

Department of Civil Engineering University of West Attica



9th International Symposium & 31st National Conference on Operational Research (HELORS 2 0 2 3)

June 29-30 and July 1, Athens, Greece



Book of Proceedings

Editors Vryzidis Isaak Dimitrios Em. Alexakis Vassilios C. Moussas

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June 29-30 and July 1, Athens Greece

Editors:

Isaak Vryzidis

Department of Civil Engineering University of West Attica

Dimitrios Em. Alexakis

Department of Civil Engineering University of West Attica

Vassilios C. Moussas

Department of Civil Engineering University of West Attica



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Note: All papers published in this conference proceedings have been reviewed by at least two members of the scientific committee.

Welcome



Nikolaos Matsatsinis President of HELORS Technical University of Crete <u>nmatsatsinis@isc.tuc.gr</u>

President of HELORS

Dear Colleagues and Dear Friends,

On behalf of the Hellenic Operational Research Society (HELORS), let me warmly welcome you to our country and to HELORS 2023, the 9th International Symposium and 31st National Conference on Operational Research. We would like to offer a warm welcome to participants from countries around the world.

The Hellenic Operational Research Society (HELORS - <u>www.eeee.org.gr</u>) was founded in 1963, with the objective of promoting the study and applications of Operational Research methodology, for the benefit of the Hellenic economy and society. HELORS is a member of the 'Association of European Operational Research Societies - EURO' within IFORS, the 'International Federation of Operational Research Societies'. In 1984, the Macedonia-Thrace annex was founded, aiming primarily at the growth of Operational Research in the greater area of Balkans and at an improved organization and communication of the members of Northern Greece.

In the sixty years since its inception, HELORS has evolved into a scientific entity with an important presence in the scientific and economic life of the country, with hundreds of members that stand out for their theoretical background, their entrepreneurial endeavors, and their professionalism. Our members are mainly engineers, mathematicians, economists, etc. Over 35% of the members hold an MSc in Operational Research / Business Administration, and 40% hold a PhD. The rest are PhD candidates, postgraduate students, and undergraduate students.

During these years, our society presents a wide range of activities. Among them, HELORS publishes in collaboration with Springer, the scientific journal 'Operational Research' with IF 2021: 2,708, in which we invite you to consider submitting your valuable work. HELORS has organised in various Greek cities thirty (30) National Conferences, of which the last eight (8) are international conferences, and six (6) Balkan Conferences on Operational Research (BALCOR). It has organised the 12th International Conference on Operational Research of IFORS in Athens (June 1990), the European Conference EURO XX in Rhodes (July 2004) and the 31st European Conference of EURO in Athens (July 2021)

In closing, I would like to thank the University of West Attica, the Conference Chairs, the Organizing and Scientific Committees, and those who worked and contributed to the success of this conference.

Above all, I would like to thank all of you who, with your participation contribute to the advancement and dissemination of operational research.

Let's enjoy the Conference.

Nikolaos Matsatsinis

President of HELORS



Isaak Vryzidis General Chair of the Conference organising committee University of West Attica <u>i.vryzidis@uniwa.gr</u>

Chair of the HELORS 2023 Organisation Committee

Dear Colleagues and Dear Friends,

On behalf of the Organizing Committee, I am very pleased and proud to welcome you to the University of West Attica, host of the 9th International Symposium and 31st National Conference on Operational Research.

I would like to thank the Hellenic Operational Research Society for entrusting us with the organisation of HELORS 2023. Organising such a great conference is a great honour for the Department of Civil Engineering but also a challenge. When we were appointed to organise this conference, we accepted the challenge of organising the first conference of HELORS on site since the beginning of the COVID–19 crisis. Our target was to provide an atmosphere capable of facilitating networking, debate, and presentation of new applications and advances in OR.

Unfortunately, the uncertainty caused by the different possible dates of Greece's National Elections forced us to constantly review our goals and plans. In these dynamic conditions, we decided to organise the conference in the last week of June and set as our primary goal to hold a successful conference. To achieve this, we increased the degrees of freedom of the conference participants by giving them more opportunities to make decisions about their participation as close to the conference dates as possible. This was made possible by postponing the submission deadlines, registrations and changes as late as possible.

We knew that with these key decisions, we faced a significant risk for the conference's success, but with the hard work of the Organizing Committee, the Program Committee, and the HELORS, we turned this into a great success in the current circumstances.

The result of this effort is the correspondence from more than 170 authors and co-authors from 18 countries and the submission of more than 80 papers. The schedule promises to be exhausting, and we hope we managed to achieve the desired atmosphere for interacting with old and new friends and make your participation in the conference a memorable and fruitful experience.

Finally, I would like to express our appreciation to the members of the scientific committee for their kind participation and effort in reviewing process of the articles included in this conference proceedings.

Welcome to the University of West Attica.

Isaak Vryzidis

General Chair of the Conference organising committee

Organisation

The <u>Hellenic Operational Research Society</u> (HELORS) and the <u>Department of Civil Engineering</u> of <u>University of</u> <u>West Attica</u> are organising the conference with the contribution of the Postgraduates programs of the University of West Attica.







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The Coordinate Method of Solving Multiobjective Problems Optimization on the Combinatorial Configurations

Liudmyla Koliechkina University of Lodz Poland, Lodz Olena Dvirna National University "Yuri Kondratyuk Poltava Polytechnic" Ukraine, Poltava

Abstract

This work is devoted to the actual problem of developing a method for solving a multiobjective optimization problem on combinatorial configurations. Multiobjective optimization problems (MOPs) on combinatorial configurations represent a significant area of research with diverse practical applications across various domains. Combinatorial configurations offer a versatile platform for modeling complex systems characterized by discrete decision variables and multiple conflicting objectives. By considering many criteria simultaneously, MOPs on combinatorial configurations allow decision-makers to explore trade-offs and identify Pareto-optimal solutions representing the best compromise among competing objectives. The article presents a coordinate method for solving multiobjective optimization problems on combinatorial configurations. The coordinate method for solving MOPs works directly with the system of restrictions of polyhedra combinatorial configurations and also uses the representation of combinatorial sets as a set of schemes. This technique allows you to analyze a group of permutation elements at once and reduce the number of points required to complete the permutation graph analysis. This makes it possible to quickly obtain a solution to the problem.

KEYWORDS

multiobjective problem, combinatorial configurations, polyhedra, permutation.

1. INTRODUCTION

The multiobjective optimization problem is a problem involving multiple objective functions that should be considered separately and optimized simultaneously [1-5]. Such tasks are well-suited for modeling many real-world applications involving multiple criteria, such as decision making [1, 4], scheduling [4-7], design [7, 8], etc. The task of multiobjective optimization becomes more complicated if it is considered on one of the combinatorial sets - permutations, partial permutation. In this article, we consider the problem of solving MOP on a finite set of configurations and a method for solving it. ext.

Let the set Π' of combinatorial configurations be defined according to [9, 10], and $\Pi \subseteq \Pi'$ the subset distinguished from the set Π' by means of additional restrictions. Several mappings are given $\varphi_i : \Pi' \to \mathbb{R}^1, i \in J_n$, the extreme values of which must be found. Then they can be written in the form of a vector criterion. $\Phi(\pi) = (\varphi_1(\pi), \varphi_2(\pi), ..., \varphi_n(\pi))$. The problem will have the form: find all such π , that

$$\Phi(\pi) \to extr , \ \pi \in \Pi \subseteq \Pi'.$$
⁽¹⁾

Let π_i^* – is the element that determines the extreme value of φ_i , then $\varphi_i^* = \varphi_i(\pi_i^*)$, $i \in J_n$.

The set of Pareto-optimal solutions (1) will have the form on the set:

$$P(\Phi,\Pi) = \left\{ \pi \in \Pi : \exists \pi' \in \Pi : \Phi(\pi') \ge \Phi(\pi), \Phi(\pi') \ne \Phi(\pi) \right\}.$$
(2)

When combinatorial configurations are immersed in the arithmetic space, there is a transition to Euclidean combinatorial optimization, and the problems described above in the combinatorial setting will have corresponding analogues [9, 10-12].

Let the set $Z' = X \subseteq \mathbb{R}^m$ of Euclidean combinatorial configurations in the space \mathbb{R}^m , and $Z = D \subseteq X$ – the set of admissible values of e - configurations that is separated from X by means of additional constraints $\langle a_{ij}x_j \rangle \leq b_i, i \in N_k, j \in N_m$. Functions $f_i : X \to \mathbb{R}^1, i \in J_n$ will correspond to the mapping $\varphi_i : \Pi' \to \mathbb{R}^1, i \in J_n$. Then problem (1), (2) will take the form

$$F(x) = (f_1(x), ..., f_n(x)) \to extr,$$
(3)

$$x \in D \subseteq X$$
 . (4)

Problem (3)-(4) is a problem of multiobjective Euclidean combinatorial optimization (MECO).

Assume that all components of the vector optimality criterion are linear functions, i.e.

$$f_i(x) = \langle c_{ij} x_j \rangle, i \in J_n, j \in J_m,$$
(5)

and D is separated from X using linear constraints.

Then problem (3)-(4) takes the form: under condition (4), find the set X^* of optimal values of the functions $f_i(x) = \langle c_{ij} x_i \rangle \rightarrow extr, i \in J_n, j \in J_m$, (6)

where $extr = \{\min, \max\}$ is the optimization direction, *D* is formed by the constraints of the view

$$\left\langle a_{ij} x_{j} \right\rangle \leq b_{i}, i \in N_{k}, j \in N_{m}.$$
⁽⁷⁾

We will call the problem (4), (6), (7) the Multiobjective problem of linear Euclidean combinatorial optimization (MLECOP). When solving a problem, it is necessary to find a set $X_p^* = P(F, X)$ Pareto optimal solutions [1, 6].

A set X can be sets of Euclidean combinatorial configurations of permutations, partial permutation, polypartial permutation, polypermutations, and others [6-8, 11]. The properties of Euclidean combinatorial configurations are the basis for the development of methods for solving the given problems. One of the important areas is the connection of combinatorial configurations with combinatorial polyhedra and their graphs [8, 10]. This representation of Euclidean combinatorial configurations allows structuring sets of e-configurations for the analysis of function values on them.

2. PRELIMINARIES

The basis for developing a coordinate method for solving multiobjective optimization problems on Euclidean combinatorial configurations is the use of grid-graph *e*-configurations properties. Let be the set X of *e*-configurations, and let be G(V,U) is some graph for which the number of vertices coincides with the cardinality of the set X.

Definition 1. If there is a bijective mapping $\psi: X \to V$, where X is the set of e-configurations, and V is the set of vertices of some graph G^X , and the adjacency conditions of the vertices Ψ are also defined, then G^X is a graph of the set of e-configurations X.

According to the grid graph's definition, it is determined by the type of the vertex \tilde{v} - parameter that determines the order of the first \tilde{t} coordinates of each vertex of the current grid graph, and \tilde{h} fixed coordinates. If you form a set of grid graphs with the same dimension of \tilde{t} and \tilde{h} parameters such that all points of a given set X of *e*-configurations will be covered, you can evaluate the value of a linear function on the set X. Let's consider an example of defining vertex types and calculating the number of *e*-configurations grid-graph.

Example 1. If the vertex type is the order of the first $\tilde{t} = 3$ coordinates, then this order is increased by the set $\{(123), (213), (132), (312), (231), (321)\}$ and the set of corresponding types of the grid-graph vertex is denoted by $v_i, i \in N_6$ the chosen order of the first three coordinates, which is additionally a set. For a set of permutations of 6 elements, under the condition that $\tilde{h} = 1$, such a number of such grid-graphs will be:

$$\gamma = \tilde{t} ! \frac{m!}{(m - \tilde{h})!} = 3! \frac{6!}{(6-1)!} = 36$$

Example 2. Let it be necessary to build a grid-graph of *e*-configurations of permutations from six elements under the condition $\Upsilon' = \langle x_6 = 2, v' = (1,2,3) \rangle$. Some linear function with increasing coefficients is given: $g(x) = 2x_1 + 4x_2 + 6x_3 + 9x_4 + 11x_5 + 55x_6$. It is necessary to find all the vertices of the grid graph, in which the inequality $g(x) \le 243$ is true.

According to the definition of the grid graph, the top of the leak will have coordinates $x^0 = (1, 3, 4, 5, 6, 2)$. According to the condition Υ' he last coordinate for all vertices $Gr(X, \Upsilon')$ will have the value 2. The coordinates x_5 and x_4 will successively change their values by means of transpositions of the form $x_{i'} \leftrightarrow x_{i'-1} \leftrightarrow \ldots \leftrightarrow x_{h+1} \leftrightarrow x_{j_i} \leftrightarrow x_{j_{i-1}} \leftrightarrow \ldots \leftrightarrow x_{j_2} \leftrightarrow x_{j_1}, v \in V'_{j'}$

According to the properties of the grid-graph of *e*-configurations, the value of the function g(x) will decrease (or not increase) with each subsequent transposition, therefore, in order to find all the points that will meet the condition $g(x) \le 243$, it is necessary to find the first satisfactory values in the direction from the source to the drain. We denote the coordinates of some vertices and the value of the function at the vertices of the grid-graph $Gr(X, \Upsilon')$ in Figure 1. For clarity, we shade those vertices that satisfy the linear constraint $g(x) \le 243$.



Figure 1: Grid-graph $Gr(X, \Upsilon')$, $\Upsilon' = \langle x_6 = 2, \nu' = (1, 2, 3) \rangle$ with function values g(x) at its vertices

3. COORDINATE METHOD FOR SOLVING MULTIOBJECTIVE OPTIMIZATION PROBLEMS ON EUCLIDEAN COMBINATORIAL CONFIGURATIONS

The coordinate method is based on the construction and properties of grid-graphs of e-configurations, which allows considering not all elements of the configuration since the direction of the decreasing value of the function is known. The specified method can be used for solving vector problems, as it is possible to use it as a procedure and to combine it with known methods of vector optimization.

An example of such a modification can be the method of sequential input of constraints, combined with the procedure of the coordinate method for solving problems on Euclidean combinatorial configurations, which will be described in the following steps:

Step 1. Set the variable k = 0. Set the maximum allowable distance to the "ideal" point ρ^* .

Step 2. Using the coordinate method, determine the points of the combinatorial configuration that satisfy each of the initial constraints $D_i \subset X$, where $i \in N_s$: Use the procedure of the coordinate method, which consists of the following:

- **1.** Set initial values of variables: t = 1, $\tilde{k} = m \tilde{h}$, i = m.
- **2.** Fix the type of vertex $v_i = (i_1, i_2, ..., i_{\tilde{i}})$, where $i_1 \cup i_2 \cup ... \cup i_{\tilde{i}} = \{1, 2, ..., \tilde{t}\}$. Subgraph number is i.

3. Set the value as follows: $x_s = i$, $x_{s-1} = max\{N_s \setminus x_s\}$, $x_{s-2} = max\{N_s \setminus (x_s, x_{s-1})\}$, ..., $x_4 = max\{N_s \setminus (x_s, x_{s-1}, ..., x_5)\}$. Arrange the numbers $\{N_s \setminus (x_s, x_{s-1}, ..., x_{\tilde{k}})\}$ in ascending order

 $j_1 < j_2 < ... < j_{\tilde{t}}$. Then $x_1 = j_{i_1}, x_2 = j_{i_2}, ..., x_{\tilde{t}} = j_{i_{\tilde{t}}}$. These will be the coordinates of the main vertex (source) x^0 . Let's calculate the value of the function in the code of the main vertex $g(x^0)$.

4. Set the value as follows: $x_s = i$, $x_{s-1} = min\{N_s \setminus x_s\}$, $x_{s-2} = min\{N_s \setminus (x_s, x_{s-1})\}$, ..., $x_4 = min\{N_s \setminus (x_s, x_{s-1}, ..., x_5)\}$. Arrange the numbers $\{N_s \setminus (x_s, x_{s-1}, ..., x_4)\}$ in descending order $j_1 < j_2 < ... < j_{\tilde{t}}$. Then $x_1 = j_{i_1}, x_2 = j_{i_2}, ..., x_{\tilde{t}} = j_{i_{\tilde{t}}}$. These will be the coordinates of the lower right vertex - the drain x^{st} . Let's calculate the value of the function in the vertex-drain code $g(x^{st})$.

5. Search optimization: determine the direction of the search in the built network by comparing the values of $g(x^0)$ and $g(x^s)$ with the given B^* according to the following rule: if $g(x^0) - B^* \le B^* - f(x^s)$, then search from the source to the drain (go to point 6), otherwise - from the drain to the drain (go to point 7).

6. Consider and arrange in descending order values $x_k, k \in N_k$: $j_k > j_{k-1} > ... > j_1$. Expand the graph in the direction of the coordinate x_k , through successive transpositions: $j_k \Leftrightarrow j_{k-1} \Leftrightarrow ... \Leftrightarrow j_1$, which will lead to the formation of the coordinates of more k-1 vertices: $p_2, p_3, ..., p_k$. These vertex coordinates are the coordinates of the grid graph vertices. Go to point 8.

7. Consider and order by increasing values $x_k, k \in N_k$. Expand the graph in the direction of the coordinate x_k through successive transpositions: $j_1 \Leftrightarrow ... \Leftrightarrow j_{k-1} \Leftrightarrow j_k$, which will lead to the formation of the coordinates of more k-1 vertices $p_{st2}, p_{st3}, ..., p_{stk}$.

8. Find the value of the function at these vertices using their coordinates: $g(p_n) = g(p_{n-1}) - \Delta_{n-1}$, $\Delta_{n-1} = (j_n - j_{n-1})(c_n - c_{\mu(n-1)})$, where $\mu(\lambda)$ – is the place number of j_{λ} in the permutation code p_{n-1} .

- 9. Check the fulfillment of the following conditions:
 - a. If $g(p_m) \ge B^*$ (the searched values can be contained in the subgraph), then we include *m*-th permutation in the next search. Go to point 10.
 - b. If for all the found coordinates $g(p_m) < B^*$ and $i-1 \le 1$ (the searched values are missing in the constructed subgraph, but not all coordinates were fixed for the specified type of the vertex), then proceed to the consideration of grid graphs, fixing the next coordinate $x_s = i go$ to point 2.
 - c. If for all found coordinates of the vertices g(p_m) < y* and i−1=0 (searched values are missing in the constructed grid-graph, all coordinates were fixed and considered for the specified type of vertex), then set i=6 and proceed to consideration of grid-graphs with the type of vertices V_{t+1}. Go to point 9d.
 - d. If $t+1 \le 6$ (not all types of vertices were considered), go to point 2, otherwise, complete the work of the coordinate method procedure for the current constraint.

Step 3. Find the intersection of sets $D^* = D_1 \cap D_2 \cap ... \cap D_s$, $D^{(k)} = D^*$.

Step 4. Determine the optimal values of each criterion on the set $D^{(k)}$ and form the "ideal" estimate $f^{*(k)}$ as a vector of the optimal values of the criteria.

Step 5. Determine the values σ_i^k , $i \in N_m$ according to the formula $\sigma_i^k = \frac{1}{m} \sum_{l=1}^m \frac{f_i^{\max(k)} - f_i(x^{ll})}{f_i^{\max(k)} - f_i^{\min(k)}}$, where x^{il} is the alternative that maximizes the l-th criterion on the set $D^{(k)}$; $f_i^{\max(k)}$ and $f_i^{\min(k)}$ – respectively the best and worst value of the i-th criterion on the set $D^{(k)}$.

Step 6. Calculate the weighting coefficients of the criteria according to the formula: $a_i^k = \sigma_i^k / \sum_{j=1}^m \sigma_j^k$, $i \in N_m$.

Step 7. Determine the optimality supercriterion: $F = \sum_{i=1}^{k} a_i^k f_i \rightarrow max$.

Step 8. Find x^k as a solution to the problem $Z(F, D^{(k)})$ and its evaluation y^k .

Step 9. If y^k meets the "perfect" rating $f^{*(k)}$, so $\rho(y^k, f^{*(k)}) \le \rho^*$ go to step 10, otherwise go to 11. Step 10. Find deviations for each criterion $\Delta_i = f_i(x^k)/f_i^{\max(k)}$, $i \in N_m$ and determine $\Delta_r = \max(\Delta_1, \Delta_2, ..., \Delta_m)$. That is r – the number of the criterion whose value needs to be improved, ω_r – the level to which the

selected criterion should be improved. Increase the value k by 1. Add the constraint k -th in the form $f_r(x) \ge \omega_r$ to the constraints of the problem. Go to step 3.

Step 11. x^k – the desired solution. End the algorithm.

The described method involves receiving information from the decision-maker about the pairwise merits of the criteria, as well as the distance from the "ideal" point and the amount of improvement in the value of the "worst" of the criteria at step 9 of the algorithm. The procedure is applied to each of the constraints of the problem only once and does not require constant recalculations.

4. CONCLUSIONS

The properties of the linear function on the grid-graph of e-configurations were investigated. These properties make it possible to estimate the value of the function on a certain part of the set corresponding to the vertices of the given grid graph. Based on the properties of grid-graphs, a coordinate method for solving the vector optimization problem on e-configurations is constructed. This enables the prompt attainment of an MOP solution.

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Benchmarking of European Countries in terms of Sustainability: A DEA Approach

Magda Benjelloun - Arabi Athens University of Economics and Business (AUEB) <u>maqda.benjelloun@hotmail.com</u> Michael A. Madas University of Macedonia, Department of Applied Informatics <u>mmadas@uom.gr</u>

Abstract

With the rise in environmental challenges and economic and social inequalities, sustainable development has emerged as a critical issue of our time. It is evident that the sustainability initiative is a complex and great challenge, for which the coordinated effort of nations is required. In this context, the UN with organized efforts dating back to 1992, created in 2015, the Seventeen (17) Sustainable Development Goals - SDGs, widely known as the 2030 Agenda. Despite the growing importance of Sustainable Development Goals (SDGs) in achieving sustainable development, research on benchmarking practices with SDGs remains limited. This paper offers a comparative evaluation of the performance of European countries between 2010 and 2020, with a particular focus on the indicators outlined by the United Nations for measuring progress towards Sustainable Development Goals (SDGs). Two DEA models were developed, with the first model describing a country's production system, while the second model compiled most social indicators. The analysis was carried out under constant and variable returns to scale, using the BCC and CCR models, respectively. Also, Malmquist DEA Analysis was conducted to study the performance of countries over time and the impact of adopting sustainability goals on performance regarding sustainability. The issue of undesirable outputs that arose, as in every case of environmental DEA, was addressed by introducing undesirable outputs as regular inputs. The research findings show a positive correlation between signing the Agenda and sustainability performance. Sweden, Finland, and Iceland ranked highest, while Bulgaria, Romania, and Greece ranked lowest. Large economies such as Spain, Italy, and France were inefficient in the social dimension. Furthermore, the study revealed that Greece was inefficient in all sustainability dimensions. The results of the study are further validated by comparing them with the UN's SDG index, which displays a noteworthy correlation, affirming the proposed models' reliability in evaluating sustainability performance among countries.

KEYWORDS

sustainable development, performance benchmarking, SDGs, DEA

1. INTRODUCTION

In today's global reality where social, economic and climate equilibriums are in a particularly fragile balance, finding solutions to ensure sustainable development is deemed necessary. Therefore, the implementation of sustainable practices is crucial to "meet the needs of current generations without compromising the ability of future generations to meet their own needs", (Brundtland Commission, 1987). Challenges related to climate change, economic hardships, inequality in the standard of living of the European citizens and social inequalities (e.g., gender, origin, etc.) have created a complex and multidimensional issue, for which the coordinated effort of nations is required. In this context, the UN, with organized efforts dating back to 1992, created in 2015, the seventeen (17) Sustainable Development Goals - SDGs, widely known as Agenda 2030. The EU, which strives for the creation of an equal and sustainable economy, aligns with the UN goals by endorsing the Agenda 2030. More about the 17 SDGs can be found on the United Nations' web page: www.un.org. Sustainability is commonly subdivided into three independent dimensions: economic, social, and environmental. For its assessment, a Data Envelopment Analysis (DEA) method was employed. DEA is a quantitative method used in operations research and management science to measure the relative efficiency of decision-making units (DMUs), such as organizations or companies. It helps identify best-performing units and provides insights for improving efficiency and resource allocation. It compares the input-output relationships of DMUs to assess their efficiency in utilizing resources and generating outputs. As it considers multiple criteria of varying types and magnitudes, it is well-suited for sustainability benchmarking. The DEA method was first introduced by Charnes, Cooper & Rhodes (1978) with CCR model that assumes constant returns to scale. The researchers used Farell's theory on productivity as a foundation, which suggests that the total productivity (or efficiency) is calculated as the ratio of "total output" to the "total input". Banker, Charnes & Cooper (1984) enhanced the foundation model, CCR, by assuming variable returns to scale. The

proprosed model is named BCC after their initials. The paper's structure is as follows: Section 2 cites concise literature. Section 3 describes the methodology. Section 4 presents the research findings. The final section, Section 5, presents the main conclusions.

2. LITERATURE

Numerous authors have utilized DEA methodology to evaluate the sustainability efficiency of entities, considering the contextually appropriate aspects. Some of them follow a more closed-spectrum approach by introducing only certain dimensions of sustainability in their assessment. Camarero et al. (2013) and Moutinho et al. (2018) evaluated the environmental efficiency of 22 OECD countries between 1980 – 2005 and 16 countries of Latin America between 1994 - 2013, respectively, by considering gas emissions as input and GPD as output. Camarero et al. (2011) followed constant returns to scale model (CRS), while Moutinho et al. (2018) employed both in constant returns to scale (CRS) and variable returns to scale (VRS) analysis, as well as Malmquist analysis to measure changes in efficiency over time. As for the economic dimension of sustainability, energy efficiency is considered a crucial factor for the economic viability of entities, being the key resource for generating profit. Therefore, it is necessary to focus on optimizing energy efficiency. On this pattern, Menegaki (2013) evaluated the energy efficiency of 31 European Countries between 1994 – 2013 using CRS, VRS and Malmquist analysis, considering greenhouse emissions, capital, employment rate and gross inland energy consumption as inputs, and GDP as output. Representative study of the evaluation of the sustainability's social dimension is this of Skare & Rabar (2017). Skare & Rabar (2017) studied the socioeconomic efficiency of 30 OECD countries between 2002 – 2011 implementing 4 different VRS models and considering the following indicators: inflation rate, GDP, exports/imports cover ratio, scientific and technical journal articles, public health expenditure, seats held by women in national parliaments, unemployment rate and CO₂ emissions. Inflation rate was used as input in every case. Just a few researchers approached the issue of sustainability, considering the triple bottom line of sustainable development. A representative example is the study by Bruni et al. (2011), where an economic, an environmental and a social indicator were considered. Specifically, the performance of 20 Italian regions in 2011 in terms of sustainability was estimated. For research purposes, 4 different models were implemented using energy consumption as input and GDP (economic factor), CO₂ emissions (environmental factor) and poverty rate (social factor) as outputs. However, the unique cases of approaching the sustainability issue with respect to the 17 Sustainable Development Goals were those of Koçak et al. (2019) and Cristóbal et al. (2021). Specifically, Koçak et al. (2019) studied the efficiency of OECD countries for the period 2013-2015 conducting a three-stage DEA analysis. The main interest was Goal 4, regarding quality education. On the other hand, Cristóbal et al. (2021) covered the entire spectrum of sustainability goals, using 85 indicators. A total of 156 countries worldwide, for the period 2010-2018, were studied and the expenses' efficiency of each country in relation to sustainability was evaluated. In conclusion, previous research on approaching sustainability from an SDGs perspective has been inconclusive. This study aims to fill that research gap by providing a comparative evaluation of the sustainability performance of European countries between 2010 and 2020, with a particular focus on the indicators outlined by the United Nations for measuring progress towards the SDGs.

