexistence of two opposites (from the 15th–20th century): the Habsburg Empire/afterwards Austro-Hungaria Empire and Ottoman Empire, which accords also with findings from [4].

A closer look at the 22 countries, included in these two empires, shows turbulent turnovers within five centuries, being under one or another empire, or being governed at the same time even by two or more power states (e.g., Croatia under Habsburg Monarchy, Ottoman Empire from the 16th to the end of the 17th century, and the Venetian Republic), having different degrees of autonomy, and different opportunities for the preservation of culture and national identity [3, 6]. In this sense should be understood the merging of countries into clusters from 1-5 (depicted with dotted lines), pointing to more or less shared traits between countries governed by these two mighty empires.

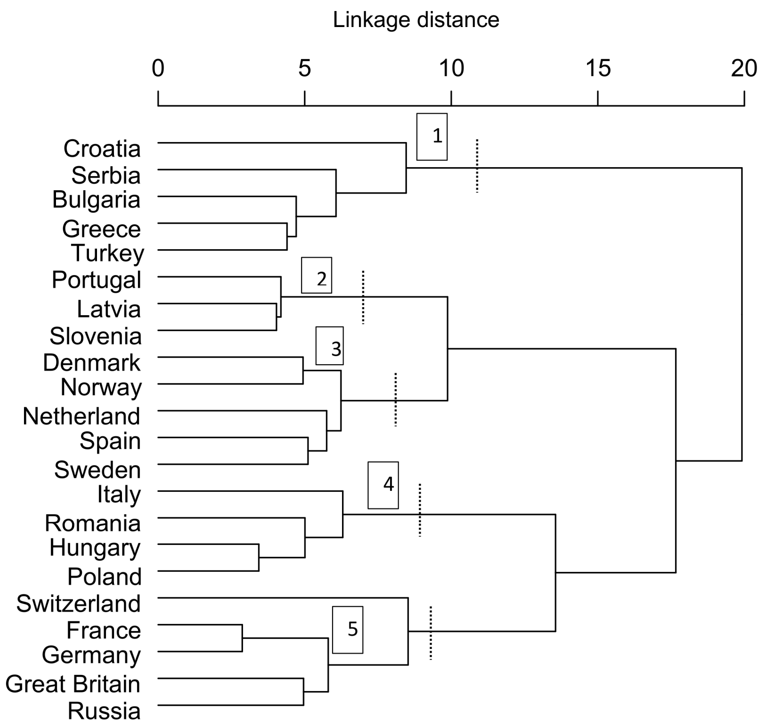

Figure 2: Dendrogram showing the (dis)similarities between countries when conjoining all the three genres.

4 CONCLUSION AND FUTURE WORK

The preliminary results have shown differences between the three genres (FS, CFS, and CS) used in the comparison task. Two of them (children's folk songs and children's songs), considered to be 'non-representative' in cross-cultural studies, are according to the results, contributing to the (dis)similarity found in the 22 European countries, however, to which extent, is (to date) still not clear, and will therefore be our future work. The comparison between 22 European countries have shown diversity in musical cultures, regardless of the fact of a close geographical distance (e.g. Serbia and Hungary), and shared historical/economical/social/cultural traits. The results have shown also 'outliers', countries geographically being very distanced, however, found to be placed in the same cluster (e.g., Slovenia and Latvia), pointing to plausible common historical roots. The results are motivational, and the future work will be an in-depth cross-cultural study, with the purpose to reveal the relations between these 22 European countries.

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BUSINESS PROCESS MANAGEMENT AND CUSTOMER EXPERIENCE MANAGEMENT CONVERGENCE – A LITERATURE REVIEW

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Abstract: Even though business process management and customer experience management initiatives normally strive towards achieving customer satisfaction, their efforts are often not aligned. Therefore, further research is required in the domain of business process management and customer experience management convergence approach. In order to do so, systematic literature review of the current state of this domain in necessary in order to be able to clearly identify the problem, formulate the goals and eventually conceptualize and structure the business process management and customer experience management convergence model. This research is relevant for both commercial and public services organizations, as well as within the smart city setup and enablement.

Keywords: Business Process Management, Customer Experience Management, Convergence, Customer Orientation, Customer Journey, Literature Review.

1 INTRODUCTION

Temkin [39], Davis [13], Niehaves and Plattfaut [26] and Niehaves et al. [27] emphasize that organizations are often focused on their internal business processes - their analysis and optimization, and thus neglect or forget the needs of their customers. It is necessary to further explore the area of convergence of BPM (Business Process Management) and CXM (Customer Experience Management) approaches in terms of the model or structure for integrated modeling, analysis, redesign and control of processes related to internal resources and customers external to the organization at the same time [16; 20; 37].

Accordingly, customer orientation in the context of BPM initiatives unfortunately often remains just a slogan, while efforts to improve the process are viewed exclusively from an "inside-out" perspective [19]. Numerous authors emphasize the need for further research in the field of convergence of CXM and BPM, and point out the lack of a model or structure of integrated modeling of processes related to internal resources and external customers related to the organization at the same time [5; 16; 20; 37; 38].

Despite the fact that BPM and CXM strive to provide organizational prerequisites for achieving customer satisfaction, their efforts are often not aligned [37]. Successful convergence of BPM and CXM should address the identified problems in a way that organizations understand the needs of customers in order to analyze internal processes.

This is relevant for both commercial and public services organizations. Public services need to adapt to the needs of their customers, the citizens [15]. Even though in many cases new e-services are technology-initiated, Smart Cities actually start with the user [15]. Within the context of smart city services, re(design) of processes and modelling of information systems should be customer (user) oriented.

2 SYSTEMATIC LITERATURE REVIEW: METHODOLOGY

Systematic literature review was performed in the domain of convergence of BPM and CXM approaches. Literature was found by searching some of the most significant databases – Web of Science (WoS) and Scopus [2; 4; 32]. According to Webster & Watson [41], literature review stands for one of the key prerequisites for making progress in research in any field.

Author decided to use the methodology adapted from Wolfswinkel, Furtmueller and Wilderom [42], Boel and Cecez-Kecmanovic [7] and PRISMA methodology [29]: 1. Select relevant databases; 2. Select keywords; 3. Select filtering method; 4. Remove duplicates; 5. Remove irrelevant papers based on abstract and keyword reviews; 6. Remove irrelevant papers based on a review of the entire paper; 7. Add relevant papers based on forward / backward citation method.

All papers cited in Scopus and WoS databases were included in the analysis. The analysis was conducted in April 2021, and all the papers published until day of the search (April 1, 2021) were included. Literature review strategy included a review of papers within all the research areas without a time filter. The search was performed in 4 iterations as follows:

1. „Business process management“ AND „Customer experience management”: Such a search yielded no results except for two papers published by the author of this paper.
2. „Business process“ AND „Customer experience“: This approach resulted in a total of 126 papers found (23 in WoS, and 103 in Scopus).
3. „Business process“ AND „Customer journey“: This approach resulted in a total of 19 papers found (5 in WoS, and 14 in Scopus).
4. „Business process“ AND „Customer orientation“: This approach resulted in a total of 71 papers found (24 in WoS, and 47 in Scopus).

A total of 216 papers were included in the analysis (52 in WoS, 164 in Scopus), not including backward and forward citation methods. The data collected in this way were subject to general and logical methods of scientific research.

3 SYSTEMATIC LITERATURE REVIEW: RESULTS

Within the initial elimination of duplicate papers (appearing in both WoS and Scopus databases, appearing multiple times based on search for different keyword combinations), 50 records were eliminated. There were 166 papers left that have entered the first round of analysis. During the analysis and removal of irrelevant papers based on titles, abstracts and keywords, 132 papers were removed. This included papers that met the defined search criteria, however a more detailed analysis found that they do not analyze the previously described context. In most cases, these are the papers that are oriented to the domain of BPM, and the customer is mentioned in the summary or keywords, most often as a phrase - while the paper itself is oriented exclusively to the perspective of internal processes. After this elimination phase, 34 papers remained.