3. METHODOLOGY

This paper evaluates the efficiency of 28 European Countries and Iceland, in terms of sustainability, between 2010 and 2020. The chosen period enables the evaluation of the relative efficiency, prior to and following the Agenda 2030 adoption by EU. For the evaluation, two DEA models, A and B, were developed. The inputs and outputs were selected based on indicators defined by the UN for the evaluation of SDG's, also considering similar applications found in literature. The most significant indicators, associated to the SDGs, were divided between the two models, (A and B), firstly, to prevent calculation errors arising from the surplus inputs and outputs and secondly to ensure the equal treating of the indicators. Both models are considered crucial to encompass the broadest array of SDGs. The first model, (Model A), formed to describe each country's production system in which energy and labor are used, and GDP (SDG 8 – economic), greenhouse emissions (SDG 13 – environmental) and people at risk of poverty or social exclusion (SDG 1 – social) are produced. Observationally, each output corresponds to one of sustainability's dimensions. This approach is similar to Bruni et al.'s (2011). The second model, (Model B), gathers the rest of crucial indicators, measured on a

percentage scale, which are the GINI Index (SDG 10 – socioeconomic), occurrence of crime, violence, or vandalism (SDG 16 – social), bachelor's level (SDG 4 – social), women in national parliaments (SDG 5 – social) and recycling rate (SDG 11 – environmental). For the evaluation of Model A, analysis with CCR method and BCC method was conducted for each year between 2010 and 2020. Subsequently, a Malmquist analysis was employed to study the performance of the European Countries over time. On the other hand, for the evaluation of Model B, analysis only with CCR method was used, as the data of inputs and outputs were standardized (percentage scale). The analysis covered the years 2010, 2015, and 2020. To address the issue of undesirable outputs, they were introduced as regular inputs, a common approach highlighted by Halkos & Petrou (2019). Finally, all data was obtained from Eurostat database. To provide a comprehensive view of countries' efficiency in sustainability considering the SDGs, overall technical efficiency was estimated by averaging the efficiencies are compared to the SDG Index. SDG is a measurement tool for assessing and tracking the progress of countries towards achieving the UN's SDGs. It considers a range of indicators, including those used in this paper, to illustrate the actual goal achievement. Therefore, it can be assumed that the countries with the highest SDG Index are more efficient in sustainability.

Table 1: Overview of Model A & B.

| Model | Inputs – (SDG No.) | Outputs | Туре | Time |
|-------|---|--|---------------------------|-------------------------|
| A | GDP per capita, People at Risk of Poverty or Social Exclusion (*), Greenhouse Gas Emissions (*) | Energy Consumption, Labor Force | CCR, BCC, Malmquist | 2010 to 2020 |
| В | GINI Index (*), Population reporting occurrence of crime, violence, or vandalism (*) | Tertiary educational attainment, (bachelor's level), Proportion of seats held by women in national parliaments, Recycling Rate | CCR | 2010, 2015 & 2020 |

(*) Undesirable Inputs

4. **RESEARCH FINDINGS**

According to Figure 1, there are countries such as Bulgaria, Croatia, Latvia, and Lithuania that are efficient in the BCC model, while they are inefficient in the CCR. This suggests that those countries have reached their highest level of technical efficiency. So, to enhance their performance, they must create bigger economies of scale. In any case, the countries with higher performance are Czech Republic, Finland, France, Germany, Iceland, Luxembourg, the Netherlands, Norway, and Poland, while those with lower performance are Bulgaria, Croatia, and Greece. According to Figure 2, in Model B, Norway, Belgium, Germany, Iceland and Sweden are outperformed, while Romania, Bulgaria, Malta and Greece are underperformed.



Figure 1: Model A results: CCR method (left) & BCC method (right).



Figure 2: Comparison of the Models A (left) & B (right), implemented with CCR method.



Figure 3: Comparison of average sustainability performances (left) to the SDG Index (right)





In addition, it is observed that Spain, Italy, France, Poland, the Czech Republic, and Hungary, are more efficient in Model B, which mostly gathers social indicators, rather than Model A. It is vital to note that Model B emphasizes the social dimension rather than the economic one. Therefore, it is possible for smaller economies to be more efficient in such an approach. In contrast, Model A describes a real system where a country transforms its resources towards achieving goals. Therefore, it is to be expected that larger economies show greater efficiency. According to Figure 3, the overall technical efficiencies of the European Countries and the SDG Index demonstrate similar scores. In both cases, Finland and Sweden are the most efficient, while the most ineffective are Bulgaria, Romania, and Greece. In addition, Italy, Portugal, Spain,

Hungary, and Croatia have similar returns. After comparing the two graphs and considering the observed concordance and discrepancies, the validity of the models and research results is confirmed. Figure 4 depicts positive correlation between goal adoption (year 2015) and the sustainability performance of European Countries. On the other hand, after 2015, Greece followed a period of decline. In 2020, both Europe and Greece showed a recovery according to the Malmquist Index, that can be attributed to the confinement of coronavirus pandemic that led to a significant reduction of greenhouse gas emissions and energy consumption.

5. CONCLUSIONS

This paper employs DEA analysis to benchmark European Countries in terms of sustainability, focusing on the SDGs Goals. The study is based on 28 European Countries, plus Iceland, for the period 2010-2020. The variables were chosen according to indicators defined by the UN for the evaluation of the SDG's. A vital finding of the study is that the Agenda 2030 adoption seems to affect positively the sustainability performance of European Countries. In addition, the research findings showed that Greece was consistently inefficient, with relatively ineffective utilization of its inputs, while large Mediterranean economies, such as Spain, Italy and France lagged behind in the social dimension. In general, higher performances were observed in countries located in the northern regions, excluding the Baltic countries, while lower performances were observed in Balkan and Baltic countries. Sweden, Finland, and Iceland ranked the highest, while Bulgaria, Romania and Greece ranked the lowest. Finally, the relation to the SDG Index (Actual Goal Achievement) indicates that the model is representative for assessing efficiency in relation to the goals, as well as overall sustainability. The proposed models, albeit not covering the entire spectrum of the goals, can be reliably utilized.

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Marketing strategies based on multicriteria analysis of consumer behavior: The case of a cosmetics company

Nikolaos Kalogerakis, Fotini Kalafati, Efstathios Gerampinis, Nikolaos Matsatsinis Decision Support Systems Laboratory

Technical University of Crete, University Campus, 73100, Chania, Greece

Email: <u>nkalogerakis@tuc.gr fkalafati@ergasya.tuc.gr egerampinis@tuc.gr</u> <u>nmatsatsinis@tuc.gr</u>

Abstract

Market penetration forecasting is crucial to mitigate the high costs associated with commercial failures of new products. This study aims to develop an effective model by analyzing consumer behavior using MUSA-KANO and MUSA multicriteria methods. Understanding consumer behavior is essential for companies aiming to optimize their product offerings and meet customer preferences. A specialized questionnaire was used to collect consumer data. The MUSA-KANO and MUSA methods were then applied to evaluate La vie en Rose's cosmetic products from the customer's viewpoint. The study findings contribute to reducing commercial failure risks by aligning product offerings with consumer requirements, enhancing customer satisfaction, and improving market penetration. These multicriteria methods empower companies to refine marketing strategies and make informed decisions during product design, fostering success in the competitive cosmetics industry.

Keywords:

multi-criteria analysis, customer satisfaction analysis, consumer behavior, consumer preferences, cosmetic products, market research

1. INTRODUCTION

Consumer satisfaction (Grigoroudis and Siskos, 2010) plays a critical role in the success of companies when developing products and services. It is essential to understand customer needs and expectations to deliver high-quality offerings and cultivate customer loyalty. The measurement and analysis of consumer satisfaction have gained significant importance in marketing research. Satisfaction can be evaluated by assessing performance or by comparing expectations with actual outcomes. The identification of satisfaction serves multiple purposes, such as identifying market conditions, addressing customer complaints, and gaining valuable insights into customer needs. Before developing the methodology for the current research, we conducted an extensive investigation on analyses conducted on facial creams. This research study aims to investigate the factors that influence customer satisfaction with face creams. To achieve this, a satisfaction questionnaire will be administered to customers of La Vie en Rose cosmetics company. The study will employ multi-criteria analysis methods (Greco et al., 2016) such as MUSA-KANO (Krassadaki and Grigoroudis, 2018) and MUSA (Grigoroudis and Siskos, 2000; 2010) to analyze the data. The objective is to gain valuable insights into consumer behavior and preferences, which will facilitate informed marketing decisions and enhance customer satisfaction in the competitive cosmetics industry. The findings of this research are expected to contribute to mitigating commercial risks and achieving market success.

2. LITERATURE REVIEW

The analysis of literature concerning the managerial and organizational aspects of the cosmetics industry reveals a narrow and selective approach to investigating the related issues. Moreover, there is a scarcity of studies utilizing computer modeling and simulation to address managerial challenges in this domain.

Given the rapid expansion of the beauty and health services market in both developed and developing countries, there is an urgent demand for decision-making models that cater to the requirements of both service providers and consumers. This necessity has been emphasized by researchers such as Cho, Kim, and Kim (2015) and Yen-Cheng, Yu, Tsui and Lee (2014).

Sviderska and Kukhta (2021) stress the pivotal role of innovation in securing a competitive edge in the global cosmetics market. Their research proposes a different approach utilizing diverse quantitative and qualitative methods, including SMART, SAW, and LINMAP, for small to medium-sized cosmetics businesses to select optimal investment alternatives in innovation development.

Dursum et al. (2020) utilized an Interval Type-2 Fuzzy DEMATEL method to assess the significance of dimensions and criteria in the cosmetic service sector. Their Interval Type-2 Fuzzy TOPSIS approach ranked 13 Ukrainian cosmetic service providers, revealing that consumer focus holds the highest importance, whereas learning and development rank as the least critical factor.

The cosmetology service market suffers from information imbalances, hindering accurate quality assessment. Inadequate formalized models, particularly the Musa and Musa-Kano multi-criteria methods, exacerbate this issue. Implementing these approaches offers a valuable contribution to cosmetology service evaluation, addressing existing literature gaps.

3. METHODOLOGY

The methodology framework presented in this paragraph aims to illustrate the process by which the problematic of this research is addressed. The primary objective of this methodology, as depicted in Figure 1, is to identify the specific requirements of customers with the aim of increasing their satisfaction levels. Additionally, the methodology involves analyzing the strengths and weaknesses of the products to enhance the company's efforts in creating new products or improving existing ones, all with the overarching goal of increasing customer satisfaction.



Figure 1: Methodological framework

The steps of the methodology that need to be followed to solve the problematic are as follows:

1. Data collection of satisfaction for database creation: Develop an online questionnaire using the Google Docs platform to create a database. Include sections on demographic characteristics, purchase and use of face creams, and satisfaction ratings on a five-point scale for La Vie en Rose products on a set of criteria and sub-criteria (Figure 2). Additionally, the questionnaire will include questions specifically related both to the satisfaction regarding the identified criteria and sub-criteria of the product and the global satisfaction. Figure 2 depicts the weights assigned to the criteria and sub-criteria, as well as their corresponding satisfaction levels. It is worth noting that the weights exhibit variations in the fourth decimal place, which may lead to the appearance of equality due to rounding.



Figure 2: Satisfaction Criteria – Example: Brilliant Rose

- Pre-processing of the database: Examine extreme and missing values in the surveys. For electronic questionnaires, focus on analyzing the correctness of satisfaction responses, checking for randomness and uniformity. Non-electronic questionnaires require scrutiny of missing and extreme values for all questions.
- 3. Application of the multi-criteria method, Musa, for the entire dataset: Use the Musa multicriteria method, utilizing satisfaction responses as input. Derive weights of each criterion, average satisfaction indices, demand, and effectiveness. Compute average satisfaction index and determine corresponding weights for use in the Musa-Kano methodology to construct dual importance diagrams.
- 4. Action and Improvement diagrams: Generate action diagrams by merging weights of satisfaction criteria and average satisfaction indices. Create improvement diagrams by combining effectiveness and demand indices. These diagrams facilitate identifying product/service strengths, weaknesses, and areas requiring enhancement.
- 5. Categorization of customers into satisfied and dissatisfied based on criteria: Categorize customers based on their satisfaction ratings. Customers indicating "Very Satisfied" or "Satisfied" fall into the satisfied category, while customers indicating "Neither Dissatisfied nor Satisfied," "Dissatisfied," and "Very Dissatisfied" belong to the dissatisfied category. This categorization results in two groups of customers for each criterion separately.
- 6. Application of Musa for each customer category: For the n satisfaction criteria, MUSA runs n*2 times: once for satisfied customers and once for dissatisfied customers.
- Dual importance diagram and categorization of quality characteristics Kano (Kano, 1984): After applying MUSA, weights and relative weights are obtained for each consumer group to categorize the *n* criteria into Kano quality dimensions. This is achieved through the dual importance diagram.

4. **RESULTS**

To create the database, an electronic questionnaire was developed and administered to a targeted sample of La Vie en Rose's most frequent customers. A total of 569 completed questionnaires were collected, resulting in a substantial data set for analysis. The main aim of this data collection was to obtain a significant number of satisfaction questionnaires specifically related to facial creams offered by La Vie en Rose. The large sample size was essential to conduct a robust analysis using the multi-criteria methods of Musa and Musa-Kano. This ensured the reliability of the results obtained from the analysis.

Before implementing the multicriteria methods, thorough data pre-processing was conducted to ensure accurate and reliable results. During the pre-processing stage, it is important to note that the analysis was limited to six specific facial creams due to a relatively small number of collected questionnaires for those products, which did not exceed the threshold of 50. As a result, further analysis for these creams was not pursued. This decision aligns with the recommended practice of applying the multi-criteria Musa method on a substantial dataset, typically with a minimum threshold of 50 data points. Adhering to these guidelines ensures the robustness and reliability of the subsequent analysis and its outcomes.

Following that, the obtained results for the face creams, specifically Brilliant Rose, are presented and analyzed in an illustrative manner. Brilliant Rose was selected as a representative example to demonstrate the application of the multi-criteria methods and highlight the insights derived from the analysis. By focusing on this particular cream, the study aims to provide a comprehensive understanding of the evaluation process and showcase the effective utilization of the multi-criteria Musa and Musa-Kano methods in assessing customer satisfaction and preferences.

Figure 3 displays the comprehensive assessment of customer satisfaction regarding Brilliant Rose cream. The data clearly indicates that the respondents express a notably high level of satisfaction, reaching 98.77% approval for the product. Additionally, the relative overall demand exhibits an exceptionally low value of - 57.18%. This pattern extends to the specific criteria requirements, with the highest demands attributed to cream quality, company support, and staff service.



Figure 3: Global Criterion

Further analysis employing the relative improvement and action diagrams reveals significant insights. According to these diagrams, the criterion of company support (Blue) emerges as the most significant and efficient. However, it is noteworthy that despite having low requirements, this criterion displays limited effectiveness, as indicated by the improvement diagram. These findings shed light on the specific areas where Brilliant Rose cream excels in satisfying customers while highlighting the need for further improvements in the effectiveness of company support.

Subsequently, the Musa-Kano method was employed to evaluate all the creams, and in this case, the findings for the Brilliant Rose cream are presented as an illustrative example.



Figure 4: Dual Importance Diagram - Brilliant Rose

Based on Kano's model, desired quality is related to the characteristics of a product/service. Low performance in these characteristics leads to dissatisfaction, while high performance results in satisfaction. It's crucial to note that quadrants I and III encompass the one-dimensional characteristics in this context.

Figure 4 illustrates the face creams' criterion Quality is a characteristic of high importance for both categories of consumers, as it belongs to the first quadrant. In addition, the Price is a criterion of low importance for both categories of consumers, as it belongs to third quadrant. Low performance on these criteria causes dissatisfaction while high performance leads to satisfaction. Furthermore, regarding the majority of the criteria (Staff Service, Appearance and Results Cream), are belong to the fourth quadrant, is concluded that the dissatisfied customers attach to assign lower importance to these characteristics, suggesting that their dissatisfaction may not be attributed to potentially low performance on those attributes. If a low-performing

characteristic doesn't affect satisfaction, any sudden improvement brings unexpected satisfaction, defining quadrant IV as attractive quality.

Regarding the Company Support criteria, which belong to the second quadrant, which means that it is the main feature that the face cream must have. It is important to mention that quadrant II includes the must-be characteristics. The high performance of the specific characteristic does not imply high satisfaction, on the contrary, low performance implies great dissatisfaction.

5. CONCLUSIONS

In conclusion, the assessment of customer satisfaction for Brilliant Rose cream reveals exceptionally high levels of approval, with 98.77% of respondents expressing satisfaction. The cream effectively meets customer demands, as indicated by a low relative overall demand (-57.18%). Cream quality, company support, and staff service emerge as key criteria with high requirements. While company support has room for improvement, its significance is evident. In summary, based on the survey's classification criteria according to Kano's three levels of quality and in relation to consumers' perceived needs, expectations, or experiences, the following findings are: 1. The characteristics that do not cause dissatisfaction while their improvement will create high satisfaction include Appearance, Staff Service and Result of cream. Therefore, non-satisfaction of the above characteristics (criteria) does not necessarily lead to dissatisfaction. 2. The basic characteristic whose low performance creates great dissatisfaction while high performance does not imply high satisfaction include the Company Support criterion. Therefore, satisfaction of this characteristic, when leading to dissatisfaction, may not bring satisfaction, yet simply eliminate dissatisfaction. 3. The criteria that have characteristics that lead to dissatisfaction with low performance and satisfaction with high performance include Price and Quality. Strategic decisions can be guided by this knowledge to enhance customer satisfaction and overall product performance. Further research can explore additional factors to gain a comprehensive understanding of customer satisfaction dynamics.

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Sustainable investments in the building sector: a critical review of financing tools and methods

Ioanna Andreoulaki * Aikaterini Papapostolou * Charikleia Karakosta * Filippos Dimitrios Mexis * John Psarras * * Decision Support Systems Laboratory, School of Electrical & Computer Engineering, National Technical University of Athens, 9, Iroon Polytechniou str., 15780, Zografou, Athens GREECE

Abstract

Although it is evident that the implementation of energy efficiency measures, upgrades of energy consuming systems and installation of sustainable technologies are effective ways of reducing energy needs and consumption in buildings, renovation rates in the EU remain quite low. A plethora of factors might hinder the application of retrofitting actions in the building sector, including technical issues, financial barriers, behavioral aspects, as well as risks related to the economy and energy market. With the aim of incentivising energy efficiency investments in buildings, an approach has been followed to identify, explore and categorise the most common financing instruments that promote retrofitting actions in the building sector. Towards this direction, a literature review of financing tools for renovation projects is conducted. Specific examples of renovation projects and financing schemes in European countries are presented, to validate the correlation between building typologies and financing schemes. Current barriers and issues that need to be addressed to encourage energy efficiency financing and, thus, increase renovation rates are highlighted. The findings of the research provide useful insights for market actors interested in energy efficiency financing and stakeholders engaged in renovation projects. Moreover, the conclusions of the analysis can become a starting point for further research on the topic, setting a basis for standardising sustainable investments in the building sector by matching renovation projects with the appropriate financing methods.

KEYWORDS

Energy Efficiency Financing, Renovation Projects, Building Retrofitting Actions, Financing Schemes

1. INTRODUCTION

The building sector is the largest energy consumer in the EU [1]. Although various measures can increase the energy performance of a building, such as building envelop interventions, upgrades in heating and cooling systems, lighting retrofitting, renewable systems installation and employment of automated systems, significant energy efficiency (EE) potential in buildings remains untapped [2].

This is due to several barriers hindering EE projects in buildings. These barriers include technical inadequacies (e. g. improper energy savings predictions [3]) or behavioral issues (consumer's behavior changes after the renovation, known as the rebound effect [1], split incentives between owners and tenants [4] etc.). There are also barriers and limits to the simultaneous energy and seismic retrofitting of structures. More specifically, seismic safety and energy efficiency upgrades should be applied together to avoid damage, life and financial losses, especially in the EU since there are a lot of seismically active countries [5]. These limits include cultural risks (related to historic design and heritage protection [6]), legal aspects (bureaucratic obstacles and lack of standards [5]), as well as social factors (insufficient awareness and knowledge regarding seismic risk [7]). The heart of the problem, however, are the financial barriers. Lack of awareness, repayment uncertainty, unavailability of private capital, high upfront costs and limited access to finance impede the application of retrofitting actions [8], [9]. In this context, the scope of this paper is to focus on the financial aspect of energy retrofitting, exploring available financing tools and their correlation with building typologies, to set the basis for standardisation of EE financing. The proposed approach is shown in Figure 1.



Figure 1: Methodological approach

Apart from this introductory session, the paper is structured as follows: In section 2 the conducted literature review is presented. In section 3 the identified financing schemes are correlated with building typologies. In section 4, the results of the research are discussed and a solution for the identified challenges is proposed. Finally, the conclusions and prospects for future research are elaborated in section 5.

2. LITERATURE REVIEW OF ENERGY EFFICIENCY FINANCING TOOLS

Using the 2019 JRC report [10] as a reference point, 2015 as a starting year and based on the selected keywords (Table 1), 83 publications were detected related to tools and mechanisms that finance EE in buildings.

Table 1: Keywords for literature review

| Finance – related | Building – related | Renovation – related |
|-------------------------------|--------------------------------------|----------------------------------|
| Financing, funds, funding, | Buildings, green buildings, nZEB, | Renovation, retrofitting, energy |
| investments, financial tools, | residential, commercial, historical, | efficiency measures, actions, |
| mechanisms, schemes | private, public, households | interventions, upgrades |

The examined sources for the literature review consist of research and review articles published in journals relevant to energy and economics, while official websites of the European Commission were investigated as well (mainly when it comes to EU funding mechanisms). The financing schemes included in the publications were categorised, as shown in Figure 2 (illustrating the percentage of publications referring to each category of financing schemes). The main categories of financing schemes that were identified are:

Grants/Subsidies: Grants are the most prominent financial tool discussed in relevant literature. They are typically provided by governments, political institutions, private foundations, or non-profit organisations and apply to a wide variety of retrofitting actions [11]. Subsidies, also provided by government agencies, encourage renovation by offering tax credits, deductions or low-interest loans, and usually apply to projects that have significant public benefits [12], [13]. Such funding mechanisms promoting EE in the building sector have been employed by the European Union (e. g. Recovery and Resilience Facility (RRF) [14], European Structural and Investment Funds (ESIF) [15]).

Funds based on achieved energy savings: This category mainly refers to Energy Performance Contracting (EPC). Energy Service Companies (ESCOs) invest in EE upgrades, providing a wide range of energy-related services. The renovation cost is covered through the energy savings [11]. Other financing tools in this category include Energy Efficiency Feed-in Tariffs (EE-FiTs), similar to feed-in tariffs for renewable energy, and Energy Efficiency Obligations (EEOs), financial rewards for EE measures [12], [16].

Tax – related financing instruments: Tax incentives might include tax credits, deductions, and accelerated depreciation [11]. Another tax-related financing tool is the Property Assessed Clean Energy (PACE), through which, building owners can finance EE improvements by lending money and repaying them thanks to a special appraisal in their property tax account [17]. Incremental property taxation also aims to encourage building owners to invest in energy renovation [18].

Debt financing: Loans and Energy-efficient mortgages (EEM) can cover the costs of various aspects of retrofitting projects and are obtained from several sources (banks, credit unions, private lenders) [12], [13].

Besides the financing schemes that fall into the above-mentioned categories, another financing method is equity financing, which refers to ownership in a company or project (selling ownership shares to investors) and is often combined with debt financing [11], [19]. Additionally, On-bill finance (OBF) enables funding of EE upgrades by lending money and repaying them through utility bills [11]. Crowdfunding is another innovative financing tool which can promote EE investments, especially for small – scale projects [20]. Finally, one-stop-shops (OSSs) offer inclusive support for EE projects, various financing options and can also provide their own financial resources (but are not purely a financing tool) [21].



3. CORRELATION OF BUILDING TYPOLOGIES AND FINANCING SCHEMES

To further explore the financial aspects of building renovation projects, an attempt was made to correlate building typologies and financing schemes based on the literature review (Table 2).

| Financial Mechanism | Building Ownership | Building Type |
|-----------------------|--------------------|-------------------------|
| Grants & Subsidies | Public & Private | All |
| RRF | Public & Private | All |
| ESIF | Public | All Public |
| EFSI | Public & Private | All |
| H2020 | Public & Private | All |
| ELENA | Public & Private | All |
| LIFE programme | Public & Private | All |
| Cohesion Policy Funds | Public | Commercial, Public |
| Tax incentives | Public & Private | All |
| Loans & EEMs | Public & Private | All |
| EEOs | Public & Private | Residential, Commercial |
| EPCs | Public & Private | Mainly non-residential |
| OBF | Public & Private | Residential, Commercial |
| PACE | Private | Residential, Commercial |
| EE-FiTs | Public & Private | All |
| OSSs | Public & Private | All |
| Crowdfunding | Private | Residential, Commercial |

Table 2: Correlation of building typologies and financing schemes

The stemmed correlation is quite broad, demonstrating that most financing mechanisms apply to buildings regardless of their ownership status and generalised building type. Thus, to gain further insight into EE financing in buildings, 65 case studies of renovation projects from 17 European countries were examined, mainly from datasets relevant to the Energy in Buildings and Communities Programme (EBC) [22] and the H2020 Triple-A project (<u>https://aaa-h2020.eu/</u>) (anonymised data accessed for research purposed by authorised partners). Indicative results of the case study examination are shown in Figure 3 and 4.



Despite the fact that the detected case studies include a wide variety of building uses, most of them considered residential buildings, as shown in Figure 3. In several cases the retrofitting actions were implemented in tertiary buildings (buildings offering specific services), such as administrative buildings, hotels or commercial buildings (mainly supermarkets and retail centers). Educational facilities, including schools, preschool buildings and day care centers, have also been examined in a considerable portion of the considered case studies. An important observation is the fact that in the residential sector, the renovation measures were not applied in single apartments or houses. Instead, the buildings have been aggregated. A few of the case studies in this category concerned social housing facilities, which are often in need of deep renovation. Entire neighborhoods have been renovated in some of the cases, thus both residential and non-residential buildings were included. The collective retrofitting of buildings located in a specific area enables the deployment of additional measures, for instance installation of heating networks or retrofitting of outdoor lighting. On the other hand, non-residential public buildings of large scale, such as administrative, educational, sports facilities or medical institutions etc. do not necessarily have to be aggregated and grouped so as to be financed and renovated.

When it comes to financing schemes (Figure 4), half of the examined case studies have been financed through funds granted by the EU or local public authorities. Not as many projects have been financially covered fully by private investors, however both private and public financing schemes have also been combined in several cases. Overall, it has been observed that based on the examined cases studies, the most commonly applicable financing schemes were subsidies, grants, and debt financing in the form of loans and EPCs.

4. DISCUSSION OF THE RESEARCH RESULTS

From the conducted review, it becomes evident that traditional financing instruments remain the most prominent in relevant literature, whereas innovative financing schemes represent a small percentage of reviewed publications, revealing the need to furtherly examine the potential of newer schemes. As far as real case studies are concerned, the most common financing schemes are grants, subsidies, loans and EPCs. Public financing was provided by the EU, local governments and municipalities. Grants were often combined with private investment, but fewer projects were financed exclusively by private financing sources. Numerous building uses are considered, but the residential sector prevails. It has been observed that grouping projects and creating aggregates is a promising method, especially for renovation of residential buildings. The concept of aggregation is also interesting when it comes to renovation of buildings located in the same geographical area, since additional retrofitting measures can be applied.

The literature review also revealed that each one of the examined financing methods presents its own challenges. For instance, grant and subsidies risk to attract free riders, and the budget provided is usually restricted [10], [12]. The success of tax – related instruments is significantly influenced by the tax collection credit of the country [12]. Furthermore, there might be insufficient awareness of tax incentives [23]. Loans are perceived as risky, while vulnerable groups might not be eligible for them [10], [12].

Some researchers believe that the market is not mature enough for EPCs, while ESCOs might also become too indebted [10], [24]. When it comes to EEOs, building occupants are not prompted to deliver more than the mandated energy savings [12]. EE-FiTs, on the other hand, risk to favor cheap EE interventions and their application might be considered too complex [10], [12]. As far as OBF is concerned, it requires credit risk

evaluation, which can be challenging, and the risk of no payment is viewed as quite high [10]. Finally, the regulatory framework of crowdfunding is still weak and online fraud remains a crucial threat [20].

As a result, to face the challenges and barriers, thus increasing the chances of project completion and success, the following steps should be applied: firstly, it is necessary to find the most appropriate technical team to execute a project, guiding the selection of optimal renovation strategy according to the building's typology. Furthermore, the projects should be matched with financiers interested in sustainability in the building sector, according to suitable energy – related and financial Key Performance Indicators (KPIs). When needed, projects could be aggregated to attract financiers. The aggregation process could be based on the identification of similarities between different projects so that they can be bundled in one larger project that will be a more interesting and worthwhile investment for the financier. Finally, parties involved in the project should document and validate results in an organised manner. To optimise and automate the process, offering standardisation of procedures, the involved parties could interact in an easy-to-use communication medium, an environment where they can participate in risk-free investments, therefore boosting EE financing in buildings.

The creation of such an environment is the ultimate goal of ENERGATE (Energy Efficiency Aggregation platform for Sustainable Investments) (<u>https://energate-project.eu/</u>), an EU-funded project developing an EE marketplace for buildings. The marketplace will be hosted on a platform with users divided into two pillars (Pillar A – building stakeholders and Pillar B – financial stakeholders) and the procedure will be divided in three main stages. During the "Fetch" stage (collection of information on building renovation projects) Pillar A users insert all the necessary data describing the EE project, in a structured, well-defined manner. In "Process" stage (aggregation and matchmaking) projects are aggregated to become more attractive investment packages. A ranked list of projects and aggregates is presented to Pillar B users based on their declared preferences and a multicriteria method. The Pillar B users can then choose a project. Finally, in "Deliver" stage (flow of "real" information) users validate project results, contributing to the standardisation of EE financing.

5. CONCLUSIONS

The conducted research reveals that, to increase renovation rates and enhance the energy performance of the building stock, there is a need to upscale private investment, since over – reliance on non – refundable financing methods such as grants is not a sustainable policy. Business models relying on revolving funds based on achieved EE should be promoted, since they encourage EE, while innovative financing schemes should be further explored. Each financing method comes with different barriers, risks and challenges that stakeholders should focus on, and in many cases combining different schemes might be preferable and more effective. The correlation of building typologies and financing schemes could be strengthened if EE financing was made more predictable and standardised. Furthermore, more effective and systematic collection of data on EE projects and financing schemes could contribute to the identification of patterns in EE financing, which could lead to process optimisation and detection of best practices. The research at hand also sets the basis for evaluating potential incorporation of various financing schemes in an interactive ICT platform, the ENERGATE marketplace.

Future research on the matter of EE financing in buildings could focus on examining more datasets and information about real life case studies (e. g. by other EU projects), to better examine the patterns of EE financing and contributing to the standardisation of sustainable investments. Furthermore, specific strategies for overcoming barriers of identified financing policies could be developed. In the context of the ENERGATE project, future research could determine the most important KPIs (e. g. payback time, energy savings etc.) which apply to different financing schemes.

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Key performance indicators in the retail sector: A literature review

Anastasia S. Saridou

Aristi Karagkouni

Athanasios P. Vavatsikos

Engineering Dpt, Democritus, University of Thrace asaridou@pme.duth.gr

University of Thrace arkaraqkouni@qmail.com Engineering Dpt, Democritus, University of Thrace avavatsi@pme.duth.gr

Production and Management Economics Dpt, Democritus Production and Management Economics Dpt, Democritus University of Thrace ddimitri@econ.duth.gr

Dimitrios Dimitriou

Abstract

In today's ever-changing and competitive retail environment, businesses are trying to keep up with new trends while maintaining profitability. They use business intelligence software to monitor various operations within the business over time such as the OnLine Analytical Process in combination with other tools. This provides retailers with metrics to track and measure their performance. Therefore, Key Performance Indicators (KPIs) are widely used in the retail industry to measure and evaluate the performance of retail businesses by combining these metrics. They provide standardization that ensures comparability, enabling both time series and sectorial analysis. Moreover, KPIs provide retailers with insight into how well their operations are performing and where improvements are needed. Retail KPIs are closely related to supply chain performance KPIs, with the former focusing on measuring business performance from the customer's perspective, while the latter measure the performance of a business's supply chain operations. Some of these retail and supply chain KPIs are interdependent as measurements of one can affect the performance of the other. In addition, they are critical to the success of a retail business because they can support data-driven decisions that provide a comprehensive view of business's effectiveness. In conclusion, the use of KPIs can ultimately lead to increased sales, improved customer satisfaction, and greater profitability for retail businesses when interpreting the indicators' results. The current research presents a literature review spanning twenty-three years identified 2,091 articles on retail and supply chain KPIs. After evaluation, 70 relevant articles were selected, with 23 journal articles selected for further analysis. This process ensured focus and consistency in the research, facilitating a comprehensive exploration of the topic. The evolution of the KPIs has therefore been recorded to explore the difference of the business's needs over these years. A total number of 502 different KPIs were identified and classified according to their performance area as suggested in the related literature (e.g. sales, inventory, growth, transactions).

KEYWORDS

Retail, Supply chain, KPIs, Performance evaluation, retail, MCDA

1. INTRODUCTION

In the dynamic and highly competitive world of modern retailing, companies strive to adapt to changing trends and achieve profitability. Businesses use business intelligence (BI) tools to monitor many operational factors over time. Retailers have access to key metrics to track and assess their performance by using technologies such as Online Analytical Process (OLAP) in combination with other resources. Key performance indicators (KPIs) also known as performance metrics are variables that denote quantifiable performance, and they are directly linked to the business goals and objectives (Karl et al., 2018). They reflect the critical areas that need to be monitored and improved to drive success. KPIs are typically defined within specific time frames, allowing for regular tracking and comparison of performance over time. Moreover, they provide meaningful information that can be used to make data-driven decisions and drive improvement. In this way, KPIs are the indicators used to measure performance against organizational objectives.

BI is critical to business sustainability because it helps marketers gain insights into business performance and understand their consumers. In addition, marketers can use these insights to create customized marketing strategies and identify market trends. Real-time data allows businesses to make decisions based on the most up-to-date information available. By accessing data as it happens, organizations can respond quickly to emerging trends, market changes, or operational issues. BI systems play a critical role in collecting data from multiple sources, while this data are then integrated and organized to create a unified view of the business (Demirdöğen et al., 2022). Once the data is collected and integrated, businesses define and establish their KPIs. BI enables businesses to effectively collect, analyze, and visualize data, while KPIs provide the specific

metrics that guide performance measurement and management. By leveraging BI capabilities, organizations can monitor their KPIs, gain insight into performance, and drive improvements in line with their strategic objectives. Additionally, georeferenced data allows them to perform local analysis and helps them make even more focused marketing strategies based on the area's characteristics. This gives the business a competitive advantage and increases revenue.

The difference between supply chain KPIs and retail KPIs is their focus but they are also closely related and can have a significant impact on each other. Supply chain KPIs measure the performance of a business's supply chain operations, while retail KPIs measure the performance of the business from a customer-facing perspective (Anand & Grover, 2015; Kim & Kim, 2009). These KPIs, when combined, may help firms streamline their operations, increase profitability, and deliver better customer service. Thus, MCDA provides valuable information in the process of selecting the appropriate KPIs for a business. It provides a structured framework for evaluating different KPI options or alternatives. It is the process of identifying relevant criteria and assigning weights to them that reflect their importance. Each KPI option is assessed against the identified criteria using appropriate evaluation techniques. MCDA generates rankings for each KPI option based on the evaluation results. These rankings help identify the most suitable and relevant KPIs for the business. The rankings consider the weighted criteria and provide an objective basis for decision-making.

2. METHODOLOGY

In the context of evaluating a retail business and supply chain performance as they are interconnected a literature review was conducted to identify KPIs used to measure performance. For the purpose of this research, a specific time frame of twenty-three years, spanning from 2000 to 2023, was defined. A comprehensive search, a total of 2,091 articles. Subsequently, duplicates were removed, resulting in a selection of 1,221 articles (fig.1). To ensure relevance to the study's focus on KPIs in the context of the retail and supply chain sector, a careful examination of titles and abstracts was performed, leading to the identification of 90 articles meeting the criteria. Further refinement of the selection process involved a thorough reading of the introductions and conclusions of the 90 articles. This step aimed to narrow down the list to only those articles directly associated with the research topic. As a result, a final set of 70 articles were considered for further analysis, excluding case-specific articles as they showed no correlation with the subject matter. This decision led to a final set of 23 journal papers that served as the primary sources for the research. All literature can be found in the references section.



Figure 1: Research design flow chart.

3. FINDINGS

Over the period spanning from 2000 to 2023, there has been a noticeable rise in the volume of published research papers focusing on the topic of KPIs within both the retail and supply chain sectors (fig.3-left). Through an extensive review of the articles, a comprehensive compilation of 502 distinct KPIs was obtained, thoughtfully organized into various categories. These categorizations revealed diverse themes, each uniquely distinct from one another, albeit exhibiting some areas of commonality. In the course of our research, an all-encompassing analysis allowed the discrimination of eight distinct categories. Subsequently, we diligently allocated the majority of the collected KPIs into these specifically identified categories. A total of 128 KPIs were found to be related to the financial perspective, with the most common being return on investment (used 5 times), return on assets, return on equity, and payback period among the 23 papers examined.



Figure 2: KPIs categorization and description.

Seventeen were centered around employee category, and 24 focused on the customer perspective. Moreover, 73 KPIs were categorized under the agility category, 35 were associated with the environment, 96 were related to internal processes, 19 pertained to inventory management, and 8 revolved around suppliers. Lastly, a subset of 102 KPIs emerged as case-specific, defying classification within any of the predefined categories. Figure 2 presents a comprehensive compilation of the frequently observed KPIs along with their corresponding descriptions. In the context of selecting the appropriate KPIs, MCDA methods were used in the literature in addition to adding weights to them. To discern the most significant KPIs from a range of available options, MCDA methods are employed, with the widely renowned fuzzy-AHP emerging as a prominent choice (fig.3-right). Other methods used are AHP, TOPSIS, fuzzy DEMATEL, fuzzy TOPSIS etc.



Figure 3: Number of articles per year (left), cumulative number per MCDA method used (right).

4. CONCLUSIONS

Over the years, there has been a notable and continuous growth in the publication of scientific papers, highlighting the increasing significance and necessity of monitoring various aspects within the retail business and its supply chain operations. Particularly, in the pursuit of sustainable business practices, the deployment of business intelligence software becomes crucial, as it provides real-time updates of data to effectively monitor performance. As a result, the formation of Key Performance Indicators offers a diverse array of metrics, enabling data-driven decisions through the comprehensive interpretation of these valuable data points. Multicriteria decision analysis encompasses a diverse array of methodologies, each capable of offering effective solutions when it comes to the selection of the most important KPIs from a given set of options. These methods provide valuable decision-making frameworks that consider multiple criteria and facilitate the identification of KPIs that align most closely with organizational objectives and priorities.

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Robustness in ordinal regression analysis: The effect of additional constraints on the MUSA method

Stratos Kartsonakis School of Production Engineering and Management, Technical University of Crete University Campus, Kounoupidiana 73100 Chania, Greece Evangelos Grigoroudis School of Production Engineering and Management, Technical University of Crete University Campus, Kounoupidiana 73100 Chania, Greece

Abstract

Ordinal regression aims at inducing parameters of a preference model (parameters of a value function), which represents some holistic preference comparisons of alternatives given by the Decision Maker (DM). One of the most widely used ordinal regression approaches is the MUSA (Multicriteria Satisfaction Analysis) method. The main objective of the MUSA method is to assess collective global and marginal value functions by aggregating customer's judgments. It uses linear programming (LP) techniques for its solution and, similarly to the additive utility models of the UTA methods, it consists of a post-optimality analysis phase in order to overcome stability issues. Given the LP modelling of the MUSA method, it is possible to add or remove constraints in order to improve the stability of the solution. One of the most intriguing proposals refers to the additional properties for the assessed average indices. However, there is not extended research on how the extra constraints affect the robustness of the MUSA method. Hence, the goal of this study was to conduct a comparative analysis between the basic MUSA method and the extended one under various scenarios. A data generator was created in order to compare the solutions of different and various cases under a simulation process. The results indicate that in certain scenarios, there is indeed an improvement of the stability of the MUSA method, but the main outcome is that it can assist the DM to apply the basic or the extended version of the MUSA method, but the main outcome is that it can achieve more reliable feedback on customer satisfaction evaluation and analysis.

KEYWORDS

MUSA method; Ordinal regression analysis; Robustness.

1. INTRODUCTION

Ordinal regression is a technique designed to estimate the parameters of a preference model, specifically the parameters related to a value function. This value function captures overall preference comparisons made by the Decision Maker (DM), as discussed by Greco et al (2010). The process of parameter estimation in ordinal regression is carried out using an aggregation-disaggregation approach, as introduced by Siskos et al. (2005).

In practical decision-making scenarios, directly extracting preference information from the DM can be impractical due to the significant cognitive effort involved. Consequently, within the context of Multi-Criteria Decision Analysis (MCDA), several methods have been proposed to indirectly determine the parameters that define the decision model. This indirect approach to preference elicitation is less cognitively demanding and is predominantly employed within the framework of ordinal regression (Corrente et al., 2013).

One of the most commonly employed techniques for ordinal regression is the MUSA (Multicriteria Satisfaction Analysis) method. MUSA is a multicriteria preference disaggregation approach that offers quantitative measures of customer satisfaction. Its primary objective is to assess collective global and marginal value functions by aggregating customer judgments (Grigoroudis and Siskos, 2010). This method adheres to the principles of ordinal regression analysis under constraints and employs linear programming (LP) techniques for its solution, Since its introduction the MUSA method has been implemented in various cases in the banking sector, in the shipping sector in the education sector, in logistics, in the health sector, for estimating the satisfaction of seasonal employees in summer destination luxury resorts (Grigoroudis et al., 2002), (Siskos et al., 2001), (Politis and Siskos, 2004), (Manolitzas et al., 2014), (Glaveli et al., 2019) etc.

The utilization of LP modeling in the MUSA method often leads to the challenge of multiple or nearly optimal solutions, impacting the robustness of the results provided. Factors such as data quality and the inability to engage with customers contribute to the complexity of finding consistent solutions. Additionally, there may

be a disparity between the decision-maker's 'true' model and the model derived from the computational disaggregation process, as highlighted by Siskos et al. (2005).

Generally, the robust analysis in multicriteria decision analysis has gained significant attention over the last years. Robustness according to Roy (2010) can be considered as a tool for decision analysts to eliminate approximation and ignorance zones. Moreover, robustness should refer to the result and the decision support activities. In the area of ordinal regression multiple approaches have been proposed such as UTA^{GMS} (Greco et al., 2008), GRIP (Figueira et al., 2009) and RUTA (Kadziński et al., 2013).

In the MUSA method, robustness is addressed as a problem of post or near-optimality analysis, particularly concerning the form and scope of the feasible solution polyhedron, where the variance observed in the post-optimality phase reflects the degree of final result instability. The LP formulation of the method allows for the incorporation of additional constraints related to specific characteristics of the evaluated model variables. Grigoroudis and Politis (2010) introduced an extended version of the MUSA method, which introduces constraints related to additional properties of the assessed average indices. These properties encompass:

- a. Average satisfaction indices, representing the mean values of the global and marginal value functions, serving as fundamental performance benchmarks.
- b. Average demanding indices, which indicate the customers' level of demand and denote the average deviation of the estimated value functions from a 'normal' (linear) function.

Within this context, the principal objective of this study is to assess the impact of robustness when additional constraints are integrated into the fundamental LP framework of the MUSA method. To explore how robustness is influenced, we conducted a comparative analysis between the core MUSA method and the extended version with additional constraints. Through the development of a simulation model, we were able to observe and compare the two methods across various scenarios, ultimately yielding precise outcomes.

2. MUSA METHOD AND ADDITIONAL CONSTRAINTS

The MUSA method assesses global and marginal value functions, Y^* and X^* by aggregating customer's judgments about their global satisfaction Y and their satisfaction with regard to the set of discrete criteria X_i . The primary aim of this method is to attain the highest possible consistency between the value function Y^* and the customers' judgments Y (Grigoroudis and Siskos, 2010). It adheres to the principles of ordinal regression analysis within specific constraints and employs linear programming (LP) techniques for its solution with a methodological framework initially developed by Siskos et al. (1998). The equation for ordinal regression analysis, with the inclusion of a double-error variable, has the following form:

$$Y^{*} = \sum_{i=1}^{n} b_{i} X_{i}^{*} - \sigma^{+} + \sigma^{-}$$

 Y^* is the estimation of the global value function, n is the number of criteria used in the analysis, b_i is the weight of the *i*-th criterion, while σ^+ and σ^- are the overestimation and underestimation errors, respectively. The sum of weights $\sum_{i=1}^{n} b_i X_i^*$ is equal to one. Both global and partial functions, Y^* and X_i^* , are monotonic and normalized in the interval [0,100]. In order to assure monotonicity, MUSA uses the following transformation equations:

$$z_m = y^{*m+1} - y^{*m} \text{ for } m = 1, 2 \dots a - 1$$
$$w_{ik} = b_i x_i^{*k+1} - b_i x_i^{*k} \text{ for } k = 1, 2, \dots, a_i - 1 \text{ and } i = 1, 2, \dots n$$

Where *a* and a_i are the number of levels of global and partial functions, x_i^k is the level of criterion $i(k = 1, 2, ..., a_i$ and y^m is the m level of total satisfaction (m = 1, 2, ..., a)

Thus, the basic LP formulation of the MUSA method is the following:

$$\begin{cases} [min]F = \sum_{j=1}^{m} \sigma_{j}^{+} + \sigma_{j}^{-} \\ subject to \\ \sum_{i=1}^{n} \sum_{k=1}^{t_{ij}} w_{ik} - \sum_{m=1}^{t_{j-1}} z_{m} - \sigma_{j}^{+} + \sigma_{j}^{-} = 0 \ \forall j \\ \sum_{m=1}^{a} z_{m} = 100 \\ \sum_{i=1}^{n} \sum_{k=1}^{a-1} w_{ik} = 100 \\ z_{m} \ge 0, w_{ik} \ge 0, \sigma_{j}^{+} \ge 0, \sigma_{j}^{-} \ge 0, \forall i, j, k, m \end{cases}$$

As previously highlighted, the MUSA method incorporates a post-optimality analysis to address the challenge posed by optimal or post-optimal solutions, providing valuable insights into the stability of the derived results. Consequently, the final solution is obtained by exploring the polyhedron of near optimal solutions, which is produced by the constraints of the previous LP.

 $\begin{cases} [min]F' = \sum_{k=1}^{a_i-1} w_{ik} \text{ for } i = 1, 2, \dots n) \\ \text{ subject to } \\ F \leq F^* + \varepsilon \\ \text{ all the constratins of the LP} \end{cases}$

where F^* is the optimal value of the objective function of the basic LP and ε is a small percentage of F^* .

The reliability evaluation of the analysis relates to both the fitting index and the stability index (Grigoroudis & Siskos, 2010). The average fitting indices (AFI) are related to customer satisfaction data, while the average stability index (ASI) is related to the results of post-optimality analysis (Grigoroudis & Siskos, 2010).

Table 1: Fitting and Stability Indexes

| AFI1 | AFI ₂ | AFI ₃ | ASI |
|------------------------|------------------|---|---|
| $1 - \frac{F^*}{100M}$ | $\frac{M_0}{M}$ | $1 - \frac{F}{M\sum_{m=1}^{a} p^m \max\{j\}}$ | * $y^{*m}, 100 - y^{*m}$ } $1 - \frac{1}{n} \sum_{i=1}^{n} \frac{\sqrt{n \sum_{j=1}^{n} (b_i^j)^2 - (\sum_{j=1}^{n} b_i^j)^2}}{100\sqrt{n-1}}$ |

Among the key outcomes yielded by the MUSA method, the average satisfaction indices hold significant importance. The estimated value/satisfaction functions show the real value, in a normalized interval [0, 100], that customers give for each level of the global or marginal ordinal satisfaction scale. The form of these functions indicates the customers' degree of demanding.

$$S = \frac{1}{100} \sum_{m=1}^{a} p^m y^{*m} S_i = \frac{1}{100} \sum_{k=1}^{a_i} p_i^k x_i^{*k}$$

offer insights into the level of demand exhibited by customers. These indices are evaluated using the following formulas refer to the average global and partial demanding indices, which represent the average deviation of the estimated value curves from a 'normal' (linear) function. These indices are normalized in the interval [-1, +1] and offer insights into the level of demand exhibited by customers. These indices are evaluated using the following formulas:

$$D = \frac{\sum_{m=1}^{a-1} (\frac{100(m-1)}{a-1} - y^{*m})}{100 \sum_{m=1}^{m-1} \frac{m-1}{a-1}} \quad D_i = \frac{\sum_{k=1}^{a_i^{-1}} (\frac{100(m-1)}{a_i^{-1}} - x_i^{*k})}{100 \sum_{k=1}^{a_i^{-1}} \frac{1}{a_i^{-1}}}$$

Given the LP formulation of the MUSA method, additional constraints may be considered regarding special properties of the assessed model variables. Assuming that that the global average satisfaction index S is an aggregation of the partial average satisfaction indices S_i and if a weighted sum aggregation formula is used, then the following property occurs:

$$S = \sum_{i}^{n} b_{i} S_{i} \iff \sum_{m=1}^{a} p^{m} y^{*m}$$

Considering the transformation variables z_m and w_{ik} , the previous formula can be rewritten as follows:

$$\sum_{m=2}^{a} p^m \sum_{t=1}^{m-1} z_t = \sum_{i=1}^{n} \sum_{k=2}^{a_i} p_i^k \sum_{t=1}^{k-1} w_{it}$$

Similarly, a weighted sum formula may be assumed for the demanding indices:

$$\frac{\sum_{m=1}^{a-1} 100(m-1) - (a-1)\sum_{t=1}^{m-1} z_t}{a(a-1)} = \sum_{i=1}^n \frac{\sum_{k=1}^{a_i} (k-1)\sum_{t=1}^{a_i-1} w_{it} - (a-1)\sum_{t=1}^{k-1} w_{it}}{a_i(a_i-1)}$$

Considering the previous modelling, which refers to the desired properties of the collective preference system an extension of the MUSA method may be modelled as a MOLP problem:

$$[min]F = \sum_{j=1}^{M} \sigma_{j}^{+} + \sigma_{j}^{-}$$
$$[min]F_{sd} = \sum_{j=1}^{M} s_{j}^{+} + s_{j}^{-} + \sum_{j=1}^{M} d_{j}^{+} + d_{j}^{-}$$
Subject to:

All the constraints of the basic LP of the MUSA method All the constraints regarding the satisfaction and demanding indices

Where $s_i^+ + s_j^-$ are the respective overestimation and underestimation errors of the constraints on the desired properties of S, and $d_i^+ + d_i^-$ are the respective overestimation and underestimation errors of the constraints on the desired properties of D.