During the next phase - the elimination of papers based on review and analysis of the entire text, 13 papers were eliminated. Same elimination criteria from the previous phase were used. Since the focus of this research is on the convergence of BPM and CXM, papers that do not focus on at least one of the following criteria have been eliminated: 1. Inclusion of customer experience as a concept within BPM initiatives (CX-BP); 2. Inclusion of customer journey as a concept within BPM initiatives (CJ-BP); 3. Inclusion of customer orientation as a concept within BPM initiatives (CO-BP); 4. Papers that propose some form of a new model or methodology for a certain way of convergence of BPM and CXM initiatives (BPM-CXM). After elimination, 21 relevant papers remained. According to the same criteria, backward (added 1 paper) and forward (added 4 papers) citation methods were conducted.

Finally, 26 relevant papers in the BPM and CXM convergence domain were identified. Within the next step, a detailed analysis was performed while the papers were classified into categories accordingly. An overview of all the papers that qualified for a detailed analysis is shown on the table 1 below.

Table 1. Overview of qualified papers based on the systematic literature review process

Title	Year	Database	Paper type	Research method	CX -BP	CO -BP	CJ -BP	BPM -CXM
Schiavone et al. [35]	2020	Scopus	Scientific paper	Qualitative	x	x	x	
Helmy et al. [19]	2020	WoS Scopus	Scientific paper	Qualitative	x	x		
Kreuzer, Röglinger, and Rupprecht [22]	2020	Scopus	Scientific paper	Mixed		x		
Frank et al. [17]	2020	Scopus	Scientific paper	Qualitative		x		
Pavlic and Cukusic [30]	2019	WoS Scopus	Conference proceeding	Qualitative	x	x	x	x
Pavlic and Cukusic [31]	2019	WoS Scopus	Conference proceeding	Qualitative	x	x	x	x
Osman and Ghiran [28]	2019	WoS Scopus	Conference proceeding	Qualitative	x	x		
Shongwe and Seymour [36]	2019	Scopus	Conference proceeding	Qualitative		x		
Afflerbach and Frank [1]	2016	Scopus	Conference paper	Qualitative	x			
Laga, Kherbouche, and Masse [23]	2016	WoS	Conference proceeding	Qualitative			x	
Trkman et al. [40]	2015	WoS Scopus	Scientific paper	Qualitative		x		x
Hewing [20]	2014	Scopus	Book	Qualitative	x	x		x
Sanz [34]	2014	WoS	Scientific paper	Qualitative	x		x	
Esfahani, Rahman, and Zakaria [14]	2013	Scopus	Conference proceeding	Qualitative		x		x
Moormann and Palvolgyi [25]	2013	Scopus	Conference proceeding	Qualitative		x		
Margaria et al. [24]	2012	Scopus	Book chapter	Qualitative		x		
Botha, Kruger, and de Vries [9]	2012	WoS Scopus	Scientific paper	Mixed	x	x	x	x
Czarnecki, Winkelmann, and Spiliopoulou [12]	2011	Scopus	Conference proceeding	Qualitative		x		
Kohlbacher and Weitlaner [21]	2011	Scopus	Conference proceeding	Qualitative		x		
Brocke, Uebernickel, and Brenner [11]	2010	Scopus	Scientific paper	Qualitative		x		
Botha and Rensburg [10]	2010	WoS Scopus	Conference proceeding	Qualitative	x	x	x	x
Heckl and Moormann [18]	2007	Scopus	Conference proceeding	Qualitative		x		
Bhatt and Troutt [6]	2005	WoS Scopus	Scientific paper	Quantitativ e		x		
Alt and Puschmann [3]	2005	Scopus	Scientific paper	Qualitative		x		
Bolton [8]	2004	Scopus	Scientific paper	Qualitative		x		
Rajala and Savolainen [33]	1996	WoS Scopus	Scientific paper	Mixed		x		