3. EXPERIMENTAL COMPARISON ANALYSIS

"Experimental research stands out as the primary approach for assessing and contrasting alternative methodologies. The initial phase of the experimental comparison analysis revolves around structuring a simulation model, with the objective of producing customer satisfaction datasets with different predefined attributes, as illustrated in Table 2."

Table 2: Properties of the generated data sets

| Customers | Criteria | Satisfaction Scale | Deviation Level | Beta.Inv(a,b) | Beta.Inv (a,b) |
|-----------|----------|--------------------|------------------------|---------------|----------------|
| 200 | 5 | 5 | 1 | 6 | 1,7 |
| 500 | 10 | 7 | 0.5 | - | - |
| 800 | 15 | - | - | - | - |

The next step includes the generation of a set of value functions for the overall satisfaction Y^* and the marginal satisfaction $b_i x_i^{*k}$ (i = 1, 2, ..., n), where the following principles must be followed:

- $\begin{array}{ll} & y^{*1}=0 \mbox{ and } y^{*a}=100 \\ & y^{*m}\leq y^{*m+1}, \mbox{ } m=1,2,\ldots,a-1 \\ & b_i x_i^{*1}=0 \mbox{ and } \sum_{i=1}^n b_i \, x_i^{*a_i}=100 \mbox{ } i=1,2,\ldots,n \\ & b_i x_i^{*k}\leq b_i x_i^{*k+1} \mbox{ } k=1,2,\ldots,a_i-1 \mbox{ and } i=1,2,\ldots,n \end{array}$

Then, the subsequent phase involves the data generation process where random values: $v_1, v_2, ..., v_n$ with $v_n \sim B(a, b)$ are generated respecting the produced satisfaction levels. The beta distribution has been chosen, due to the fact that it is able to produce data that are more fitting to real customer's judgments. The final step entails a consistency validation using the formula: $\sum_{i}^{n} b_{i} x_{i}^{*ij} - y^{m} \leq 1$ D_e . If the values $v_1, v_2, ..., v_n$, are consistent they are added to the data set, else they are rejected, and new random values are generated.

Through the aforementioned simulation process, 36 datasets were generated, and both the MUSA method and its extended version were applied to these datasets. It's noteworthy that each of the 36 datasets underwent approximately 100 iterations during the simulation to ensure the acquisition of more precise results.

4. RESULTS

Table 3 showcases the primary results from three distinct datasets, each notable for its varying number of customers. Notably, the average stability index (ASI) exhibits a substantial increase when additional constraints are integrated compared to the basic MUSA method. These findings are justified by the fact that

the incorporation of additional constraints restricts the polyhedron of the feasible solutions, thereby yielding results characterized by greater robustness.

Table 3: Fitting and stability comparison results

| | | | | | | | Ν | /IUSA | | | M | JSA _{sd} | |
|-----------|----------|-------|----|-----------|-----------|-------|-------|-------|-------|-------|-------|-------------------|-------|
| Customers | Criteria | Scale | De | beta(a,b) | beta(a,b) | AFI_1 | AFI_2 | AFI_3 | ASI | AFI_1 | AFI_2 | AFI_3 | ASI |
| 200 | 5 | 5 | 1 | 6 | 1.7 | 0.908 | 0.066 | 0.897 | 0.683 | 0.908 | 0.070 | 0.898 | 0.993 |
| 500 | 5 | 5 | 1 | 6 | 1.7 | 0.906 | 0.057 | 0.895 | 0.590 | 0.907 | 0.055 | 0.897 | 0.994 |
| 800 | 5 | 5 | 1 | 6 | 1.7 | 0.905 | 0.055 | 0.894 | 0.552 | 0.905 | 0.057 | 0.895 | 0.994 |

Furthermore, it's noteworthy that the fitting indices remain nearly unchanged, suggesting that the introduction of additional constraints has a negligible impact on the fitting level of the MUSA method.

The enhancement in robustness is also substantiated by the variance observed in the weights during the postoptimal analysis phase. For instance, as illustrated in Table 4, the weight assigned to criterion 1 fluctuates from 0.056 to 0.512 when using the basic MUSA method, whereas this variation is significantly reduced in the extended version of MUSA. Similar findings were observed in other datasets created, reinforcing the notion that the average final solutions achieved by MUSA_{sd} are more representative.

| | | MUSA | MUSA _{sd} | |
|-------------|---------|-------|--------------------|--|
| Criterion 1 | Min | 0.056 | 0.092 | |
| | Max | 0.512 | 0.093 | |
| | Average | 0.284 | 0.924 | |
| Criterion 2 | Min | 0.150 | 0.170 | |
| | Max | 0.669 | 0.177 | |
| | Average | 0.409 | 0.173 | |
| Criterion 3 | Min | 0.089 | 0.155 | |
| | Max | 0.612 | 0.182 | |
| | Average | 0.351 | 0.169 | |
| Criterion 4 | Min | 0.078 | 0.186 | |
| | Max | 0.438 | 0.192 | |
| | Average | 0.258 | 0.189 | |
| Criterion 5 | Min | 0.073 | 0.364 | |
| | Max | 0.442 | 0.390 | |
| | Average | 0.258 | 0.377 | |

Table 4: Variance of weights

5. CONCULSIONS

The primary focus of this study was to assess the robustness of the original MUSA method in comparison to an extended version that incorporates additional constraints pertaining to the desired properties of the assessed global and partial satisfaction and demanding indices. This extension is formulated as a Multiple Objective Linear Programming (MOLP) problem, with a heuristic approach employed to attain satisfactory solutions. To explore the scope of this research, a novel simulation model was constructed to generate datasets with characteristics resembling real-life customer judgments.

The integration of additional constraints into the original MUSA method appears to notably enhance the stability of the results provided. Remarkably, the fitting level remains consistent in both cases, suggesting that the inclusion of additional constraints does not entail a tradeoff between stability and fitting level in the method.

Given that the experimental analysis was conducted using artificial data, the validation of these findings could be further strengthened by collecting real data with diverse characteristics and applying both methods. Furthermore, it may be beneficial to explore additional MOLP techniques. Lastly, the development of additional fitting and stability measures could facilitate the investigation of various extensions of the MUSA method."

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Introducing a "Smart" Urban Governance concept through novel policy and process holistic approaches.

Dr. Ioulia Moraitou Department of Civil Engineering University of West Attica Petrou Ralli & Thivon 250, 122 44 Egaleo Professor Georgios Varelidis Department of Civil Engineering University of West Attica Petrou Ralli & Thivon 250, 122 44 Egaleo

Abstract

This paper anticipates contributing to policy analysis for regional-urban development in times of recovery from economic/fiscal-migration- COVID 19 pandemic- and climate change crises. These crises while constantly question the policy process, tools, and achievements/outcomes, urge for an approach that will be discussing among others a new set of research questions and response tools (e.g. the World Bank urban regeneration tool). With the aim to provide an enhanced assistance to decision making highlighting the role of infrastructures as investments is important. Exploring the use of theoretical, technological, and analytical tools, while increasing the understanding of these factors, potentially provides optimized strategic planning and related decisions, to positively affect both cities' efforts and their users, by delivering a "smart" urban governance process.

KEYWORDS

Urban regeneration, smart urban governance, innovations, investments, climate change, strategic planning.

1. INTRODUCTION

Crisis and post crisis countries are most of the times countries in a long-term transformation phase often risking to not occur finally. Political and administrative reforms, Urban Governance and Regional Development are key topics in a development - resilience agenda dialogue. Post crisis (economic, social, environmental, public health) and recovery periods are decisive to reach Resilience. Past and current conditions, in a context of crises (financial/migration/ COVID 19 – Public Health & economic / energy crisis / system inflation crisis), in southern Europe, mainly resulting from a continuing decline in economic activity and recurrent heavy impacts out of a refugee/immigration crisis, combined with COVID-19 pandemic, are some of the most critical challenges that Greece (and its regions and its cities) has to face too.

The economic crises from which some countries are still recovering has been the worst economic downturn for at least the last fifty years. The new Great Depression that started in 2008 had different expressions and impacts across countries around the world. Crisis has also an important impact on regions among which and the metropolitan ones. Regional economies are important parts of the economy especially in Europe. European Union itself has built upon and evolved through regionalism. European regional policy was the driving force for promoting competitiveness and strengthening cohesion of the new Europe.

Through the implementation of multi-level and multi-annual programming a large amount of funds has been invested in economic cohesion. The crisis puts at great risk the achievements of cohesion policy since regional economies experience a significant decline in economic activity which questions the viability of local economies and the sustainable path for economic convergence.

2. THE CHALLENGES: FROM COHESION TO RESILIENCE

These long-term challenges along with their asymmetric impacts in the various EU member states urge academia and practitioners to call for anchoring Cohesion more firmly in the territories and place Cohesion Policy as the Game changer. (Council Conclusions on the Communication on the 8th Cohesion report "Cohesion in Europe towards 2050", Council 9796/22).

These new conditions reinstate issues of social inclusion, spatial (urban) resilience, creativity-productivity, urban rehabilitation, risks reduction and the need for innovative practices when setting the priorities of

development strategies, from the European to the local level, while the tourism sector is seen as one of the strongest development tools (though easily vulnerable) in the effort for sustainable urban development.

Apart from its global perspective this is also about a crisis of urbanization. In an urbanized world the urban dimension of economic, migration and climate crisis and the ways out, constitute hot topics for the viability of the current global economy and social resilience. As a result, it comes with no surprise that most impacts of economic crisis were more evident in cities. The housing market which triggered the crisis is firmly connected with the agglomeration of people and economic activities in cities. The financial and real estate activities affect primarily cities and locate in cities. All these could potentially end up into a necessary RESTART, in the aftermath of crises.

Cities have become the arena for the modern economy and have become the new nexus for contradiction between prosperity and poverty, employment opportunities and social exclusion. Such target also requires to primarily include all the above stated concepts in a wider research discourse (both applied and theoretic), by potentially investigating the specific typologies, exploring the processes of social integration-insertion, by checking likely conflicts and available techniques that could enable policies innovation and feedback in view of new, 'decentralized' but "holistic" governance roadmaps.

The green and digital transitions are major challenges which offer new opportunities for European growth towards which we should orient our investments and ensure fair adaptation, to avoid new disparities arising from these transitions.

Innovation, entrepreneurship, and economic diversification as well as good governance can be key determinants of long-term regional economic growth and of a greater resilience to asymmetric shocks (Council Conclusions on the Communication on the 8th Cohesion report "Cohesion in Europe towards 2050", Council 9796/22).

This work targets among others to underline the weight (importance) of an assessment of: the mechanisms of local growth and the urban, economic, and/or physical regeneration; the factors and activities that influence the landscape and the uses of a city with the aim at enhancing cohesion and urban resilience; for instance, by highlighting the role of infrastructures as investments and of commerce, tourism and other productive sectors enhancing both creative activities and innovation in the city. Increasing the understanding of these factors could be an ideal step when studying the complexity in decision – making and the concrete ways to facilitate a "priorities-planning/policy" process.

3. CITIES OF TOMORROW; A 'SOCIAL EXPERIMENT' IN A POST CRISES ERA

If we decide to put more light to the territorial and transformational dimensions of a development model (place based and climate neutral one, in accordance with the new Territorial Agenda and Leipzig Charter) it is very important to take over a role of further exploring critical parameters in this process, to enable territorial cohesion. At this point it is important to highlight the role of social innovation in the process of participatory and collaborative urban planning, expected to act as transitions catalyst.

To do so European policies framework is often giving the green light; for example, Eurocities, focus on the New Leipzig Charter, «It's a new chapter for urban development that builds on the earlier Leipzig Charter, from 2007, and the more recent experience of the Urban Agenda for the EU, both of which have inspired urban policy in Europe and beyond. The New Leipzig Charter helps to refocus on the linkages between urban governments and other levels of governance. It also provides an urban policy framework to deliver global and European agreements such as the United Nations 2030 Agenda for Sustainable Development and the Paris Agreement, the Urban Agenda, and the European Green Deal». And the European Parliament has voiced its support for the Leipzig Charter with his 2008 resolution; moreover, its relevant explanatory texts underline that the «Transformative power of European cities, identifies three spatial levels of European cities – the neighborhood level, local authorities and functional area – as well as three dimensions of European cities – just, green and productive – which, when combined, can help to build resilient cities that can deal with social, economic and ecological challenges and ensure a high quality of life for all. While recognizing that the key working principles from the 2007 Leipzig Charter are still valid, section three on the key principles of good urban governance emphasizes that they need to be updated in view of today's global challenges and implemented by all urban development actors, outlining five key principles: urban policy for the common

good, integrated approach, participation and co-creation, multi-level governance and a place-based approach».

The proposed hybrid concept and action plan (theoretic and applied) particularly cares to comply with the historic policy background and new guidelines framework of the Charter focusing both on the three spatial levels of the European cities for its proposed implementations (urban regeneration areas from the neighbourhood level to the functional area level) as well as the five principles as proposed especially for urban cohesion, multilevel governance, and the place-based approach.

Along the same lines the World Bank stresses that, "Every city has pockets of underused and underutilized land or distressed and decaying urban areas. These pockets of underused land weaken the city's image, livability, and productivity. They are usually the result of changes in the urban growth and productivity patterns". In addition, Roberts and Sykes depict that "Urban regeneration is a widely experienced but little understood phenomenon. Although most towns and cities have been involved in regeneration schemes, and whilst many development companies, financial institutions and community organizations have participated in one or more such ventures, there is no single prescribed form of urban regeneration practice and no single authoritative source of information". At the same time, competitiveness - cities' ability of creating job opportunities and attracting investments – and inclusion – a phenomenon that, for Sameh Wahba, is intrinsically linked to distortions in land and housing markets - are part of the key challenges that local governments must face in order to offer optimal living conditions for people. Those three main urban challenges - resilience, inclusion, and competitiveness - are what any urban transformation project that seeks to generate a positive impact from an integrated perspective must address». Multiple examples of this approach can be urban renewal projects targeting at achieving «improved living conditions for a large population that has been living close to the city center but historically shut off from economic opportunities and improved services».

Very relevant in this perspective is an assessment of a) the mechanisms of local growth and the urban, economic, and/or physical regeneration; b) the factors and activities that influence the landscape and the uses of a city (primarily focusing small – medium sized urban centers; c) the introduction of targets such as those of urban cohesion and resilience. These components draw on the complexity in decision–making while exploring the concrete ways to facilitate a "priorities-planning/policy" process.

To strategically plan and sustainably implement that type of projects consensus is essential; again, for Roberts and Sykes "consensus is based on the premise that successful urban regeneration requires a strategically designed, locally based, multi-sector, multi-agency partnership approach. The emergence of such partnerships can be seen as a particular response and challenge to the rapid and fundamental social, economic, and institutional changes that society has witnessed over the past few decades... The industrial revolution made cities the focus of production, population, culture, and society in Britain and elsewhere but the last three decades have been characterized by a loss of employment and population, a relocation of manufacturing and the readjustment of other economic structures. After a long period of continued growth, the advent of decline led to questions being asked about the role of the city in a modern economy, including the need for cities to readjust to current multifaceted and very complex challenges (such as cc, pandemics, natural and manmade disasters, migratory movements, terrorism, and hybrid warfare events)".

Analysis would be also focusing (on a case by case basis) for example: on revealed or stated preferences modelling about various urban services, residential locations, household moving behaviour in relation to background variables, housing market variables, housing and location attributes; relevant stakeholders would be approached around the hot spots and/or other areas (sample areas) in order to assess the size and the impact of a potential rise of an 'insecurity' feeling to the local social and economic activities.

By acknowledging that in the urban environment context, development policies that are often proposed for implementation are largely based on regeneration strategies, on rehabilitation to the existing building stock and of the open space, then it is also possible to underline that the expected results are often encouraging for mainly middle and richer classes most of the times at the expense of the weaker that already lack the financial means to move to better housing conditions. Minding to carefully insert in the regeneration approach the notions of territorial justice and quality of life definitions by the local stakeholders directly, this is the first step towards cohesion and resilience at the urban scale, complying with the Green Deal, the 2030 Territorial and 2020 Leipzig agenda priorities as well.



Figure 1: Tools for Urban Regeneration – the four phases. (Source: About /Urban Regeneration, worldbank.org)

As regeneration is a long-term, transformative process of change that entails disruption and risk, political leadership is essential to managing the change process so that the "city" that is, the multiple constituencies ranging from corporate and business chief executives to locals/residents, feels engaged in the process, understands its importance to the future of the city, and has genuine outlets in which to participate.

It is in the nature of the regeneration projects that their benefits are often not realized and experienced until much later, whereas the sacrifices (budget trade-offs), risks (investment of public funds), and hardships (such as residential and business displacement) are experienced up front in the early years of the project.

Their spatial and environmental dimension primarily involve the study of the urban density and morphology, land cover/use (open/public space availability), building stock (including building heights), demography – ageing- migration- vulnerable population typologies, mobility, micro-climatic conditions, and topography.

Furthermore, their socio-economic dimension includes an assessment of the necessity for more decentralization and for institutional flexibility, simplification, upgrading with the cooperation of the local authorities and the National and Regional Statistical Services or other specialized statistic services a considerable amount of information will be collected to inter-relate the socio-economic characteristics of the regions of reference.

The political leadership must provide the confidence that the costs and benefits of regeneration are in the best interests of the city. Communicating this effectively and openly is essential. <u>About | Urban Regeneration</u> (worldbank.org).

4. CONCLUSIONS

Nowadays, multifaceted types of crises are affecting all countries: rich, emerging, poor and the various existing city typologies. So far, health and economic challenges are mainly tackled, but what about the social, the spatial, the ecological, the developmental, and the geostrategic- safety - security ones? What are the lessons generated?

To effectively contribute at gaining a greater understanding of how cities could be benefiting from long term sustainable outcomes through better analysis, planning efforts, governance and responses; to do so, the following key - interrelated thematic topics are critical: city centre redevelopment, urban revitalization processes, multicultural city, social dynamics social integration and insertion, creativity, entrepreneurship and tourism in the city, risks reduction, flexibility and simplicity in the institutional framework, citizens and local stakeholders which can generate more sustainable, resilient and open systems at city level.

Addressing the question how exactly to speed recovery while focusing on providing better planning responses we could propose: a) an integrated-sustainable urban governance model for cities centres in the context of the new 2030 territorial agenda and the New European Green Deal urban strategies, urban planning, b) a new, "smart" role of Infrastructures as long-term Investments serving both an enhanced connectivity target and a new "circular" economy approach.

To better link Research results with decision making processes at the local and regional levels three similar methodological approaches are highlighted with the aim to further generate and valorise win - win results (World Bank methodology, Panteion University post graduate programme exercise 2015-2018, the World Bank Urban regeneration tool etc.).

The local authorities and the relevant University Departments could take further action towards the implementation of all the above stated points. This would be also an additional opportunity for more urban renewal in the degraded (distressed) urban space of the Greek Capital, and elsewhere nation-wide.

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Adopting Unmanned Aerial Vehicles (UAVs) for real-time stock count process in warehouse facilities: Evidence from experimental results

Nikolaos–Christoforos Thomaidis Department of Financial & Management Engineering, School of Engineering, University of the Aegean, 41 Kountouriotou Street, 82100, Chios, Greece, <u>fmer21003@fme.aegean.gr</u>

Vasileios Zeimpekis

Department of Financial & Management Engineering, School of Engineering, University of the Aegean, 41 Kountouriotou Street, 82100, Chios, Greece, <u>vzeimp@fme.aegean.gr</u>

Abstract

E-commerce has skyrocketed since COVID-19 hit, with consumers increasingly ordering items online rather than venturing out to a store, demanding rapid delivery and easy returns. To address customers' requirements, logistics operations and especially warehouse process must be more efficient and cost effective. The use of emerging technologies to manage warehouses in an efficient and timely manner is vital and Unmanned Aerial Vehicles (UAVs) are considered a key technology for that. UAVs may execute repetitive and demanding logistics tasks with minimal human intervention or supervision, making them an economical and safe solution for warehouse operations completion, including stock count. The latter is a critical process since it allows warehouse staff to regularly monitor and increase gross profit, reduce loss, improve control of allowances, and reduce waste. This article presents evidence from experimental results that assess the use of UAVs coupled with RFID technology for real-time stock count execution. The results from laboratory experiments demonstrate the effect of certain operational parameters, such as UAV speed, number of rack levels, and RFID tag location on products, during the execution of the stock count process in terms of RFID reading accuracy and efficiency. A 2⁴ full factorial design (design of experiment) is used to test UAV and RFID technology in a warehouse with products that are stored in an ambient environment. The results of the experiments are encouraging showing that the use of UAVs coupled with RFID tags may support faster, cost-effective, and safer stock count in warehouses.

KEYWORDS

drones, logistics, industry 4.0, stock count, warehouse, RFID technology

1. INTRODUCTION

Managing warehouses has become increasingly complex due to factors such as the demand for more frequent and smaller order execution, increased e-commerce sales, international competition, and the need for faster response times (de Koster et al., 2007; Marchet et al., 2015). The concept of Industry 4.0 has paved the way for smart warehouses that use the latest advances in technological enablers like automation and robotics. Unmanned Aerial Vehicles (UAVs) are considered a key technology for smart warehouses since they can carry out repetitive and demanding tasks with almost no human intervention or supervision (Harik et al., 2016; Van Gils et al., 2018). This article presents evidence from experimental results that assess the use of UAVs coupled with RFID technology for real-time stock count execution. The research methodology adopted combines three different methods, namely systematic literature review, survey via questionnaire and interviews, as well as laboratory testing. This approach is used to investigate operational and technical parameters that affect the use of UAVs during the stock count process.

2. LITERATURE REVIEW ON UNMANNED AERIAL VEHICLES (UAVs)

The literature review that was conducted focused on the identification of technical and operational characteristics of Unmanned Aerial Vehicles (UAVs) as well as the parameters that affect UAVs adoption in logistics processes. Out of the total 46 papers reviewed, 69.6% (32 papers) were journal papers and 30.4% (14 papers) were conference papers. The limited number of published articles in academic journals and conferences, along with the distribution of the reviewed studies over time, indicates that the field is relatively new from a research perspective. The highest number of papers was published in 2019, with 15 papers (8 journal papers and 7 conference papers) identified. From the review conducted, it can be concluded that

there is a limited number of articles that investigate parameters that affect the performance of UAVs in logistics operations. Furthermore, we concluded that to the best of our knowledge, there is no detailed classification that provides: a) The type of available drones based on their technical and operational characteristics, b) List of logistics processes where drones may be adopted, and c) List of parameters that affect the performance of UAVs in stock count mainly in warehouses. To this end, we developed a categorization of UAVs based on their technical and operational features. Eight (8) categories of technical characteristics are identified, namely: a) UAV flight control, b) UAV weight type, c) UAV wing type, d) Propulsion system e) Wing span, f) Flight range, g) Flight range and, h) Operational altitude and four (4) categories of operational characteristics are identified, namely: a) flight zone, b) mission, c) environment and d) applications. We also identified multiple logistics processes that can be executed by UAVs such as: a) Inventory management, b) Intra-logistics, c) Picking, d) Inspection, and f) Facility physical security & Surveillance. In this article we focus on stock count, which is a complex, dangerous, and time-consuming process and we investigate via laboratory testing how four parameters (i.e. number of warehouse racks' levels, UAV speed, RFID tag location and UAV tag reading method) affect the efficiency of stock count process.

3. MAPPING OF USER REQUIREMENTS

To map the requirements for real-time stock count, two research methods were used. The first method involved a structured questionnaire that was distributed to 35 companies to investigate current logistics practices and the potential use of drones for stock counting in warehouses. The second method involved personal interviews with 5 logistics and IT executives to confirm the survey findings, explore the potential use of UAVs for automating certain logistics processes, and map future trends and challenges in the use of drones.

Questionnaire Analysis

The results highlight that companies face high operating costs, human errors, and low productivity in their logistics processes. Specifically, the stock count process, stock control of re-usable products, and stock control of raw materials and/or final products are particularly inefficient. The results reveal that 58% of the companies are aware of the use of UAVs for certain logistics processes, and 78% are interested in identifying methods to automate logistics processes. Furthermore, the majority of the respondents (86%) are interested in automating the stock count process by using UAVs.

Confirmation of the findings of the survey via interviews

The responses from the interviews confirmed that there is indeed an interest in using UAVs to increase productivity and decrease operational costs in logistics processes. The participants estimated the time period for the adoption of UAV technology, in a period of 3-5 years. Furthermore, the participants highlighted the interest of companies in UAV-based logistics systems for stock counting, intra-logistics, and other logistics processes. They also indicated that cost, Return on Investment (ROI), and existing legislation are key factors in the adoption of UAV technology.

4. DESING OF EXPERIMENT

In order to carry out the experimental procedure for the investigation of parameters that affect the performance of drones during real-time stock count process, we adopted the methodology of Design of Experiments (DoE) which was proposed by Montgomery (2012) and Antony (2014) respectively. The parameters that were taken into consideration based on the findings of the literature review are presented as follows.

- UAV speed: Drones must adjust their speed so that they can scan all the required products and avoid misreading of RFID tags, and at the same time move as fast as possible to save time (Hassanalian and Abdelkefi, 2017; Rejeb et al., 2021). After a series of tests, we decided to test two UAV speeds, these are 0,5m/s and 1,5m/s respectively.
- *Tag location:* The tag location is defined as the centroid of the probable region which is recorded by the latitude and longitude of the UAV when a tag is identified (Durić et al., 2018). After examining the position of the RFID tag on all four sides of a carton, we decided to test two positions, back side, and front side

- UAV tag reading method: This parameter refers to the reading method followed by the UAV during its flight within the aisle of warehouse. This parameter has two levels: along a rack and across racks.
- Number of levels per rack: In this case we investigate the movement of the UAV in a single and in double rack level.



Figure 1: Illustration of the Parameters

5. EXPERIMENTAL RESULTS

As mentioned above the aim of this experiment was to investigate whether certain parameters, namely: a) Number of levels, b) UAV speed, c) Tag location, and d) UAV tag reading method, affect the accuracy and total stock count time in stock count process of warehouses (Figure 2). To carry out the experiment under investigation, the Design of Experiments (DoE) method was used, in particular the special case of general factorial design, which is suitable for experiments involving several factors where it is necessary to study their common effect on a response.



Figure 2: Model for accuracy and stock count prediction

Table 1 presents the selected factors as well as their corresponding levels which were used for the experiments. As mentioned beforeabove the levels of each factor were selected by taking into consideration the experimental results for the selection of factors to be investigated and values of levels of DoE.

| Table | 1: | Selected | factors | and | their | levels |
|-------|----|----------|---------|-----|-------|--------|
| rable | т: | Selected | Tactors | anu | their | levels |

| Factors | Level 1 | Level 2 |
|------------------------|--------------|--------------|
| Number of Levels | 1 level | 2 levels |
| UAV Speed | 0,5 m/s | 1 ,5 m/s |
| Tag Location | Back side | Front side |
| UAV tag reading method | Along a rack | Across racks |

There are $2^4 = 16$ configurations, and each run was replicated three times, thus we obtained a total of 48 samples. The aim of experiments was to test the efficiency of the system (i.e., reading 32 RFID tags that were placed in cartons in specific racks of a warehouse aisle, with a total distance of 13m).

For the evaluation of the stock count system two parameters that affect productivity and performance were measured. The first parameter was the stock count time and the second was the accuracy of stock count process. The read rate was counted manually after the completion of the stock count process. In order to investigate whether the parameters under consideration were statistically significant, certain null hypotheses were introduced, as follows.

- The first null hypothesis (H0,1) states that the stock count time was the same when either the number of levels was 1 level or 2 levels: H0,1: t1 level = t2 levels
- The second null hypothesis (H0,2) states that the stock count time was equal when either the UAV speed was 0,5m/s or 1,5m/s: H0,2: t0,5 m/s = t1,5 m/s
- The third null hypothesis (H0,3) states that the stock count time was equal either when the tag location was back side or front side: H0,3: t back side = t front side
- The fourth null hypothesis (H0,4) states that the stock count time was equal either when the UAV tag reading method was along a rack or across the racks: H0,4: t along a rack = t across the racks

Following the data collection, a quantitative analysis of the order picking time and accuracy was performed by using ANOVA. The results of the ANOVA showed that for cases: H0,1, H0,2 and H0,4, the null hypothesis was rejected while for case H0.3 the null hypothesis cannot be rejected. This means that the use of the parameters of Number of levels, UAV speed and UAV tag reading method significantly affect the stock count time. To this point, it is important to mention that the level of significance which was used for this analysis was 5% (a=0.05).

| Source | F-Value | P-Value |
|--|---------|---------|
| Model | 1071,82 | 0,000 |
| Linear | 3633,04 | 0,000 |
| Number of levels | 6344,24 | 0,000 |
| UAV speed | 3108,46 | 0,000 |
| Tag Location | 1,19 | 0,283 |
| UAV tag reading method | 5078,26 | 0,000 |
| 2-Way Interactions | 248,81 | 0,000 |
| Number of levels*UAV speed | 468,74 | 0,000 |
| Number of levels*Tag Location | 0,97 | 0,333 |
| Number of levels*UAV tag reading method | 677,11 | 0,000 |
| UAV speed*Tag Location | 0,51 | 0,482 |
| UAV speed*UAV tag reading method | 345,38 | 0,000 |
| Tag Location*UAV tag reading method | 0,13 | 0,719 |
| 3-Way Interactions | 13,08 | 0,000 |
| Number of levels*UAV speed*Tag Location | 0,06 | 0,803 |
| Number of levels*UAV speed*UAV tag reading method | 52,08 | 0,000 |
| Number of levels*Tag Location*UAV tag reading method | 0,11 | 0,745 |
| UAV speed*Tag Location*UAV tag reading method | 0,06 | 0,814 |
| 4-Way Interactions | 0,01 | 0,934 |
| Number of levels*UAV speed*Tag Location*UAV tag reading method | 0,01 | 0,934 |
| Error | | |
| Total | | |

We also investigated the system configuration that results ton the shortest stock count time. More specifically, according to Figure 3, it can be observed that the stock count time is lower when the number of rack levels that the drone is simultaneously reading RFID tags is double, the tag is placed in the front side of a carton, the speed of the UAV is 1.5m/s and the tag reading method of the UAV is across the racks.



Figure 3: Boxplots for stock count time for statistically significant factors

6. CONCLUSIONS

This article presented evidence from experimental results that assess the use of UAVs coupled with RFID technology for real-time stock count execution. The results from laboratory experiments demonstrate the effect of certain operational parameters, such as UAV speed, number of rack levels, and RFID tag location on products, during the execution of the stock count process in terms of RFID reading accuracy and efficiency. A 2⁴ full factorial design was adopted to test UAV and RFID technology in a warehouse with products that are stored in an ambient environment. The results of the experiments are encouraging showing that the use of UAVs coupled with RFID tags may support faster, cost-effective, and safer stock count in warehouses.

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A Multicriteria DSS for Spatial Consumers Satisfaction Analysis

Anastasia S. Saridou Production & Management Engineering Dpt, Democritus University of Thrace asaridou@pme.duth.gr Athanasios P. Vavatsikos Production & Management Engineering Dpt, Democritus University of Thrace <u>avavatsi@pme.duth.gr</u> Evangelos Grigoroudis School of Production Engineering and Management, Technical University of Crete <u>egrigoroudis@tuc.gr</u>

Abstract

Consumer satisfaction (CS) can be considered as a key performance indicator that businesses have always tried to monitor in order to increase their profitability, as it provides valuable information about business performance. CS is a multicriteria problem due to its multi-dimensional nature given that consumer preferences are based on a number of evaluation criteria. The MUSA method is a regression-based approach that takes into account consumers' partial and overall evaluations. As a result, it provides measures of satisfaction and demandingness, as well as action and improvement diagrams for interpretation. Taking advantage of businesses' databases, as well as location-based technologies, marketers are provided with geo-referenced information. Geographic Information Systems (GIS) are computerized tools that can handle and visualize this spatial information. The use of GIS technologies to spatially examine a company's data is known as geomarketing. By using location data businesses can gain insights about consumers and better understand consumer behaviour. The proposed framework extends the typical MUSA framework into its spatial context by generating maps representing the method's indices. First, the examined area is clustered into multiple market areas based on a set of characteristics using k-means algorithm. The MUSA method is then applied to each cluster and the results are related to the market areas formed. A local interpretation of the results allows the formation of personalized marketing strategies based on the characteristics of the market areas. In conclusion, a model is developed in QGIS software that takes as input shapefiles consisting of consumer responses to the questionnaire formed by the company and demographic data expressed in city blocks to perform the spatial MUSA analysis.

KEYWORDS

MUSA method, Market area, Consumer satisfaction, GIS, Geomarketing

1. INTRODUCTION

Decision support systems are computerized software designed to assist and endorse the decision-making process of individuals. Thesesoftware have the ability to systematically accumulate, process, and meticulously examine a wide range of information and data. The growing number of online data resources serves to give an increased degree of importance upon spatial data, primarily because the preponderance of such data is inherently geolocated. Geographic Information Systems (GIS), on the other hand, manifest themselves as computational frameworks specifically designed to collect, store, manage, analyze, and even revise data with distinct geo-referencing attributes. The rise of GIS tools has consequently led to the establishment of an entirely new and rapidly developing academic field, commonly referred to as Spatial Decision Support Systems (SDSS). SDSS are capable of efficiently handling spatially related information (Keenan & Jankowski, 2019).

The term "Geomarketing" is a newly researched field, resulting from the development of geoinformatics in combination with the company's data. It relates marketing, geography, and information systems with the aim of supporting knowledge-based marketing decisions supported by geographical analysis (Cliquet, 2013). To better understand consumer needs, geomarketing should move to spatial marketing in a more localized or global perspective of markets, known as "glocal". "Glocalization" refers to the process of globalization of business strategy, while the appeal to consumers is achieved by localization of marketing tactics (Cliquet, 2020). Glocalization seeks to uncover hidden insights into satisfaction drivers and to investigate whether companies can be benefit from tailoring their marketing policies to the local characteristics to the market area examined.

Over the years, various models have been developed using different techniques to investigate consumer satisfaction. There are a/the KANO model, b/ Customer Satisfaction Indices (CSI) such as the Swedish Customer Satisfaction Barometer (SCSB), the American Customer Satisfaction Index (ACSI) etc., c/statistical methods, d/ multicriteria models. Multicriteria Satisfaction Analysis (MUSA) is a preference disaggregation method that takes as input consumers' judgments regarding several criteria and provides performance and demandingness metrics using ordinal regression (Grigoroudis & Siskos, 2009). Thus, a new innovative SDSS has been developed in GIS software to measure consumer satisfaction based on the MUSA method. The tool

uses a simple questionnaire as input and provides the marketer with results on consumer preferences and levels of demandingness, grounded in the evaluation of each individual criterion under investigation.

2. METHODS

Multicriteria satisfaction analysis

М

MUlticriteria Satisfaction Analysis (MUSA) is method that follows the principles of ordinal regression to estimate consumers' satisfaction based on various criteria (Grigoroudis & Siskos, 2009). The method aims to attain the highest possible alignment between the value function Y* and consumers' judgements Y forming an ordinal regression equation (eq.1).

$$\tilde{Y}^* = \sum_{i=1}^n b_i X_i^* - \sigma^+ + \sigma^-$$
(1)

Where \tilde{Y}^* is the estimation of the global value function Y^* , and σ^+ and σ^- are the overestimation and the underestimation errors, respectively.

$$[min]F = \sum_{j=1}^{N} (\sigma_j^+ + \sigma_j^-)$$
(2)

$$\sum_{\substack{i=1\\\alpha-1}}^{n} \sum_{k=1}^{x_j^{i-1}} w_{ik} - \sum_{m=1}^{y^j-1} z_m - \sigma_j^+ + \sigma_j^- = 0, \quad for \ j = 1, 2, \dots, M$$
(3)

$$\sum_{m=1}^{\infty} z_m = 100 \tag{4}$$

$$\sum_{i=1}^{n} \sum_{k=1}^{\alpha_i - 1} w_{ik} = 100$$
(5)

$$z_m = y^{*m+1} - y^{*m}, \qquad for \ m = 1, 2, ..., a - 1$$

$$w_{ik} = b_i x_i^{*k+1} - b_i x_i^{*k}, \qquad for \ k = 1, 2, ..., a_i - 1 \& i = 1, 2, ..., n$$
(6)
(7)

Where M represents the number of consumers, y^j and x_i^j are the global and partial satisfaction judgements of the *jth* consumer, y^{*m} is the value of the y^m satisfaction level, x_i^{*k} is the value of the x_i^k satisfaction level, α and α_i are the numbers of global and partial satisfaction levels, F^* is the optimal value for the objective function and ε is a small percentage of F^* . To reduce the size of the mathematical problem, the monotonicity constraints are removed (eq.3,4,5) and transformation variables takes their place representing the successive steps of Y^* and X_i^* value functions (eq.6,7).

$$[max] F' = \sum_{k=1}^{\alpha_i - 1} w_{ik}, \qquad for \ i = 1, 2, ..., n$$
(8)
$$F \le F^* + \varepsilon$$
(9)

To explore the existence of multiple or near optimal solutions the method supports post optimality analysis to examine the model's stability by solving n linear programs (eq. 8,9).



Figure 1: Action diagram (left), Improvement diagram (right)

MUSA generates normalized relative indices. The Average Satisfaction Indices (D_i) are defined in [-1,+1] interval. The closer to 1 D_i are the higher consumers' satisfaction is. Based on Average Demanding Indices (S_i) , indicating consumers' demandingness, three discrete consumer attitudes can be generated using equal interval classification. "Non-demanding" [-1, 0.33), "Neutral" [-0.33, 0.33] and "Demanding" (0.33, +1] consumers attitudes. These intervals are expressed subjectively and may change. Average improvement indices (I_i) indicate the improvement margins of each criterion. Based on the indices prementioned two types of diagrams are generated. Action diagrams indicate the strong and weak points of consumer satisfaction and define the required improvement efforts. Although these diagrams indicate which satisfaction dimensions should be improved but they cannot determine the output of the improvement efforts. That is why improvement diagrams are being developed for.

k-means algorithm

Clustering is a method that classifies multi-attribute datasets into a predefined number of groups, referred to as clusters, based on their common features. k-means is an unsupervised learning algorithm that is widely used due to its simplicity (Awawdeh et al., 2019). It is an iterative process that attempts to determine a new centroid for each cluster during each round of iteration. Given the instances and their associated attributes, along with the predefined number of clusters k, the algorithm assigns each instance to the nearest centroid using Euclidean distance measurements and reorganizes the clusters in each subsequent iteration (Nainggolan et al., 2019). The number of k clusters is determined using the elbow technique.

3. FRAMEWORK

The introduction of a new framework is proposed, which aims to enhance and extend the application of the fundamental MUSA method and CS analysis by incorporating them into the spatial context. This new framework seeks to leverage spatial considerations, thereby extending the scope and capabilities of the methodology. In the context of CS analysis, consumers preferences are identified through the use of questionnaire surveys. The primary objective of these surveys is to gauge the satisfaction experienced by the consumers of the specific product or service under evaluation. The intention behind this endeavor is to quantitatively assess and potentially rank the levels of satisfaction observed among these consumers. Consumers' preferences are captured using a linguistic scale that measures the intensity of their preferences i.e., Likert scale. These responses are converted into numerical values, which allows the subsequent application of multicriteria analysis of an area in a local manner. Localization is achieved by clustering the sample into smaller groups with similar characteristics. In this way, localization is intended to facilitate the subsequent analysis of satisfaction in relation to consumers' income levels. Due to the lack of income data in Greece, which is not provided by the Greek authorities, the segmentation of the sample is carried on the basis of different building attributes, which serve as indirect indicators of the financial condition prevalent in the

respective area. Using the results of the MUSA method, the tool highlights areas for improvement and provides guidance on the actions to be taken.

4. GEOMARKETING TOOL DEMONSTRATION

In Quantum GIS, a free open-source software, a tool was developed to support the CS analysis of an area in a local manner. The geomarketing tool is a sequence of processing tools developed in the graphical modeler, resulting in four output layers (figure 2).



Figure 2: Spatial MUSA tool in modeler

To initiate the execution of the model, the user needs to insert two layers, which are shapefiles, into QGIS. The first layer refers to the specific region of interest and represents the fundamental building components of a city. This shapefile must contain attributes associated with the characteristics of the city blocks, enabling the functionality of the 'k-means with elbow' tool. Furthermore, the user must also select from these attributes, resulting in the segmentation of the city into k groups. Subsequently, the MUSA analysis is then performed within each of these groups, providing localized metrics. The "Dissolve" tool combines the individual city blocks within a cluster into a single block, making it easier to graph the metrics for that particular cluster. The "Join attributes by location" geoprocessing tool allows a spatial join operation to be performed between two distinct layers. In this case, these two layers are the shapefile consisting of consumers preferences and the output of the dissolve tool, which is a shapefile containing the clusters IDs. The "Spatial MUSA" tool accepts as input the output generated by the aforementioned tool. This output includes the consumers' preferences for each criterion, together with an overall score, along with the corresponding cluster identifier to which each consumer is assigned. The algorithm operates and produces a trio of result layers, namely a/ the "Results" layer consisting of each cluster id (features) in relation to the verbal characterization in terms of action and improvement diagrams, and the demandingness level of consumers in each cluster, b/ the "MatrixData" layer which are the numerical values of each index provided by MUSA, and c/ the "Weights" layer which are the weights of each criterion for each cluster.

5. CONCLUSIONS

Marketing encompasses all the actions a company takes to attract and sustain its consumers. Geomarketing is the introduction of space into marketing analysis. It uses Geographic Information Systems with decision analysis approaches to create Spatial Decision Support Systems that facilitate data-driven decisions. Over the years, several methodologies have been developed to measure consumer satisfaction. The combination of the MUSA method and GIS in the proposed framework provides results on consumer satisfaction. The global analysis provides an overall view of a sample, while the local analysis incorporates local characteristics into the investigation of the market area. The Spatial MUSA tool provides maps that assist in the creation of tailored marketing strategies based on the company's market area. Action maps allow the marketer to

identify where the company's performance is either high or low in relation to each importance. According to improvement diagrams, actions can be prioritized to form a marketing plan. Demandingness indicates the degree to which consumers satisfaction is being met. To conclude with, using QGIS's ability to symbolize data, the maps can be colored according to the quadrant color of the diagrams, making them easy to read and analyze.

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Prospects from a European Study on OR/MS Education -The Transition of Graduates onto the Labor Area

João Luís de Miranda

Portalegre Polytechnic University, *Politécnico de Portalegre*, Portugal, <u>ilmiranda@ipportalegre.pt</u> CERENA, *Instituto Superior Técnico*, *Lisboa*, Portugal, <u>joaoluismiranda@tecnico.ulisboa.pt</u>

Abstract

This work addresses recent enhancements originated from the European survey on Operational Research/Management Science (OR/MS) Education; the survey was conducted in collaboration with the EURO association, and it targeted the OR/MS field in the European countries. The relation between Higher Education Institutions (HEI) and the labor market was also surveyed; in addition, to better promote graduates' employability, the digital applications and platforms (*e.g.*, Artificial Intelligence-AI, Big Data Analytics-BDA, Cloud-based services, Digital Twins-DT, High Performance Computing-HPC, Internet of Things-IoT, Machine Learning-ML, Robotics, Virtual Reality and Extended Reality-VR/XR) are rapidly evolving and shall be addressed too. For other side, OR/MS methodologies and tools are often developed to support decision-making, and also to improve the capabilities of Decision Support Systems (DSS); although the diversity of OR/MS tools applied on education fields, there is an important gap when addressing good practices in OR/MS education. In this way, enhancements about the transition of graduates onto the labor area are focused, as well as prospects about the digital phenomena within the OR/MS Education fields are discussed.

KEYWORDS

OR/MS Education; European survey; Graduates; Labor Area; Digitalization.

1. INTRODUCTION

The transition of graduates onto the labor area, as well as employability concerns, are important indicators in Higher Education (HE), due to the impacts both on programs accreditation and in students' enrolment. For that, the relations between Higher Education Institutions (HEI) and the labor area are continuously monitored, supervised, and enhancements originated from the European survey on Operational Research-Management Science (OR/MS) Education are recently reported (Teixeira *et.al.*, 2022).

The primary focus of the European survey was to get a general appreciation of the status of OR/MS education in Europe. In addition, a country-specific analysis was also possible if a sufficient number of respondents from that country completely filled in the survey, and by identifying their country too (Belien *et. al.*, 2018). Five key factors are addressed: (A) the enrolment of students; (B) the attrition and failure of first year students; (C) the usefulness of OR/MS courses in face of programs restructuration; (D) the OR/MS teaching practices; and (E) the transition to the labor market.

In section E, aiming at the HEI synergies with labor area, the survey included both general and OR/MS based topics, in this way promoting the comparison between these two approaches (Belien *et. al.*, 2016).

- General topics are including curricula content, as well as the participation of HEI boards and decisionmakers in both supervision tasks and assessment activities. In the survey results, these general topics are well perceived, with the respondents' majority (ranging 50-62%) evaluating their HEI efforts positively (Teixeira *et.al.*, 2022).
- However, it is noted the trend changed when the OR/MS domain is specifically evaluated. In fact, the OR/MS based topics are not satisfactory evaluated by the majority of the respondents (only about 30-35% of positive responses), suggesting that specific OR/MS activities for the labor area are not properly disseminated, or even do not exist (about 23-24% of *Non-existent/Lacking sufficient information* responses).

Therefore, the respondents' perceptions about specific OR/MS activities and the corresponding general activities are quite different. A suggested action considers: *i*) firstly, the mapping of barriers for specific OR/MS activities and drivers for the labor area; and *ii*) improving the alignment of OR/MS based activities in relation to the general HEI activities for labor area, and exploiting the OR/MS usefulness in the chain value.

Other indicators include the level and extent of promotion directed to labor area, for example, by directly assessing OR/MS activities and comparing with other scientific/technical fields or specialties.

In other point of view, the labor area shall be well aligned with the most recent developments on Information and Communication Technologies (ICT), as well as the digital capabilities are rapidly evolving and creating innovative opportunities. In fact, the HEI general activities are now being covered by the most recent ICT tools, and the contents/materials preparation, classroom and laboratories activities, online resources, learns evaluation/assessment, and certification procedures are being digitally treated.

The digital phenomena (*e.g.*, Artificial Intelligence-AI, Big Data Analytics-BDA, Cloud-based services, Digital Twins-DT, High Performance Computing-HPC, Internet of Things-IoT, Machine Learning-ML, Robotics, Virtual Reality and Extended Reality-VR/XR) are either shortening routine tasks or reducing the number of available jobs, but also creating opportunities for innovation. While increased efficiency due to IT is reducing routine jobs in the middle of the income distribution, in particular, highly qualified jobs have increased in number (CONNECT, 2017)

Note the OR/MS methodologies and tools are often developed to improve the capabilities of Information Systems (IS) or incorporating Decision Support Systems (DSS); in this way OR/MS integrates a number of fields that are relevant for the European digital transition. Namely, it includes among others of interest, Modelling-Simulation-Optimization (MSO), Multi-Criteria Decision Aiding/Making (MCDA/M), Game Theory and applications, in a number and diverse sectors (*e.g.*, education, energy, finance, healthcare, marketing, transport).

Specific needs related with digital support for HE fields within the fast changing labor area are being addressed, and innovative elements that exploit digital technologies within the learning and teaching practices follow in next section.

2. GRADUATES EMPLOYABILITY AND APPROACHES IN OR/MS

In a good manner to promote graduates' employability, the digital applications and platforms that are highly impacting HEI and OR/MS education shall be addressed, and important ICT phenomena are focused in here. Beyond European programs and international initiatives, OR/MS methodologies and tools are often developed to support decision-making, either to improve IS or DSS, as well as they play an important part in the European digital transition. In that manner, the approaches in OR/MS education, focusing either hard skills or soft skills, are discussed too in this section.

2.1 Digital Phenomena

A number of European initiatives are dealing with both digital frameworks and OR/MS Education topics too, for example:

- Concerning the European HE Area, the "Digital Education Action Plan 2021-2027" (COM, 2020) indicated how education and training systems can make better use of innovation and digital technology, while supporting the development of relevant digital competences and skills. Education leaders play a key role in resetting education and training, because education and training systems need to evolve and adapt to the digital age, also requiring that institutional leaders and decision makers lead this change. In this way, many European initiatives are promoting online learning, blended mobility, virtual campuses, the exchange of good practices, and driving the creation of a pan-European platform for digital HE.
- Namely, for the Cluster 4 of Horizon Europe, "Digital and Industry", the intervention areas include AI and robotics, BD and HPC, key digital technologies, or the next generation internet, as presented in Table1 (ERA LEARN, 2019). Among others of interest, the relevant sub-topics are transversally considering: algorithms and codes; AI-driven, complex or smart systems; data analytics and e-infrastructures; or even competences, skills and workspaces.

Moreover, some COST Actions are directly focusing OR/MS topics and advanced training for young researchers. Namely, the Action "European Network for Game Theory" (*GAMENET*, CA16228), and the Action "Improving Applicability of Nature-Inspired Optimisation by Joining Theory and Practice" (*ImAppNIO*, CA15140), contributed with new insights to the European OR/MS field. Just starting the works in the fall of 2023 and spanning until 2027, the COST Action "Randomised Optimisation Algorithms Research Network"

(*ROAR-NET*, CA22137) is focusing practitioners needs, promoting the sustainable development of software tools, training materials and programs, with the purpose of treating critical topics of cutting-edge optimization solvers.

Table 1: Horizon Europe, Cluster 4 "Digital and Industry": partial view of Intervention Areas and Relevant Sub-Topics.

 (Source: ERA LEARN, 2019)

| | | | | | Intervention Area | 15 | | | |
|---------------------|---|--|--|--|--|---|--|--|--|
| | Manufacturing technologies | Key digital technologies | Advanced materials | Artificial intelligence and robotics | Next Generation Internet | High Performance Computing and Big Data | Circular Industries | Low-Carbon and clean industries | Space |
| | Additive manufacturing, industrial robotics, human integrated manufacturing systems | Nano- electronics design and processing concepts | Materials (including plastic, bio-, nano-, two-dimensional, smart and multi- materials) | Enabling AI technologies (explainable AI, unsupervised machine learning and data efficiency, advanced human- machine interactions) | Connectivity beyond SG, software defined infrastructures, cloud infrastructures, cognitive clouds, radio, edge computing, blockchains | key exascale and post-exascale technologies and systems; algorithms, codes, applications, anajvic tools and test-beds; world- class HPC infrastructure | Industrial symbiosis; processes and materials, to transport, transform, re- use and store resources, combining the valorisation of by-products, waste and CO2 | Process technologies; reductions or avoidance of industrial emissions of greenhouse gases and pollutants | European Global Navigation Satellite Systems; Next generation systems development for new challenges such as security or autonomous driving |
| Relevant Sub-Topics | Converging technologies, artificial intelligence, data analytics,l industrial robotics, bio- manufacturing, advanced batteries technologies | Sensing technologies for the IoT and innovative solutions on flexible and conformable materials for human-friendly interacting objects | Integrated materials proceses and production | Safe, smart and efficient robotics and complex embodied systems | Next Generation Internet applications and services for consumers, industry and society | Extreme- performance data analytics; "Privacy by design" in Big Data analysis; technologies for full-scale data platforms; management, interoperability and linking tools; | Valorisation and life-cycle assessment of materials and product streams | Industrial CO2 valorisation | Copernicus; Next generation systems development for new challenges such as climate change, and security |
| | Skills and workspaces adapted to the new technologies | Neuromorphic computing powering artificial intelligence applications, or integrated quantum computing | Materials enablers like characterisation (e.g. for quality assurance), modelling, piloting and upscaling; | User-driven Al technologies for Al-based solutions | Software-based middleware, including distributed ledger technologies, | Reduced carbon footprint of ICT processes | Enhanced life- cycle performance, durability, upgradeability and ease of repair, dismantling and recycling | Unconventional energy sources and energy and resource exchanges between industrial plants | Space Situational Awareness |
| | Flexible, high- precision, zero- defect and zero- waste cognitive plants and smart manufacturing systems | Computing architectures and low-power processors | EU innovation ecceystem of technology infrastructures | Developing and networking the research competences of Al centres | | | Recycling industry | Industrial products that require low or zero carbon emissions production processes | Secure Satellite Communications for EU governmental actors |

Many international efforts are directed to digital education and featuring advanced ICT tools. In fact, multiple initiatives about digital phenomena and digitalization are ongoing worldwide, for example:

- UNESCO is spurring and supporting initiatives on Open Educational Resources (OERs), such as promoting the impact of open courseware for HE or developing and hosting the <u>Open Training Platform</u> (OERs database designed to facilitate teaching, learning, and research).
- The SABER initiative (World Bank) aims at helping countries to systematically strengthen their education systems; for that, SABER is promoting IS for education management and IT intensive utilization to produce comparative data and knowledge on education policies and institutions.
- Many professional associations provide online resources; in OR/MS education, the most active include "The OR Society" (UK) and INFORMS (USA), with digital teaching and learning materials targeting different populations, instructors training, entrepreneurial community, and opening them widely as in the "IFORS Resources on OR for Developing Countries".