In accordance with the results of a systematic review and analysis of the relevant literature, a brief overview of individual most relevant papers and their focus is given below. **Pavlic and Cukusic** [30, 31] structured a BPM-CXM convergence approach. The mentioned approach was structured based on this literature review (its first iteration). **Trkman et al.** [40] developed a methodology for converging traditional BPM approaches with the Service Blueprinting approach. The aim was to develop a methodology that can achieve customer orientation through BPM. Accordingly, in addition to the traditional internal perspective of BPM, the scope of the observed improvement also includes the external process of the customer. It is a form of convergence of BPM and Service Blueprinting approach, where detailed business process models incorporate activities of the customer. **Hewing** [20] has elaborated and evaluated a methodology for an expanded overview of customer processes within the BPM initiatives - Business Process Blueprinting. It emphasizes the importance of understanding how value arises from customers. In addition to internal business processes, it is extremely important to understand and analyze external processes in relation to the organization - those that reflect the journey and the experience of the customer. Similar to Trkman et al [40], customer activities have been added to business process models at a detailed level. However, a top-down structure has not been established to organize customer journeys, or to analyze in more detail the impact of internal business processes on the external customer experience and vice versa.

Esfahani et al. [14] developed a methodology for customer-oriented improvement of business processes on the example of public organizations. The phases of the methodology they have developed include pre-work (organization) for improvement, customer understanding, process selection, process understanding, process improvement, implementation, and evaluation. However, their methodology has been developed on a theoretical level, while there is no indication of practical implications, or models / objects by which the approach could be operationalized. **Botha et al.** [9; 10] developed a methodology for improving the customer experience by improving internal business processes, which they called the Enhanced Customer Experience Framework (ECEF). The proposed methodology includes the phases, tools and techniques used, as well as the desired outputs of each phase. Mentioned phases include development of objectives, identification of key business processes and associated KPIs, collection of customer data, linking business processes to customer requirements, determining the impact and performance of business processes and setting priorities, estimation of the desired level of performance for each business process, specification of improvement initiatives and testing of their impact on the customer experience. Methodology is developed at the theoretical level and suggests how to prioritize BPM initiatives to effectively influence the optimization of the customer experience (and thus presents a particular form of BPM-CXM convergence). However, the methodology does not link models of internal processes and external customer journeys at the detailed operational level.

Various authors propose a model for customer-oriented modelling of processes, as well as the customer-oriented prioritization of projects to improve internal business processes [3; 8; 11; 12; 17; 18; 21; 22; 24; 25; 36].

Customer who is external to the organization should be the starting point for the design of internal business processes [25]. Organizational services should be defined in a way that they take into account the obligations of the internal organization towards the customer, as well as the operational business processes [11]. All business processes as well as stakeholders within the organization must be focused on identifying and meeting customer needs [8].

There is a need to significantly improve the customer experience when optimizing internal processes while the current conventional approach to BPM sometimes has a negative impact on customer loyalty, and thus the overall customer experience [34]. While customer satisfaction is a key driver of an organization's success, there is a need to adapt organizations and their processes to the needs of customers [17; 24].

Several authors also establish some form of convergence of BPM and CRM approaches [1; 23].

4 CONCLUSION

The results of the systematic literature review present an overview of all the papers relevant to the field of convergence of BPM and CXM approaches, which are present within the evaluated databases. The analysis of qualified papers shown that as many as 23 out of 26 papers focus on the customer orientation as a concept within BPM initiatives. 10 out of 26 papers have the involvement of customer experience as a concept within BPM initiatives in focus, while only 6 of 26 papers have the inclusion of customer journey as a concept within BPM initiatives in their focus. 7 papers (5 when papers of the authors of this research are excluded) propose some form of a new model or methodology for a certain form of convergence of initiatives for BPM and CXM.

From the results of this research, it is evident that the customer as well as the customer experience are often mentioned in the context of BPM. However, although there are studies that investigate and elaborate concepts related to BPM-CXM convergence approach, there is no fully integrated or operationalized theoretical model, at least not at a satisfactory level of detail that would allow further analysis and practical application within real organizations. Nevertheless, the relevant papers detected by a systematic literature review, along with papers from other sources, are used in forming a new BPM-CXM approach.

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Appendix

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