In plus, the HEI digital tools shall be adjusted with the new data intensive capabilities, while taking full advantage of the federated research e-infrastructures (RI) in Europe. In fact, the consolidation and maturity of the EU e-Infrastructures initiative, which is promoting an integrated networking and grid infrastructures for twenty years (2003-2023), is crucial for the European digital transition (Karayannis *et.al.*, 2023). Namely, by addressing open science and research data, from data collection to visualization, while AI and BDA are promoting novel algorithms and methodologies. Beyond methodological discussions, the FAIR procedures and adoption cases have evolved in many cross-disciplinary approaches.

- For example, the European RI are promoting general mobility for the inter-connected HEI at continent level (*e.g.*, EDUROAM), providing teleconference tooling, as well as supporting health data research from the period of COVID-19.
- And overcoming well-known gaps in ICT at national and region level, namely: by equipping females and senior people with digital skills; by upskilling or re-skilling workers from industry sectors in restructuration (*e.g.*, InCoDe.2030 program in Portugal, within the Digital Jobs and Skills Platform).

2.2 OR/MS Methodologies and Tools

Bridging HEI and labor area thus is critical, either by promoting the professional development of faculty and staff within the new digital framework, or by fostering the OR/MS methodologies and tools in the most suitable approaches to graduates employability. Namely, by addressing the hard and soft skills in need as referred in the following part.

In a prior work (Miranda and Teixeira, 2015), OR/MS practices were characterized and the related key attributes were distinguished between: **A** - "Practices on education of OR/MS"; and **B** - "Application of OR/MS tools in Education issues". Then, these two approaches (A-B) were applied to study the developments in OR/MS education originated from international cooperation.

- A) The topics directly related to the 'Practices on education of OR/MS' integrated: the teaching practices in the OR/MS classroom; the design, implementation and review of OR/MS courses; the students' performance and assessment in OR/MS subjects.
- B) The topics considering the 'Application of OR/MS tools on Education' included: DEA, Modeling-Simulation; Scheduling-Timetabling; DSS; Routing for school transportation; Data Mining; Multi Criteria Decision Aiding/Making (MCDA/M), Data Analysis; Metaheuristics; Graph Theory-Combinatorial Optimization; Statistics; and other topics of specific interest.

These topics are commonly treated in typical OR/MS courses and programs, assuming a set of hard skills with background on mathematical modeling, simulation, optimization, as well as coding, computational implementation, or data management.

A complementary approach in OR/MS education is directed to soft skills with the purpose to promote creativity, critical thinking, judgment and decision making, people management and coordinating with others, as well as negotiation, team-work, or problem-solving in complex contexts. In a recent study (OECD, 2023), Al-related skills are positively correlated with high-level cognitive ("creative problem solving") skills in several countries, namely, in the United States (Figure 1).



Figure 1: Positive correlation between jobs demand for both *AI* and *Creative problem solving* skills. (Source: OECD Social, Employment and Migration Working Papers No. 286, 2023; Figure 18, Panel B)

Figure 1 shows that skills positively correlated with AI skills (*e.g.*, 'computer animation' skills, with 0.39 AI-relatedness) are also strongly correlated with "creative problem solving" (in vertical axis, with relatedness 0.54). This suggests that any increase in the employment of AI-related jobs is likely to be associated with increasing demand for both AI and high-level cognitive skills, since they are jointly relevant in similar occupations.

Several studies are focusing soft skills and OR/MS education in different sectors and contexts, such as engineering, finance, healthcare, or marketing services. Namely, Krassadaki *et.al.* (2018) reported on the educational and professional needs within engineering programs, indicating key skills and comparing international practice too. They also indicated the necessity to address analytical skills, verbal communication, mathematical, problem-solving, interpersonal, critical thinking, written communication, and knowledge of modeling software, while presenting a pilot effort focusing the students' level of scientific knowledge along with communication (speaking, writing) and team-working skills.

- Krassadaki *et.al.* (2018) also indicated OR courses of wide interest, both at undergraduate level and at advanced level, such as "Multi-criteria Support Systems", "Advanced Non-Linear Programming", "Decision Making and Multi-agent Systems", "Evolutionary Algorithms and Optimization of Large Scale Systems".
- The referred pilot effort presented encouraging results, and was developed within the undergraduate course on "Decision Support Systems". In this way, it is important to remark again the number of OR/MS methodologies and tools directed to Education applications and DSS, with particular focus on HEI deployments.

In fact, innovative approaches are expected in the near future for OR/MS curricula and HEI teaching, including among others, assessment and evaluation of digital learns, recognition of IT-based qualifications, and simultaneously aiming at services digitalization in HEI. Important elements that exploit digital technologies within the OR/MS learning and teaching practices follow in below.

- The continuous monitoring of IT evolutions, online assessment, and the strategic utilization of advanced digital tools (e.g., AI) on HEI automatable or routine activities.
- The creation of Virtual Environments, Virtual Laboratories, and the implementation of VR/XR applications for innovative learning environments.
- The promotion of digital activities using serious games, or simple challenges focusing discrete mathematics, involving knowledge and logical reasoning, either in formal or non-formal settings (Miranda, 2021).
- Upgrading equipment and facilities necessary to the implementation of HEI digital practices (e.g., updating curricula and teaching methods, development of new HE services and activities).
- Digitalization of tasks involving faculty and staff, as well as HEI administrators and managers, including a benchmark of good practices, self-assessment tools, external and internal evaluation, digital publishing, creation of online resources, and digital repositories (data, publications, software).
- Potential enhancements to support the European OR/MS education include efforts coordination in different countries, in that manner avoiding replication and improving resources utilization, especially in the common case of HEI with tight financial constraints.

3. CONCLUSIONS

The relations and inter-connections between HEI and the labor area are discussed, with the purpose to better promote graduates' employability, since the digital phenomena (AI, BDA, Cloud services, *etc.*) are rapidly evolving and strongly impacting the labor market these days. In this way, enhancements about the transition of graduates onto the labor area are focused, as well as prospects about the digital phenomena within the OR/MS Education fields are presented.

The federated RI are consolidating and bringing new insights to the Digital Europe, allowing new computing capabilities, and a large combination of digital tools and services platforms is being made available for HEI. The emerging digital phenomena (AI, BDA, Cloud services, *etc.*) are rapidly evolving, while FAIR data and resources (*e.g.*, adoption cases, open standards) are widely promoted too. The related applications and digital tools are both focusing automatable activities, routine tasks, and reducing the number of available jobs, but also creating important opportunities for innovation and well-paid jobs.

Enhancing connections and synergies with the labor area will improve graduates' employment opportunities, namely, by adequately aligning the OR/MS contents and teaching practices to the needs of labor area. Note that by communicating well the labor attributes associated with the HEI programs, then the impact in students' enrolment will be positive too.

OR/MS methodologies and tools are often developed to support decision-making, and they are widely utilized in many areas and important sectors (education, energy, finance, *etc.*). Although the diversity of OR/MS tools applied on education areas, an important gap arises when addressing good practices in OR/MS education. At now, two complementary approaches onto OR/MS Education are being updated:

- A) OR/MS-based digital applications aiming at Education purposes; and
- **B)** Innovative practices in the education of OR/MS that will be supported in digital platforms and e-infrastructures.

In this manner, future developments will include enhancing the transition of graduates onto the labor area, by promoting both the described approaches (A-B). In particular, exploiting the digital phenomena in a manner to enhance both hard and soft skills within the education of OR/MS, with new practices in classroom, by updating courses and programs, as well as providing digital assessment and evaluation.

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Sustainable Development without exclusion: Agenda 2030 for Sustainable Development with an emphasis on Social Protection of Immigrants in Greece

Eleni A. Karanasiou University of West Attica, Greece <u>ekaranasiou1@gmail.com</u> Anastasios Sepetis University of West Attica, Greece <u>tsepet@uniwa.gr</u>

Konstantinos Dalakouras University of West Attica, Greece <u>kdalakouras@uniwa.gr</u> Georgios Pierrakos University of West Attica, Greece <u>gpierrakos@uniwa.gr</u>

Aspasia Goula University of West Attica, Greece agoula@uniwa.gr

Abstract

The present research is carried out in the context of investigating the living conditions of vulnerable groups such as immigrants and refugees, their connection with environmental changes and the goals of the 2030 Agenda. Cross-border migration and the influx of immigrants/refugees in Greece in recent years, makes it necessary to ensure decent living conditions, access to health services/medical care, inclusion in educational programs that enrich with knowledge and skills for finding a job, equal treatment. elimination of inequalities and in general the integration of immigrants/refugees in the host country in accordance with human rights and the SDGs. A total of 53 immigrants participated in the study, of which 26 are women and 27 are men. According to the research, we find that the living conditions of immigrants/refugees are at a good level in our country, especially health services (compared to other countries) although the sample was not what was expected and in addition, the questionnaire was answered by immigrants who they live in the Athens area.

KEYWORDS

Sustainable Development Goals (SDGs), Sustainable Local Development, Social Protection in Greece, Social Exclusion, Poverty, Immigrants, Climate change.

1. INTRODUCTION

The concept of sustainable development, in its complexity, presents a multifaceted and multi-leveled form, which strongly includes the dimension of the environment and its relationship with the issues of society, economy and development, such as poverty, health, education, of equality, democracy, human rights, environmental protection, energy, peace and cooperation and is formed through the course of the processes at the European and international level.

The purpose of this research is to establish the living conditions of the vulnerable group of immigrants and additionally the approach to the goals of sustainable development in Greece, which contribute to the elimination of exclusions and functional social protection. The formation of an inclusive society that is essentially achieved by the effort to implement the goals of Agenda 2030, mainly those related to health, education, work and employment, equal treatment as they directly concern the decent living of the population and the economic development as a whole. The causes of migration attributed to environmental disasters are the gradual degradation of the environment (causing economic impacts), ecosystem changes as well as natural disasters from extreme weather events such as floods, droughts, hurricanes, earthquakes, volcanic eruptions, fires, sea level rise level but also industrial accidents as well as human interventions such as expropriations of the environment in the context of development projects that degrade natural resources and soil productivity (Bates et al 2002' Batsi 2017' Beine, M. and Parsons, C. 2015 'Gray, C. and Wise E., 2016). Also important are the effects of war conflicts that bring about paralysis of the economy from the inactivity of industry and therefore the production of basic goods, destruction of infrastructure (water supply, sewage, energy), destruction of the environment and pollution of the atmosphere (effects on health) from the use of chemicals of nuclear weapons but also from the bombing of strategic targets (chemical industries, oil wells, etc.), (Bates 2002' Cattaneo, C. and Peri G. 2016)).

Consequently, the population affected by the aforementioned situations is led to impoverishment, poverty and, by extension, social exclusion. Therefore, in order to achieve the goals of sustainability, the actors involved in the host country must approach the immigration issue in a multifaceted way, ensuring access to

basic services such as health, education and work, and generally focus on social protection for their decent living (Cruz et al 2015 'Hess et al 2012), (https://sdgs.un.org/goals).

2. LITERATURE REVIEW

Migration flows, the large and undetermined number of migrants as well as the unprecedented increase in illegal immigration cause difficulty in living conditions that often result in social exclusion.

In the recent literature It is noteworthy the presentation of a study investigating international migration in 142 countries where it is reported that migration due to climate change is more related to an increase in temperature (drought) and less to an increase in rainfall and in addition the emphasis is on natural disasters and internal conflicts that have resulting in increased migration flows of asylum seekers or migrants without the required accompanying documents. The study documents a strong link between climate change, internal conflict and migration flows (Alem et al 'Backhaus et al 2015 ' Thiede et al 2016' Thornton et al 2008).

Additionally, a review of 82 research studies examining working conditions and occupational health in various European countries and in Canada shows that migrant workers are more exposed to physical or chemical hazards and injuries, poor psychosocial working conditions, high risk manual work due to insufficient specialization (Sterud et al 2018').

2.1 The field research

Cross-border migration and the influx of immigrants/refugees in Greece in recent years presupposes ensuring decent living conditions, access to health services/medical care, inclusion in educational programs enriched with knowledge and job-finding skills, equal treatment, inequalities and more generally the integration of immigrants/refugees in the host country according to human rights and the SDGs. The present research is conducted with these concerns in mind. Below are the details of the research:

- Participants and Methods: A total of 53 immigrants participated in the study, of which 26 are women and 27 are men residing in Athens, as the approach was made through social media where the questionnaire link was posted in immigrant associations to be answered by members. Analysis was performed with SPSS v26.0 software and the significance level were set at 0.05 in all cases.
- Inclusion criteria: Migrants forced to migrate due to an unsuitable environment (effects of climate change, conflict or internal conflict)
- Exclusion criteria: Immigrants who settled in the country for professional, personal or family reasons.
- Statistical analysis: The data was collected through the Google forms application where it is possible to export the data to a spreadsheet. The statistical analysis selected for the present study was performed with SPSS v26.0 software and the level of significance was set equal to 0.05 in all cases. X2 independence tests were performed on all examined questions.

2.1.1 Descriptive statistics & Results of the Daily Living and Vulnerability Assessment Questionnaire

The following Tables present information on the demographics of migrants and record the questionnaire questions with their response rate on perceived daily life impacts and vulnerability assessment, based on Bourgois, et al (2017) and partially modified by researcher.

According to the data it appears that 53 immigrants participated in the study, of which 26 are women and 27 are men. Their characteristics are given in the tables number 1. Specifically, regarding their age, 22 participants are 26-35 years old, 20 participants are 36-45 years old, 6 participants are 46-55 years old, 5 are 56-65 years old and only his age varies in total 18 -25. Regarding their education, table shows that 29 have a basic education, 19 have a bachelor's degree while 6 have a master's degree.

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| | • | | - |
|-----------|--------|----|-------|
| | | N | % |
| Sex | Male | 26 | 49.1% |
| | Female | 27 | 50.9% |
| | Basic | 29 | 53.7% |
| Education | Degree | 19 | 35.2% |
| | Master | 6 | 11.1% |
| | 18-25 | 1 | 1.9% |
| Ago group | 26-35 | 22 | 40.7% |
| Age group | 36-45 | 20 | 37.0% |
| | 46-55 | 6 | 11.1% |
| | 56-65 | 5 | 9.3% |
| | | | |

| Table 1 | Descriptive | data of | interviewed | immigrants |
|----------|-------------|---------|-----------------|-------------|
| Table T. | Descriptive | uata Ui | IIII III VIEWEU | miningianus |

According to the data on the incomes of the participants seems that more than 50% of the participants derive money from their work, namely 55.3%. At the same time, a large part of the total answered that they are having difficulty in the work they are currently doing, namely 63.0%. In addition, a percentage of more than 60% is observed in the answers ''yes'' to the question ''you run out of money at the end of the month'' and in the answers ''no'' to the question ''you receive some form of help, from non-governmental organism (N.G.O) '' or ''state aid''. Specifically, 61.1% answered that they run out of money at the end of the month/week, 70.4% answered that they do not receive any form of government assistance and 79.6% answered that they do not receive any form of assistance from N.G.O. Also, 66.7% of the total answered that there are no other ways to earn money and 59.3% answered that they depend on someone else for income. Finally, table 2 shows that more than 50% of the participants (specifically 59.3%) answered that there was no time when they could not pay for medical treatment or medicines at the pharmacy. A large part of the respondents have a safe place to sleep and store their belongings (specifically 88.9% of the total) and that the place they live in is rented (33 participants answered positively). It also appears that 33.3% have lived in this area for 1-5 years and in fact more than 50% (51.8% of the total) answered that the area where they live is quite clean and that their privacy is sufficiently protected/it is quiet.

It was recorded that 30 respondents feel quite that the places where they spend their time every day are safe while at the same time 27 respondents answered that they are worried about getting hurt while working, trying to earn money. Also, participants, with percentages of more than 60%, answered that they are not exposed to toxins or chemicals in their daily environment nor at ambient temperatures dangerous for their health (these answers were chosen by 69.8% and 72.2% of the total respectively). Similarly, it was observed that more than 60% of the total answered that they are not afraid to walk in their neighborhood at night or day and that they have not been attacked or stolen, nor have they been beaten and chased (these answers were chosen by 74.1% of the total and 61.1% of the total respectively). The 79.6% of the sample have adequate nutrition and access to healthy food as well as that 94.4% have facilities to cook.

In the questions about the social network, the answers it is observed that the vast majority (specifically 85.2%) have friends, family or people who help them when they are in need. In fact, 36 respondents answered that the members of their social network are family and friends. Also 47 respondents believe that this network is useful for them and stated that no one is trying to hurt them (this answer was chosen by 44 participants which corresponds to a percentage of 81.5%). In addition, shows that more than 70% chose ''yes'' to the questions ''do you have a primary care provider/other health professional'' and ''are you served when you visit public hospitals for medical reasons'' (75.5% and 92.6% of the total respectively for each question). A sample of table and diagrams are listed.

Limitations: the questionnaire on immigrants/refugees was answered by immigrants living in Athens, so it does not include opinions about living conditions of immigrants residing in other regions of Greece.





Figure 1: Independence check of responses to the question ''are you served when visiting public hospitals for medical reasons'' depending on the task.



Figure 2: Independence check of responses to the question ''do you have adequate nutrition and access to healthy food'' depending on job.



Figure 3: Control of independence of the responses to the question "do you understand the documents you need to read and submit to get the services and resources you need" by level and education.

Figure 4: Control of check of independence of the answer to the question "can you read"?

3. CONCLUSION

According to the results of the research, it was found that It is found that worldwide similar conditions prevail for immigrants/refugees, but in our country, the living conditions of immigrants are at a good level, although the sample that participated in the research is small for a more complete picture. With the increase in immigration inflows, the multiculturalism of European schools has grown rapidly and promoting the integration of young people with an immigrant background has become a priority for European society. In this process, the school system is called upon to assume a critical role and offer integrated tools useful for strengthening the school integration of all students, an act which is ongoing in our country. Among the

challenges facing schools is the need to implement interventions that are effective in preventing and addressing bullying of immigrant peers and acceptance of diversity.

Awareness of the working conditions and occupational health of immigrants as well as national minorities is important to initiate professional upgrading efforts by sensitizing governments and labor institutes. Health care systems try to approach the needs of immigrants, however, communication and the lack of necessary documents hinder their access, although in our country access to health care is easier compared to other countries, as are the living conditions. Non-Governmental Organizations facilitate access to Health Units and in addition the state has taken care of placing translators in each Health Units to facilitate immigrants/refugees. Efforts are also being made to protect the environment and although we are far from the goals, we hope that by 2030 and with honorable efforts to approach them. The state is obliged to take care by taking measures as it has already done with the acquisition of insurance registration number and the easy access of immigrants to health services as well as the hiring of Arabic language translators in nursing institutions to facilitate Arabic-speaking immigrants.

In a multicultural state such as our country, the organization and harmonization of administrative services is required in accordance with the current situation, so that the required procedures for issuing special cards to asylum seekers for example or residence permits are not time-consuming, negatively affecting access of immigrants in various services and benefits. Also, informing immigrants about their obligations and rights in the host country is a priority upon their arrival and requires the creation and distribution of an information brochure in their language with full information. Of particular importance is the inclusion of immigrants/refugees in an educational program for learning the Greek language as well as in educational training programs that will enrich and update their existing knowledge, with knowledge and skills in accordance with emerging needs in the labor market, aiming in their smooth integration into society and in finding work. Immigrants constitute a cheap and illegal labor force with the fault of both the employer and themselves, opportunistically meeting their needs in the event that they do not possess a legal residence permit. Therefore, the state with short procedures must ensure the legal stay, the fight against undeclared work and the prevention of imminent risks, protecting the immigrants themselves and the state respectively.

In addition, the questionnaire regarding immigrants/refugees was answered by immigrants living in the Athens area, it is suggested in the next research to include immigrants living in all regions of Greece, for a more comprehensive picture and assessment of living conditions.

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Public crisis response strategy and innovation performance: Perceptions on digital transformation during COVID-19

Fotis Kitsios School of Information Sciences, Department of Applied Informatics, University of Macedonia 156 Egnatias st, 54636 Thessaloniki, Greece Evangelia Nousopoulou School of Information Sciences, Department of Applied Informatics, University of Macedonia 156 Egnatias st, 54636 Thessaloniki, Greece Maria Kamariotou School of Information Sciences, Department of Applied Informatics, University of Macedonia 156 Egnatias st, 54636 Thessaloniki, Greece

Abstract

Firms that were impacted by the pandemic now understand how crucial it is to integrate digital transformation into their daily operations. But as a result of the market lockdown, they understood that they needed to digitalize their operations right away and work harder to improve their economic status by incorporating more technical elements. No research has been done on the implementation of digital transformation in the specific industry of driving schools, despite the fact that there have been many studies done on the adoption of digital transformation in small-medium enterprises. The impact of digital transformation and public crisis response strategy on innovation performance is examined in this paper. 300 driving instructors from Greece and Cyprus provided the study's data. ANOVA analysis was used to analyze data. Owners of driving schools can utilize the findings to demonstrate the value of digital transformation to their organizations. Driving schools will be able to enhance their innovation performance and improve their development in the post-COVID era based on the paper's outcomes.

KEYWORDS

Digitalization; Digital transformation; Public crisis response strategy; Innovation performance; Innovation strategy.

1. INTRODUCTION

SMEs play an essential role in the processes of fostering technological innovation, improving employment prospects, and preserving social cohesion (Kamariotou and Kitsios, 2019; Kitsios and Kamariotou, 2017; O'Regan et al., 2006). However, because of their limited resources, are substantially more vulnerable to the consequences of a national or international crisis than other kinds of firms (Barron et al., 2012; Mayr et al., 2017). The research that has been done thus far has looked at how production recovery, corporate social responsibility, and community participation all play a part in lowering the risk of public crises for small and medium-sized businesses (Ballesteros et al., 2017; Kearins, 2017; Neise and Diez, 2019). In particular, it has been found that the dynamic capabilities are the key to public response to crises (Lin and Wu, 2014; Linnenluecke, 2017; Martinelli et al., 2018). Unfortunately, it is still unknown how SMEs should construct and make use of dynamic capabilities in response to public crises such as the COVID-19 outbreak.

The current crisis in public health has created significant obstacles for the continued existence and growth of firms, with the small and medium-sized enterprises (SMEs) bearing the brunt of these difficulties. In a variety of different ways, the COVID-19 pandemic has been economically destructive. First, there has been a significant disruption in the global supply chain due to the fact that both imports and exports are being stopped because more and more governments are closing cities in an attempt to contain the pandemic. Furthermore, due to the general postponements in the reinstatement of work, companies' production capacities have been significantly reduced, but their capital expenditures, such as rent and salaries, have remained the same, leading to serious problems with cash flow. Moreover, the decrease in demand that has occurred as a direct result of the infestation has created significant risks for businesses in the service industry, particularly those in the retail and food, hospitality, and cultural tourism industries. Even worse, it is anticipated that the devastation caused by the COVID-19 outbreak will be lengthy and will have a detrimental impact on the expansion of the global economy (Kamariotou and Kitsios, 2017a; 2017b).

The current study aims to investigate the relationship between digitalization, emergency preparedness strategies for the COVID-19 outbreak, and the crisis response effectiveness of driving schools. The data for this study comes from driving schools. The findings of the survey make it abundantly evident that digitalization can assist driving schools in responding strategically to public crises over the long term, thereby contributing to an enhancement in the performance of driving schools.

2. THEORETICAL BACKGROUND

Public crises can have a significant impact on private companies. Researchers suggest that businesses should work toward transforming potential dangers into lucrative opportunities over the course of their long-term operations. In the context of the COVID-19 outbreak, for instance, the practical value of digitalization has come to the attention of a significant number of people. In addition, the economic crisis has prompted strategic shifts, such as alterations to product lines, market width, and external relations (Kirtley and O'Mahony, 2023). As a result, companies should make it their long-term goal to exploit potential opportunities presented by the current economic climate by developing and implementing appropriate strategic responses (Wan and Yiu, 2009; Wenzel et al., 2020).

Elements of public crisis interventions that are vital include having a comprehensive understanding of the crisis environment, making the most of any possibilities that present themselves, and rearranging facilities so that they can efficiently handle the situation (Ballesteros et al., 2017; Yang and Hsieh, 2013). As a result, the dynamic capabilities perspective is extremely important to the field of research on crisis response (Fainshmidt et al., 2017; Linnenluecke, 2017; Martinelli et al., 2018). Since this COVID-19 outbreak was neither anticipated nor predictable, businesses need to be equipped with the ambidexterity necessary to deal with the situation in a way that is non-procedural, inventive, and vibrant.

Companies that have the capability to be dynamic have a greater chance of recognizing and seizing new opportunities in the midst of a crisis (Ballesteros et al., 2017; Danneels, 2002; Easterby-Smith et al., 2009). A public crisis disrupts established social patterns and gives rise to novel opportunities for businesses. For instance, the shutdowns that have occurred as a direct result of the pandemic have created opportunities for the growth of online businesses. Enterprises that are installed with strategic flexibility are better able to capitalize on possibilities and are more inclined to generate and accumulate scientific understanding from the exogenous environment. This serves as a catalyst for transformation despite the ongoing economic crisis. Enterprises that are not endowed with strategic flexibility are less inclined to generate and disseminate new knowledge (Ballesteros et al., 2017; Makkonen et al., 2014).

Digitalization or digital transformation can help businesses obtain and preserve cumulative benefits by boosting their institutional agility and resilience (von Briel et al., 2018) and by enhancing their dynamic capabilities. This can be accomplished by strengthening their dynamic capabilities (Sambamurthy et al., 2003; Vial, 2021). In particular, we believe that there are advantages to be gained from digitalizing corporate processes. To begin, digitalization enables businesses to better sense the shifting environment (Vial, 2021; Yoo, 2010; Warner and Wäger, 2019). In the COVID-19 outbreak, digitalization has generated a plethora of new opportunities (Nambisan et al., 2019), and areas such as digital learning and operating as well as unpiloted transportation have demonstrated significant potential. In addition, the decentralized nature of digital technologies allows them to overcome barriers in both time and space, and it encourages interrelationships between individual companies and their concepts of collaboration, which ultimately results in an increase in the opportunities available to them within open networks (Zeng and Glaister, 2018).

Based on the analysis of the existing literature, the following hypotheses are defined:

| Hypotheses | References |
|---|------------------|
| H1: The overall degree of digitalization significantly affects the | Guo et al., 2020 |
| H2: Digital technology adoption significantly affects the | Guo et al., 2020 |
| implementation of crisis response strategies H3: Overall digitalization degree and digital technology adoption | Guo et al., 2020 |
| significantly affects driving schools' performance | , |
| H4: The implementation of crisis response strategies significantly affects driving schools' performance | Guo et al., 2020 |

Table 1: Hypotheses
3. METHODOLOGY

Variables such as digitalization, degree of digital adoption, public crisis response strategy, and public crisis response performance are based on previous surveys (Bharadwaj et al., 2013; Ekbia, 2009; Guo et al., 2020; Nambisan, 2017; Sebastian et al., 2017; Wan et al., 2009; Wenzel et al., 2020). For the purpose of measuring these variables, a Likert scale with five points was utilized.

The questionnaire was distributed to 1.300 instructors working in driving schools across Greece and Cyprus through email. The assistance of the association of driving instructors was utilized in order to locate the contact information. In the end, three hundred instructors from driving schools filled out the questionnaire. In the process of data analysis, multivariate regression analysis was employed. Educators working in driving schools are included in the sample. Driving schools are typically classified as either "micro" businesses, which have fewer than 10 employees, or "small-medium" businesses, which have fewer than 50 employees.

4. **RESULTS**

Table 2 presents that R² is 0.735 and adjusted R² is 0.882. These values indicate that 88% of the variance in success is described by independent variables. The F statistic is 258.395 with 300 degrees of freedom (1 from the regression and 299 from residuals) and the significance value is less than p < 0.05 (0.000). Therefore, the model is significant. The findings of regression analysis in Table 3 also confirm the satisfactory prediction performance of the regression model.

Table 2: Regression Analysis

| R ² | Adjust | ed R ² | Durbin-Watson | - | |
|-------------------------------|---|-------------------|------------------|---|--|
| 0.735 | 0.882 | | 1.964 | - | |
| | | | | | |
| Sum of S | quare | Df | Mean Square | e F | Sig |
| 157.919 156.455 314.374 | | 1 299 300 | 157.919 0.611 | 258.395 | 0.000 |
| | ß | | t | Sig | VIF |
| S | 0.534 | | 1.056 | 0.000 | 1.236 |
| \rightarrow | 0.168 | | 1.312 | 0.000 | 1.115 |
| | 0.430 | | 1.622 | 0.009 | 1.236 |
| \rightarrow | 0.023 | | 1.244 | 0.007 | 1.115 |
| | 0.674 | | 1.198 | 0.000 | 1.057 |
| | R ² 0.735 Sum of Si 157.919 156.455 314.374 s → | | | R ² Adjusted R ² Durbin-Watson 0.735 0.882 1.964 Sum of Square Df Mean Square 157.919 1 157.919 156.455 299 0.611 314.374 300 β t s 0.534 1.056 → 0.168 1.312 0.430 1.622 → 0.023 1.244 0.674 1.198 | $\begin{array}{c c c c c c c c c c c c c c c c c c c $ |

*Significance at <0.05, **Significance at <0.01, ***Significance at <0.001

According to the results shown in Table 4, the digitalization degree's beta value was 0.534, and its significance level was 0.000. Therefore, Hypothesis 1 was supported. The beta value of digital technology adoption was 0.168, and the significance level was 0.000. Because of this, the data support the second hypothesis. The beta value of digitalization degree was 0.430, and the significance level was 0.009. Furthermore, the beta value of digital technology adoption was 0.023, and the significance level was 0.007.Because of this, the data support the third hypothesis. Crisis response strategies had a 0.674 beta value and a 0.000 significance level. Therefore, Hypothesis 4 was supported. Table 5 displays the associations between variables, while Table 6 provides descriptive and inferential statistics.

5. CONCLUSIONS

The COVID-19 outbreak is a public health emergency that has created significant obstacles for the continued existence and expansion of driving schools. The crisis has also brought to light the significant contribution that digital technologies can make to the fight against the COVID-19 epidemic. This study examined the relationships acquired from structured questionnaires in order to evaluate the linkages among digitalization, public crisis measures, and the performance of SMEs in the framework of the COVID-19 epidemic. The results of our paper demonstrate that a SME's endeavors towards digitalization, as exhibited by their extent of ecommerce, implementation of communications technology, and taking part in various trades, can aid them in supplying a more efficacious rebuttal to public crises. These results are supported by the fact that a SME's degree of digitalization, deployment of digital technologies, and business mode influence. In addition, the implementation of public crisis response strategies is another way that digitalization helps improve the performance of driving schools.

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Optimizing complexus Bunkering Plan: Plan B

Dimitris Kaklis Danaos Research centre <u>Dk.drc@danaos.gr</u> Artemis Flori Danaos Research Centre af.drc@danaos.gr Takis Varelas Danaos Research Centre <u>tv.drc@danaos.gr</u>

Abstract

This work is focused to identify and then to resolve the shortcomings of existing bunkering plan solutions facing the substantially increased complexity of this problem. Typical linearly or dynamic programmed models have been implemented with objective to find the optimum-bunkering plan for a specific multi-leg voyage where bounds of variables are functions changed per voyage. Usually bunkering plan either it is implemented manually or utilizing working e-solutions, is feasible and is quite satisfactory but in nowadays due to complicated situations funnily enough is not the optimum. *Plan B* model optimally solves the problem when there are more than one fuel types having also the novelty of evaluation of eventual deviation for bunkering. The model also transposes to objective from minimum bunkering to fuel consumed cost and much more to maximize the voyage revenue. For this work, the *iafos genetic algorithm* is revised, enriched, improved, proved, tested and finally deployed. The objective function is formalized as multivariable decision unit taking into account financial figures (time chartering equivalent, administrative expenses, charter party options and bunkers attributes. Finally, the workable solution is presented, conclusions are summarized and ideas for further research are outlined.

KEYWORDS

Inventory control, linear programming, Artificial Intelligence, Heuristics

1. INTRODUCTION

Let start with some definitions: *Bunker* in shipping means fuel and lube oils, which are stored on a ship to be used for machinery operation only. *Bunkering* concerns all processes of the refueling of vessels. *Bunkers* represent the biggest single cost for the ship-owners or charterers and effective *bunker* procurement management focused on proper bunker suppliers' choice ensuring that ships receive the correct fuel quantity and quality. Bunkering operation in action requires utmost care and alertness to prevent any kind of fire accident or oil spill.

In this respect bunkering plan is a typical operational research problem of inventory control optimization [lee at al., 2006]. When multiple supply nodes with different prices are available, the reorder point and max stock capacity are known then a linear programming model may provide optimum feasible solution. The case of optimum vessel bunkering is an inventory control problem where reorder point *is not* a constant but variable given that the remaining on board quantity on departure should be enough to cover the distance to next bunkering port and obviously less than max capacity.

In this work will address only for bunkering plan and how to be optimized in tern of <u>fuel consumed cost</u> Consequently, the well discussed fuel consumption optimization and consequently emissions reduction algorithms and retrofit techniques *is out* of scope this study. The presented solution is the *PlanB which extends the iafos* [Varelas Orestis et al 2011] heuristic algorithm whenever more than one fuel type used and suggests the optimum plan among eventual alternative paths including bunkering ports even deviation is needed.

2. BACKGROUND

2.1 An old problem

A vessel departs from a port A_1 will berth at ports A_i (i = 2 to n) and will arrive at destination point A_n . For each f fuel type the initial remaining on board (*rob*) quantity a_1 is known as well as the total tank capacity (*cap*). The quantities to be consumed for *each* a_i - a_{i+1} leg as well as the prices per ton p_i for each port A_i are also known. The constraints are obvious. The quantity on sail s_i should be enough to cover the consumed quantity c_i to next bunkering port and should be less than *cap*. In addition, quantities on arrival a_i , departure s_i and purchased q_i should be non-negative numbers. Operation manager is called to compile the bunkering plan

following the *Ceteris Paribus principle*, assuming all other variables as constants (quality, availability, delays) with objective to minimize the total bunkering cost for the given voyage.

Few works have mentioned the bunkering plan decisions. [Kim et al., 2012] considered the optimum ship speed, refueling ports and amounts of fuel for a given ship's route, and developed an epsilon-optimal algorithm to solve the problem. Its novelty lies in considering also environmental factors such as carbon taxes, and greenhouse gas emissions. [Yao et al., 2012] designed a bunker management strategy for a single shipping liner service, h including refueling ports selection, quantities and ship speeds adjustment. [Plum et al., 2014] compiled a mixed-integer programming model for bunker and designed a column generation algorithm to solve the model. In this work as basis is used the *iafos* algorithm, since its veracity is confirmed by formalizing (figure 1) and running the core problem with LP solver except.

2.2 The iafos LP model

In order to formulate the objective function constants is imperative to underline that the total consumed cost for a given voyage is <u>not equal</u> with the cost of bunkering during this voyage. For voyage fuel, cost assessment

it should be evaluated the initial and final *rob* using the fuel prices at arrival and departure ports respectively. The total fuel voyage cost (figure1) is the cost of purchased quantities plus the value of initial rob minus the value of residual rob at destination port to be

 $MinC = \sum_{i=1}^{n} q_i p_i + a_1 p_1 - s_n p_n$ ∀i є (1: n) c_i, p_i constants except c_n, a₁=rob

Figure 1: LP model

minimized. In order to utilize LP model, the problem as formalized above needs transformation of the objective function. The reason is that quantity on departure port s_n is not given and the consumable quantity c_n to cover the distance to next port after voyage completion is also unknown. This normalization equals s_n to cap. Therefore, the objective function is transformed, easily to be proved (eq-1), to equivalent

$$MinC = \sum_{i=1}^{n} q_i p_i + a_1 p_1 - cap *_n p_n \text{ (eq-1)}$$

The algorithm in figure 2 generates the constraints functions using lower and upper bounds recursive formulas. PlanB easily proved the formulas for bounds using the epagoge peano method

$$lb_{1}=c_{1}-rob: ub_{1}=cap-rob: c_{n}=cap$$
$$lb_{i} = \sum_{1}^{k} c_{i} + rob: ub_{i} = cap - rob + \sum_{i}^{k} c_{i-1}$$
$$\forall i \in (1:n): \quad lb_{i} \leq Q_{i} \leq ub_{i} \Leftrightarrow$$

Figure 2: Recursive formula for constraints function generation

2.3 The dynamic model

[Lu Zhen, Shuaian Wang, and Dan Zhuge 2017] propose an optimal control policy for a liner ship to decide at which ports and how much fuel the liner ship should be refueled. Facing stochastic fuel consumption during each leg in its voyage as well as stochastic fuel price at each port, a liner ship can use the proposed optimal control policy to minimize the expected total fuel cost of the whole voyage under stochastic context with respect to fuel consumption and fuel. This dynamic approach optimizes further the decision in comparison with the previous linearly programming one but still in not working in case of multi fuel bunkering and eventually deviation. [Meng et al., 2015] considered different bunker prices at different ports for a tramp ship routing decision problem. The main novelty is the design of a branch-and-price based exact solution method for maximizing the total profit by routing ships to carry the given cargoes as well as determining the amount of bunker refueled at each port.

3. THE PLANB MODEL

Both dynamic and linear programming mathematical models are not able to formalize complex particularities and rules, as for example how to manage the bunkering waiting time for one or two fuels or how to incorporate weather routing. Therefore, PlanB, heuristic programmable algorithm, easily modifiable to be complied with new complex rules such as multi-fuel bunkering or deviation evaluation solution instead of LP,



Figure 3: PlanB node for each fuel fi

DP programming is suggested to overcome mentioned shortcomings. PlanB revised, enriched and extended iafos algorithm considering bunkering plan as a linked list, a graph of sequenced link nodes. Each node has as attributes: p_i and c_i that are constants and a_i , s_i , q_i quantities on arrival, sail and purchased respectively as figure 3 for each fuel f_i. Simple equations define the link of the nodes and the relation between attributes $s_i=a_i+q_i$ and $a_i=s_{i-1}-c_i$ and global constants the initial remaining on board *rob* and max capacity *cap*. The algorithm mimics the experts' decision-making approach and follows the Bellman principle of optimality minimizing expected cost at a certain port in terms of the payoff from initial decision and remaining decision values problem [Huang and Liang, 2011; Meng and Wang, 2011]. It starts with the initial optimal stage that is the node of the lower fuel price, marks it as locked: "*" and

traverses forward until a node k where a_k is less than c_k will reached_and marks it as arrived with: "a". Then goes back in its previous node setting $s_{i-1}=c_i$ and marks it as sailed with "s". This process is repeated with the next low-price node until all nodes are flagged as locked. During algorithm execution, each node has a discrete stage and rules for action and stages' change are applied whenever the node is visited. The loop is repeated for all fuels and a combinatorial algorithm provides the final solution

The PlanB designed to satisfy user requirements and initiated with application domain nodes and their

relation specification [figure 4]. The data structure includes vessel profile dataset (design, and operational), voyage plan dataset and bunkering ports details. New attributes are the total bunker capacity depending on cargo quantity, running expenses, waiting and bunkering time. We need also to know estimate bunkering attributes of the next port after the end of voyage. PlanB is designed with open architecture with gateways to external sources for bunkering (prices, availability, waiting, service time) & itinerary (delays, distances, zones etc.) information.

• Vessel profile

- foc: fuel oil consumption (tonnes/mile) = f (s: speed (miles/h))
- tanks (rob, cap)
- Running expenses (\$/day)
- Voyage plan
 - Itinerary (what next?)
 For each leg departure and arrival ports
 d: distance, speed (miles/h), days at port
 - Navigation, terms, conditions, charter party clause
- Passages, eca | non-eca, piracy, war zones
- Bunker capacity (depending on cargo quantity)
- Who pays, JIT (just in time option)
- Bunkering ports
 - Fuel: types, prices, availability
 - if Deviation required=y then distances from itinerary nodes are needed

Figure 4: PlanB Datasets

3.1 The problem: one fuel | eventual deviation for cheaper bunkering ports

It is a common life practice to evaluate cost effectiveness alternative paths with deviation to reach cheaper prices for goods like fuel. For each eventual deviation the profit from better purchasing prices must be higher than the sum of additional traveling expenses and corresponding time cost. In a multi -leg voyage may be several accessible alternate bunkering ports and consequently theoretically speaking a significant number of alternate paths. So far, it is necessary to find a feasibility criterion to eliminate the number of alternate paths. Therefore, the profit and loss of eventual deviation must be quantified.

Going from a to c via b an additional time (atc) and fuel cost (afc) with a total cost (dc) is needed and a less

atc = e*at: atc = e*($d_{ac}+d_{cb}-d_{ab}$)/(24*s) afc = foc*at: afc= foc*($d_{ac}+d_{cb}-d_{ab}$)/(24*s) $dc=(e+foc)*(d_{ac}+d_{cb}-d_{ab})/(24*s)$ fcs=($maxp_i - p_b$)*cap where Px is the bunker price (\$/ton) at port x purchasing cost is saved. Cost elements, and purchasing saving and feasibility criterion for deviation are formulated to be applied in planB algorithm as in (figure 5).

Figure 5: deviation criterion

The alternate paths are generated by the algorithm, tested for feasibility and hereafter planB optimally calculates the quantities distribution to bunkering ports and the total voyage bunkering cost (*vbc*) for each path i. Solutions are ordered and presented in descending order of vbcs.

The number of alternate paths(R) for an itinerary with p the number of itinerary and b the number of bunker ports is substantial large with reasonable negative effect in algorithm performance. Therefore, assuming that is not logical to come from and go back to the same bunker port, we applied this rule to reduce paths from R to Rej.Formulae for number of paths before and after rule applications are as follows (eq-2)

 $R=(b+1)^{(p-1)}$ Rej = [2(p-3)]b+1]b (eq-2)

3.2 PlanB with more than one grades

In our days, the bunkering plan has been become more complicated due to regulations regarding, for example, ECA (emission control areas). Vessels need different fuels HFO for non-ECA and LSFO for SECA with prices significantly different. Therefore, the voyage bunkering cost minimization is extended form two dimensions (quantity and price) to three (fuel quantity and price). PlanB took into account the availability for both grades and their prices to solve the problem with or without eventual deviations.



Screenshot 1: PlanB Multi-fuel deviation enabled user interface

PlanB using the revised iafos algorithm calculates for each alternate path the optimum-bunkering plan maximizing the total revenue. The last is linearly formalized taking into account running expenses, fuel oil consumption, deviation cost in terms of time and fuel consumption. Refueling and waiting time are also concerned and converted in cost using the TCE (time chartering equivalent). The scenarios are sorted and s the optimum-bunkering plan (fuel type, port, quantity) with the highest revenue is suggested.

3.3 PlanB In action (Screenshot1)

PlanB was deployed to plan bunkering for a voyage from Piraeus – Best -Gdansk. Vessel operational data [tanks (capacity, rob), speed, consumption, running expenses] are entered either manually or using the appropriate application program interface (API). Bunkering data [fuel prices, refueling [waiting, service time] are retrieved from BUNKEREX¹. Voyage data [miles to go from port to port (either itinerary or bunkering)

through ECA and non-ECA, running expenses per day, TCE] are ALSO retrieved from Danaos² portal. PlanB suggested deviation to Rotterdam and refuel quantities per port with 44% cost saving!

4. CONCLUSIONS

The paper presents a high -technology readiness level (TRL) applied research system for optimum bunkering plan. The suggested solution is proved by simulation, deployed and evaluated with success. Thanks to open architecture could be easily upgrade for an even better optimal control policy under stochastic context with respect to fuel consumption and price. One-step ahead could be the integration with energy efficiency programs. A multi-attribute decision making system would be the next step towards to decarbonization, environmentally friendly and maritime operation efficiency.

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¹bunkerex: <u>https://www.bunker-ex.com/</u> : bunker data provider

² <u>http://www.danaos.gr</u>: Fleet efficiency is the key element for optimal Ship management and Vessel Operations. WAVES™

Agent-based Modeling of Social Systems – The Case of COVID-19

Angelos L. Protopapas Democritus University of Thrace Department of Civil Engineering, Kimmeria Campus, 67100 Xanthi, Greece Eudokia T. Mitsou Democritus University of Thrace Department of Civil Engineering, Kimmeria Campus, 67100 Xanthi, Greece Eleftheria N. Katsiri Democritus University of Thrace Department of Electrical & Computer Engineering, Kimmeria Campus, 67100 Xanthi, Greece

Abstract

The Covid-19 pandemic has significantly affected global health, economy, and society. Governments, organizations, and citizens have implemented various measures to address the spread of the virus and mitigate its consequences. To study this multidimensional phenomenon, a social simulation model was constructed in NetLogo. The model consists of agents that move in space and transmit the virus. The course followed by an agent who is sick is as follows: admission to a hospital, admission to an intensive care unit, and finally death – all with rates based on literature. At each stage of this process, the agent can recover and acquire immunity. The age group to which each agent belongs is a fundamental characteristic of each agent. Within the framework of this study, three measures for managing the pandemic were examined: vaccination, the use of protective masks, and the initial population of the community. According to the results of the study, an increase in vaccination in the community significantly reduces hospitalizations and deaths, mainly for the age group over 65, who are at the highest risk. With an increase in the use of masks, the rate of disease spread decreases, and consequently, a small reduction in hospitalizations is observed. Finally, the initial population plays an important role in the outcome of the pandemic. In cases of overpopulation, mask use does not yield results, while in cases where the population is very small and agents are scattered, there is no spread, and most agents do not come into contact with the virus.

KEYWORDS

Social simulation, Agent-based Modeling, Covid-19, Pandemic, NetLogo.

1. INTRODUCTION

In late December 2019, a flurry of pneumonia cases appeared in the city of Wuhan, China. Despite efforts to contain the disease in China, the virus spread globally and in March 2020 the World Health Organization announced that Covid-19 is now a global pandemic [Sun 2020]. In Greece, the first cases appeared on February 26, 2020 and three years later (March 26, 2023) there was a total of 5,548,487 cases and 34,779 deaths due to the corona virus, while worldwide the total cases were 683,287,033 and the deaths are 6,826,716 as reported in the World Health Organization (WHO) database.

The Covid-19 pandemic is a multidimensional and multifactorial problem which, apart from the scientific interest, permeates and concerns the whole of our society. The general purpose of the paper is therefore the construction of a successful social simulation model to understand how the pandemic spreads and at the same time provide the user with a tool to make changes of the policy parameters and observe their effects. The specific objective of the paper essentially concerns two different policy measures. The specific objective of the paper essentially concerns two different policy measures. The specific objective mask use on the spread of the virus is studied. More specifically, the growth rate of active cases is investigated as well as the time required for the elimination of the virus in relation to different rates of mask use by the population. Secondly, it is of interest to analyze the effect of different population vaccination rates on the number of patients requiring either simple hospitalization or hospitalization in an intensive care unit as well as total deaths.

The simulation model constructed belongs to the category of multi-agent models. The Netlogo program was chosen for the simulation has a simple and flexible programming language, easy syntax and the ability to create commands from the user. The model is built through fixed elements "patches" and mobile "turtles" the number of which is unlimited. Both mobile and fixed elements are graphically displayed on the program desktop (Figure 1). The user has the ability to interact with the model directly from the control center as well as with buttons and scroll bars during iterations.

2. THE MODEL

Agents are independent entities with different characteristics that represent the members of a community during the outbreak of the virus. As a decisive role in the outcome of the disease seems to be played by the age of the patient, the agents were separated in three equal size age groups (under 30, 31 to 64 and over 65). Agents move freely in space in random directions and interact with each other. As the probability of transmission of the virus between two people is affected by many factors, it was assumed that when an agent infected with the virus meets other agents it infects them. As using a face mask was a measure to limit the spread and outcome of the pandemic, in the event that an agent is sick and uses a mask, the possibility of transmission of the virus is reduced in the model. As, on one hand, the majority of patients have mild to moderate symptoms but on the other hand, many elderly tend to require hospitalization after approximately a week of being infected, in the simulation, it was assumed that when an agent comes into contact with the virus and is labeled "sick", it continues to move and infect other agents for seven time steps, then either becomes immune or is hospitalized. Then, in case his condition worsens, he is hospitalized in an intensive care unit and finally he is either cured or dies. Note that it is expected that the health system responds immediately and that there is an adequate number of intensive care units. Finally, within the framework of the model, the assumption was made that immunity is permanent and, by extension, there is no risk of re-infection of an agent. As vaccinated patients experience milder symptoms compared to unvaccinated patients and the likelihood of severe illness and death is reduced, in the present simulation, the probability of an agent being hospitalized or in an intensive care unit and ultimately the probability of death is affected by its vaccination status. Based on the above, Netlogo simulation software [Wilensky 1999] was used to investigate how three key public policy measures affect the spread and the outcome of the disease: social distancing, vaccination and face mask use [Fathizadeh et al. 2020, Guan et al. 2020, Vyas et al. 2020, Walensky et al. 2021].



Figure 1. Net Logo desktop (left) simulation architecture (right)

2.1 Scenarios

The initial population size affects the density and represents the crowding in a given space. Distancing is essentially simulated through considering three different initial values: 100, 1000 and 10,000 for the agent population. Vaccination and mask use are quantified in the simulation through the percentage of the population that is either vaccinated or using a mask. The percentages considered for both cases are 0%, 40% and 90% per age group. From the combinations of the above variables 27 simulation scenarios are defined. In all scenarios before the simulation starts it is assumed that 15 patients exist (5 in each age group). The termination condition of simulation is that the disease is eliminated and there are no more patients. The variables studied for inference are: *hospital admissions by age group, ICU admissions by age group, deaths by age group, number of agents who are immune, sick and healthy* (not infected so far). The model is a simplified abstract representation of reality, so it is of particular interest to compare the model results to any available real data. For each age group of population, the simulation requires rates of recovery, rates of hospitalization, rates of admission to ICU, and rates of mortality in ICU (all with and without vaccination). These rates were estimated from the recent literature [Ciotti *et al.* 2020, González-García *et al.* 2021, Ortiz-Prado *et al.* 2020, Sifuentes-Osornio *et al.* 2022, Statsenko *et al.* 2022].

There is a degree of randomness in the simulation both because of the many rates and probabilities used and because of the way Netlogo works. Therefore, in order to safely draw conclusions each scenario was repeated 40 times and the average of the state variable values at each step of each simulation was used to derive the results. In addition, other statistical characteristics (min-maximum values and variance of values at each step) were analyzed in all scenarios.

2.1.1 Disease health outcomes per age group

For a population of 10,000 agents with vaccination rate of 0% hospital admissions were 4.2%, 12.7% and 29.7% in the age group 0-30, 31-64 and 64+ respectively. It is observed that in the age group 0-30:

- Hospital admissions decreased with the increase in vaccination (4.2% 3.1% 1.6%)
- The rate of ICU admissions was quite low (0.13% 0.09% 0.02%) for all three vaccination rates
- The death rate remained 0% in all three vaccination cases.

In the age group 31-65:

- Hospital admissions decreased significantly with the increase in vaccination (12.7% 8.8% 4.4%)
- In ICUs there is a decrease while the initial rate is low (0.99% 0.62% 0.16%)
- The death rate was almost zero for all vaccination rates

In the age group 65+:

- Hospital admissions decreased significantly with the increase in vaccination (29.7% 21.2% 10.1%)
- There was a significant decrease in ICU admissions (7.98% 5.21% 1.30%)
- There is a decrease in the death rate (1.58% 0.97% 0.17%)

In conclusion:

- In the age groups 0-30 and 31-64, vaccination does not have a significant impact on mortality as the probability of death of an unvaccinated person is low.
- The percentage of agents hospitalized decreases with vaccination proportionally in all age groups.
- In the age group over 65 years, vaccination has a more significant effect on disease outcome. The number of deaths for the 65+ group for each vaccination percentage is shown in Table 1.

2.1.2 Effect of social distancing on disease health outcomes

In scenarios where the initial population size was reduced from 10000 to 1000, no significant differences are observed, indicating that this level of social distancing is not sufficient to have any positive impact on the disease outcomes. In contrary by reducing the population from 10,000 to 100 significant differences are observed in all variables. The above rates appear reduced as 67.9% of the population never became ill. As expected with the reduction in dispersal and infections, the percentage of people who are hospitalized or even die is also reduced.

2.1.3 Effect of face mask use on disease health outcomes

For 10,000 initial population size, by increasing face mask use from 0% to 40% there is a maximum increase 0.26% on health outcome indicators, while increasing face masks from 0% to 90%, the maximum increase predicted was 0.21%. For most variables the results show a very small decrease with increasing vaccination (e.g., hospital admissions for vaccination 90%). For 1,000 agents initially, increasing face mask use causes only marginal decrease in most variables while for populations of 100 agents initially, increasing face mask use to 40% causes a decrease to 11 variables in total, among which, an 1.82% reduction in hospital admissions for over 65s, which is too small. Increasing face mask use up to 90%, there is a decrease in 15 variables in total, with a maximum decrease of 2.57%. In conclusion increasing the mask use the final values decrease but this decrease cannot be entirely attributed to mask use due to the randomness present in the system especially in cases where the agents are few.

2.1.4 Effect of face mask use and vaccination on virus spread

For an initial population of 1,000 agents, the increase in mask use changes significantly the disease spread, the rate of increase of patients is also considerably lower while the maximum number of agents who are sick at the same time appears significantly reduced. Also, with the increase in vaccination there is a decrease in the number of agents who get sick at the same time (Figure 2). For the case of 100 agents, for 90% face mask use, the 15 agents that were initially ill were not enough to transmit the virus, so after 7 simulation steps the ill agents decrease to 5 until they finally disappear. It is also observed that with increasing vaccination, the time to eradicate the disease decreases (Figure 3). With respect to the number of agents that have acquired immunity, in the 10,000 population, in a short period of time they were all infected regardless of their

vaccination status while the mask did not actually slow down the spread, while in the case of the 1,000 agents, increasing face mask use, increased also immunity, slower while the healthy agents declined gradually.

| Table 1: Number of deaths for the | 65+ age group p | er vaccination percentage |
|-----------------------------------|-----------------|---------------------------|
|-----------------------------------|-----------------|---------------------------|

| | 10000 | 1000 | 100 | |
|---------|-------|------|-----|--|
| vac 0% | 52 | 5 | 0 | |
| vac 40% | 33 | 4 | 0 | |
| vac 90% | 7 | 1 | 0 | |



Figure 2: Effect of the sample mean (of 40 model iterations) of face mask use on virus spread for population size 1000 and vaccination percentage 90% (left) and population size 100 and vaccination percentage 90% (right)



Figure 3: Effect of simulation time on the number of ICU admissions for the over 65 group for population size 1000 and vaccination percentage 0% (left) and population size 1000 and vaccination percentage 90% (right)

3. CONCLUSIONS

In the context of this work, the outbreak of the Covid-19 pandemic and its effects on a community were studied through simulation. Furthermore, several scenarios focusing on the simulation of three global pandemic management measures: *social distancing, face mask use* and *vaccination,* were implemented in NetLogo, either by reducing the initial population of agents participating in the simulation, (in the case of social distancing) or by defining in the model a percentage of agents using a mask and a percentage of agents that are vaccinated, respectively. Next, the effectiveness of the above measures in both a) *reducing the spread of the virus* and b) *reducing the risk of severe COVID-19,* was studied in the above scenarios. As reducing severe COVID-19 prevents not only *deaths* but also reduces *hospital and ICU admissions* these indicators were calculated in each scenario while with respect to reducing the spread of the virus, the number of *infections*, the *rate of infected agents* as well as the *duration of the epidemic* are reported.

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reducing severe COVID-19 prevents not only *deaths* but also reduces *hospital and ICU admissions* these indicators were calculated in each scenario while with respect to reducing the spread of the virus, the number of *infections*, the *rate of increase of infected agents* as well as the *duration of the epidemic* are reported.

The results show that the parameter that most influenced both the spread of the virus and the risk of severe Covid-19 was the size of the initial population. In the cases where the concentration of people is large (10,000 people) or small (100 people) the use of a face mask does not affect the final result at all and the virus is eliminated soon. In the first case all agents get sick at the start of the simulation, regardless of mask usage, and when they become immune the virus disappears. In the second case, the agents never come into contact, and, by extension, the virus does not spread, so as soon as the initial patients become immune, the virus is eliminated. Of particular interest is the case where the population was set to 1000 agents. In this case, when the percentage of the population using a protective mask is increased, the virus spreads at a lower rate, the number of patients who need hospitalization at the same time is reduced, and the virus takes twice as long to be eliminated. In addition, with the increase in the rate of mask use, the number of agents who were not infected increases and, by extension, there is a small decrease in the number of people who need hospitalization. Vaccination primarily affected patients over 31 years of age in terms of hospitalizations and deaths. In the 0-30 age group, the percentage of patients who require hospitalization or die from the virus is particularly small, therefore the role of vaccination is limited. In the over 65 age group, vaccination significantly reduces hospital or ICU admissions and deaths. With the increase in vaccination, patients recovered more quickly, yet no reduction in the rate of spread of the virus was observed.

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Opening the agenda for proposing standards on "sustainability proofing" of inland transport infrastructure/investmentsnetworks, targeting Resilience

Dr. Ioulia Moraitou Department of Civil Engineering University of West Attica Petrou Ralli & Thivon 250, 122 44 Egaleo

Abstract

The EU and our country set to call on more action in favor of combating the impacts of climate change; this paper attempts to further investigate the adverse effects of climate risks, when planning and implementing infrastructures/investments, mainly due to their weight in sustainable, regional development. The proposed work, by exploring the 2021, EC technical guidance on the climate proofing of infrastructure, covering the programming period 2021-2027, would be mainly focusing on inland surface transport infrastructure networks, further benefiting from a spirit of cross-sectoral learning and valorization of the available EC – national institutional tools. More specifically, with a view to open a discussion for proposing standards on the sustainability proofing of infrastructures, targeting Resilience, this paper will also highlight the role of the participatory approaches and co–design processes, to better implement EC environmental and cohesion policy priorities.

KEYWORDS

Sustainability proofing, Resilience, European Policies, Spatial/Regional Strategies, Inland surface transport infrastructures/ networks

1. INTRODUCTION

The nexus infrastructure / investments in a risk-resilience context, occupies more and more a special focus in current European Policy making context. To do so, infrastructure projects are approached in a broader context, which affect multifaceted parameters such as: for example, legislation, spatial-regional strategies, sectoral strategies, plans, data, guidance documents, methodologies, tools, and design standards. But, in short, what are the necessary definitions to open the discussion?

Project: an investment in physical assets and/or in activities with a clearly defined scope and objectives, such as infrastructure, acquisition of equipment, machinery or other capital expenditures, technology development, specific research and innovation activity, energy efficiency refurbishments.

Climate change: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes.

Adaptation: For each significant risk identified, relevant adaptation measures must be considered and assessed. Adaptation thus, often involve adopting a combination of structural measures (e.g., changes to the design or specification of physical assets and infrastructure, or the adoption of alternative or improved solutions) and non-structural measures (e.g., land-use planning, enhanced monitoring or emergency response programmes, staff training and knowledge sharing, development of strategic climate risk assessments, financial solutions such as insurance).

InvestEU proofing: Method to assess, report and address the sustainability performance of the proposed project. It involves evaluating, both quantitatively and qualitatively, the likely impacts of the projects on its

surroundings (e.g., positive and/or negative climate, environmental and/or social impacts), but also the impacts of a changing climate, environmental and social circumstances on the project (e.g., impacts on the project due to exposure to climate change risks or the availability of resources).

Residual impact: Adverse impact that remains even after mitigation measures were put in place.

Risk: The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social, and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence; following the EU risk assessment summary (European Commission, 2014), we differentiate between natural, non-malicious man-made, malicious man-made, and multi-hazards. Multi-hazard can be understood as a hazard, considering simultaneous, cascading, domino, and other types of causal and non-causal developments.

(Urban) resilience: The measurable ability of any (urban) system, with its inhabitants, to maintain continuity through all shocks and stresses, while positively adapting and transforming towards sustainability; A suitable generic definition, applicable also for critical infrastructure, is provided by the UNISDR (2009): "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions";

Regulations: Regulations are legal acts defined by Article 288 of the Treaty on the Functioning of the European Union (TFEU). They have general application, are binding in their entirety and are directly applicable in EU Member States. It should be noted, however, that some regulations do not apply to all Member States, and that there are exemptions, known as opt-outs, for certain Member States, such as: Denmark, for example in some parts of the area of freedom, security and justice and the monetary union; Ireland, for example in the case of the area of freedom, security and justice; and Poland in parts of the EU Charter on Fundamental Rights" (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM:114522).

2. FOCUSING ON THE POTENTIAL ADVERSE EFFECTS OF CLIMATE RISKS, WHEN PLANNING AND IMPLEMENTING INFRASTRUCTURES/INVESTMENTS; SOME METHODOLOGY STEPS

In Europe and world-wide "the current security and health crises have undoubtedly further aggravated the climate and biodiversity crisis, which has been challenging policymakers for decades. In early 2020, just 2 months before the outbreak of the COVID-19 pandemic, the European Green Deal (EGD) was approved. It puts the drive for sustainability at the center of Europe's long-term economic development strategy. The EGD is the core strategic tool to make the EU 'the world's first climate-neutral continent' by 2050". (JRC, 2023)

"According to the proposed Directive's Article 2, "resilience" means the ability to prevent, resist, mitigate, absorb, accommodate to and recover from an incident that disrupts or has the potential to disrupt the operations of a critical entity; "incident" means any event having the potential to disrupt, or that disrupts, the operations of the critical entity; "infrastructure" means an asset, system or part thereof, which is necessary for the delivery of an essential service. The operational environment in which critical entities operate has changed significantly in recent years. Firstly, the risk landscape is more complex than in 2008, involving today natural hazards (in many cases exacerbated by climate change), state-sponsored hybrid actions, terrorism, insider threats, pandemics, and accidents (such as industrial accidents). Secondly, operators are confronted with challenges in integrating new technologies such as 5G and unmanned vehicles into their operations, while at the same time addressing the vulnerabilities that such technologies could potentially create. Thirdly, these technologies and other trends make operators increasingly reliant on one another. The implications of this are clear – a disruption affecting the service provision by one operator in one sector has the potential to generate cascading effects on service provision in other sectors, and potentially in other Member States or across the entire Union" (SWD (2020) 359 final).

The systemic nature of sustainability challenges requires governance arrangements that consider the interconnectedness and complexity of a broad range of environmental, innovation, social and economic issues (EU Regulation 2021/523).

In principle, it is critical to acknowledge that the EU co-legislators have explicitly required that "implementing partners undertake sustainability proofing of investments under the Invest EU Fund. This implies 'raising the bar' and going beyond a requirement to merely comply with existing legislation. The co-legislators provide guidance on this issue in the InvestEU Regulation; for instance, some recitals refer to the European Pillar of Social Rights (7), the Paris Agreement (8), the United Nations Sustainable Development Goals (9) and the 2018 Global Risks Report (10). Article 8(5) states that projects inconsistent with the climate objectives are not eligible for support under the InvestEU Fund. Moreover, Article 8(6) of the InvestEU Regulation refers to the climate vulnerability and risk assessment to address adaptation and climate resilience, cost of greenhouse gas ('GHG') emissions, accounting of impacts on the principal components of the natural capital, social impact of the projects, and identification of projects inconsistent with climate objectives" (JRC, 2023).

As a key element of the European Policies, sustainability mainly refers to the three dimensions as for example are set out in Article 8(5) of the InvestEU Regulation: climate, environmental and social; "The sustainability proofing performed for the purposes of the InvestEU Regulation will not replace the compliance check with legal requirements under EU legislation and national law. The assessments carried out under EU and national legislation will provide the necessary input data (i.e., estimates of baseline emissions, descriptions of the likely significant effects of the project, positive effects, etc.) that will be used for the proofing, where applicable. The sustainability proofing will identify whether there are any residual impacts. It will also quantify and, where possible, monetize the residual impact that has been assessed to be of a high and/or medium risk. Subsequently, the proofing will address any residual impacts in the project's economic appraisal, together with expected benefits stemming from the positive impacts of the project. This is the real added value of the sustainability proofing beyond compliance with legal requirements (EU Regulation 2021/523).

3. DISCUSSION: RESILIENT INLAND TRANSPORT INFRASTRUCTURES – INVESTMENTS AND NETWORKS WEIGHT IN SUSTAINABLE, REGIONAL DEVELOPMENT

"Our daily lives depend on a wide variety of services – such as energy, transport, and finance, as well as health. These rely on both physical and digital infrastructure, adding to the vulnerability and the potential for disruption. During the COVID-19 pandemic, new technologies have kept many businesses and public services running, whether keeping us connected through remote working or maintaining the logistics of supply chains. An attack on electricity production could knock out telecommunications, hospitals, banks, or airports, while an attack on digital infrastructure could lead to disruptions in networks for power or finance.

As European economy and society increasingly move ever more online, risks such as these grow more acute. Develop situational awareness, early detection and rapid response to security crises through an integrated and coordinated approach, both globally and through sector-specific initiatives (such as for the financial, energy, judiciary, law enforcement, healthcare, maritime, transport sectors) and building on existing tools and initiatives are some of the basic steps on building resilience (COM (2020) 605 final "on the EU Security Union Strategy", Brussels, 24.7.2020).

The reform of the EU's Cohesion Policy for the 2014-2020 programming period and the Europe 2020 Agenda, implying that EU development policies require regions to adopt place-based policies tailored on their existing (economic) assets (through the collaborative involvement of local communities and institutions) among others introduced a new way of thinking about territorial development in the EU, that aimed to adapt development intervention to the varying conditions and potential of each region and country while, simultaneously, raising the overall effectiveness of cohesion intervention (Di Cataldo M., Monastiriotis V., Rodriguez-Pose A. 2020).

It is important at this point to recognize that place-based innovation needs a context that includes conducive governance, instruments, connections, regulatory frameworks at all levels (local, national and EU), commitment and ability to scale and diffuse successful models and solutions leading ultimately to new market creation.

In short this also means that policy must create the conditions and to stimulate local players to gain direct experience of product/service innovation, specifically for new systems-think of the mobility system of tomorrow" (World Bank, 2019).

Resilience systems analysis builds on, rather than replaces, traditional risk management approaches, by: a) adding elements that address the complexity and inter-linkages of different risks (It considers, for example, how disasters can also trigger economic shocks, and how conflicts can also leave people more exposed to disaster); b) going beyond the "known knowns", on which traditional risk management is based, to also account for uncertainty and change, by exploring how long-term trends (stressors) such as climate change, governance and insecurity, economic marginalization and volatility, environmental degradation, and demographic changes can change the nature and impact of shocks in the future; c) merging risk forecasting with critical reflection on how the system has performed in the past; d) focusing on the system, not the risk, aiming to strengthen the systems that people use to support their all-round well-being, no matter what risks they face, building on existing capacities; e) understanding the importance of power relations in helping or hindering resilience; f) considering both large scale and small-scale shocks, given that frequent, low impact events, like illness, can also have a devastating impact on people's lives (OECD, 2014).

More precisely, in terms of transport infrastructures, disruptions in such systems can take many forms...It is useful to distinguish between disruptions caused by "nature", technical failures, and unintentional errors on the one hand, and disruptions caused by malign individuals on the other hand...Internal threats in the form of technical failures, accidents and handling errors fall within the domain of system managers with more direct control compared to external causes. In some cases, a combination of both technical and human factors contributes to initiate and exacerbate the incident. The transport system is also heavily exposed to external threats such as disasters, extreme weather, and technical failures in other infrastructure. The unexpectedness of many of these threats makes it difficult to protect the transport system...as climate change continues, extreme weather can be expected to become more common and its effects on transport more severe (Koetsee and Rietveld, 2009). External threats also include deliberate attacks such as sabotage, terrorism and acts of war. Tragically, almost all modes of transport have been subject to deadly terrorist attacks. An intelligent adversary can be expected to look for vulnerabilities in a system and where and when it is poorly protected. A malicious insider can be particularly well informed about a system's vulnerabilities. Since the transport system is critical for companies and people, it is also often exposed to labour market conflicts, not least in labour-intensive modes such as air, rail, and public transport. Different transport subsystems, or modes, have different resilience characteristics.

Rail and public transport networks are generally more sensitive to disruptions than road networks. Subway and rail networks are usually rather sparse and there are often limited possibilities to redirect trains if some link is disrupted. Moreover, if a train breaks down, this will knock on delays on subsequent trains. It is therefore surprising that relatively little research has been devoted to demand-based rail and public transport vulnerability analysis (Mattsson L.G and Jenelius E., 2015).

The New Zealand Transport Agency (2012) defines resilience in the context of transport systems as "...the ability of network infrastructure to deal with a range of significant disruptions and shifting circumstances from natural disasters to changing demographics or economic shocks". Thus, a resilient transport system should be able to absorb shocks as well as accommodate slow onset long-term events such as the effects of climate change, and/or adjust and accommodate the needs of users quickly and effectively following a major disruption... Transport networks face several threats such as natural hazards and the risks of ageing infrastructure. This has led to interest in methods of assessing the resilience of transport infrastructure (Imran M., Cheyne C., Harold J., 2014). Resilience in this context also refers to the capacity of the transport system to absorb shocks, or to adjust and accommodate users' needs rapidly... According to Gordon and Matheson (2008a), resilience "relates to the ability of a roading network to continue to support the community and meet the community's social, economic and environmental needs, following a major hazard event" (p. 73 Mattsson L.G and Jenelius E., 2015).



Figure 1: Effects of decision-making on resilience (conditional vulnerability and dotted line added by the authors, Mc Daniels et al., 2008, p., 312). Source: Mattsson L.G. and Jenelius E., 2015.

3. CONCLUSIONS

The growing emphasis on the need to protect, prepare and transform the economy and society is gradually reshaping the way in which we conceive of the role of public policy, leading countries to take resilienceoriented measures on several fronts, including diversifying global value chains, building excess capacity in health systems (retraining doctors and nurses, improving logistics in pro curing and distributing vaccines and protective equipment and adopting more decentralized, digitized governance when building health data spaces). This also leads to a notion of resilience that is broader than the health domain, and encompasses individual and collective well-being, as well as economic and social dimensions, as recently reflected by the JRC in its Resilience Dashboard (JRC, 2023).

Integration of resilience in territorial, socio-economic, and environmental dimensions lead to design, implement, and assess through criteria and metrics, effective and resilient infrastructures cities/regions wide. Proposing standards on the sustainability proofing of infrastructures, targeting Resilience, contributes at alleviating risks from challenges such as climate change related extreme weather events rapid and unsustainable urbanization; moreover, could facilitate overcoming potential infrastructure disruptions with real and direct costs to entrepreneurship, impacting potentially to further market disruptions and overall (local regional) lower productivity.

Particularly focusing on resilient inland surface transport infrastructures and networks means among others to care for shorter, safer, and easier travel routes, not wasting fuel and not missing work opportunities.

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A discount-enabled mixed integer linear programming model with discrete states of changeover costs for the production planning of a steel tube mill

Paraskevas N. Georgiou Division of Management and Organization, Department of Mechanical Engineering and Aeronautics, University of Patras

Nikolaos Tsaparas ERMA FIRST ESK Engineering Solutions S.A.

Abstract

This study stems from the capacitated lot-sizing problem with sequence-dependent setup costs which is frequently used to address production planning problems in industry. A mixed integer linear programing model is developed to support the decision-making process for fabricating multiple products on the same production line at tactical level, for a finite planning horizon and known dynamic demand, applied to a case study of a steel tube mill. The proposed methodology differentiates the changeover cost imposition by recognizing two discrete states (yes/no) in case the difference between the spreads of the successive tubes produced fall within a tolerance limit. The underlying concept is that the setup time can be assumed as too small when the same steel strip size is used, thus very minor set requirements and adjustments are needed. It is a least-cost optimization model equipped with a discount piece-wise linear cost function concerning raw material purchasing, which also includes changeover, fixed and variable operation and maintenance, energy, labor, and fixed and variable storage costs. The objective is to determine the optimal quantity and timing allocation of production lots in the specific period, along with the evolution of inventory levels. A set of scenarios are examined to analyze and compare the effect of specific parameters on the elaboration and composition of production plans. Given also the actual uneven and low-production capacity utilization rate, the model generates cost-effective master production schedules which are significantly different from the business-as-usual production patterns. The size and order of production lots are tightly coupled with the trade-off between a) productivity constrained by capacity and storage caps and inventory costs, and b) flexibility mainly affected by changeover costs and their association differentiation deriving from the manufacturing process adaptability.

KEYWORDS

Production Planning; Sequencing; Lot-sizing problem; Optimization; Economies of Scale; Changeover cost

1. INTRODUCTION

The decision-making framework of an industry must be systematic, responsive, robust, and coherent to consider and satisfy a set of crucial aspects and highly demanding needs on a strategical, tactical and/or operational level. The decision support methodologies have great scientific and practical importance in the present internationalized and volatile markets in which continuously, new global players enter, competition increases, and a diversity of challenges and problems arise. Industry is prompted to take business decisions under an evolving and changeable environment of ecological, legislative, societal conditions and commitments, which strongly affect its productivity, profitability, and sustainability (Georgiadis et al., 2021).

Production planning is the general methodological concept to examine any industrial system, starting from the procurement of resources (raw materials, energy forms, labor etc.), the physical/chemical processes involved, the demand satisfaction, the storage capability etc. The lot-sizing problem determines the level (quantity) and time of production output, the size and time of ordering raw materials, as well as the inventory levels, to meet the real or forecasted demand over a finite planning horizon. Sequencing establishes the lots' ordering within a time period, accounting for the sequence-dependent setup times and costs. Integration of these two dimensions can deliver better production plans offering fertile ground for more comprehensive and more sustainable decisions. Considering the time horizon from weeks up to months, the related cases are characterized as medium-term (tactical) planning problems which must be in accordance with the directions drawn at strategic level. The anticipated objective is to generate optimal production schemes in the most efficient or economical way, while also satisfying manifold techno-economical and logical constraints (Pochet & Wolsey, 2006; Guzman et al., 2022; Guimarães et al., 2014).

Optimization models are the most prevalent means to describe and solve such industrial problems while securing the inclusion of a multiplicity of entities, specifications and requirements. The tactical planning

problems are mostly managed and expressed though mixed integer linear programming (MILP) models, which favor the representation of large-scale systems entailing material flow, balance equations and capacity constraints, as well as special features such as changeover times and costs (set-up and start-up costs and times), machine assignment, technology choices, economies of scale, and various logical conditions (Pochet & Wolsey, 2006; Guzman et al., 2022, Grossmann et al., 2002; Kallrath, 2002, 2005).

The present study based on the capacitated lot-sizing problem with sequence-dependent setup costs endeavors a reconsideration of the conceptual and modeling framework of addressing production planning problems in industry by incorporating new features in imposing changeover costs. The model developed is tested and applied on a steel industry which fabricates a variety of tubes using the electric resistance welding (ERW) method. The contribution of this work lies in a) the introduction of economies of scale through a piecewise continuous linear cost function which applies differentiated discount rates on purchasing raw materials, b) the recognition of discrete states (yes/no) in imposing changeover costs based on the relative difference between the spreads of the successive tubes produced, and c) the determination of the exact maintenance schedule of flying cutting saw monthly.

After the introductory part, Section 2 presents a summary of the literature review on production planning methodologies focusing on mathematical programming techniques. Section 3 describes the basic elements of the production planning problem and Section 4 presents the concept and selected basic characteristics of the model proposed. Section 5 includes the scenarios drawn, the results obtained and some basic points for discussion. The last section summarizes some key findings.

2. LITERATURE REVIEW

Pochet (2001), Grossman et al. (2002) and Kallrath (2002, 2005) elaborated comprehensive reviews of MILP methods, models and solution approaches used in planning and scheduling problems, presenting their corresponding characteristics and also giving some indicative examples. Guzman et al. (2022) realized a systematic review on production planning, scheduling and sequencing problems by making a classification according to a set of criteria (aggregation level, modelling approach, solution approach, integration level, data size, solution quality). Karimi et al. (2003) dealt with medium-term production planning (single-level lot sizing) problems, their attributes, and the use of exact and heuristics methods for solving them. Sundaramoorthy and Karimi (2004), Lindahl et al. (2023), Amorim et al. (2021) and Siemon et al. (2021) developed MILP models for the production planning of various industries (pharmaceuticals, chemicals, glass, copper) by engaging either a maximization of total profit or a minimization of overall costs.

Focusing on the literature review related to the production planning on the steel industry, the work of Tang et al. (2001) gave a classification of research into four main approaches: a) Operations research methods, b) Artificial Intelligence methods, c) Human-machine coordination methods, and d) Multi-agents methods. Dutta and Fourer (2001) presented a review of mathematical programming techniques and optimization applications concerning various topics such as product-mix optimization, scheduling, inventory etc.

Balakrishnan and Geunes (2003), Al-Marsumi and A'Zoza (2004), As'ad and Demirli (2011), Lu et. Al (2015), Li and Yang (2019) and Rosyidi et al. (2021) proposed customized MILP models for the optimization of production plans of coils, plates, tubes etc. by considering constraints and limitations on technological, processing, storage and policy aspects, while often including a series of cost categories (raw materials purchasing, inventory holding, changeover cost, overtime production and backorder etc.).

The present study goes beyond the typical 'combat' between productivity and flexibility as it embodies and examines different types of occurring trade-offs simultaneously. The trade-offs refer to the economies of scale in raw material purchasing, the availability of production capacity, the changeover costs and the storage capability which strongly affect the lot-sizing and sequencing objectives. A core element differentiating this work from others refers to the way the changeover costs are imposed. Interpreting the technical capability (adjustability and flexibility) of the specific manufacturing equipment, the model considers discrete states and values of changeover costs depending on the relative difference between the spreads of successive tubes. The core concept is to consider the changeover cost between two tubes of the same raw material and wall thickness, regardless their shape and outer diameter/cross-section size, produced in succession at the same time step, practically zero under the condition that their spread difference falls within a specific range. This approach allows a more realistic representation of changeover costs especially when these are calculated in an indirect way, e.g. in terms of 'lost production', without necessitating for any aggregation and loss of precision in products' features (demand, production rate, resources consumption, costs etc.). Furthermore,

the model establishes the monthly maintenance schedule of machinery parts through a novel representation of their non-divisibility, continuity of use and lifetime.

3. PROBLEM DEFINITION

The ERW steel tube mill manufactures a large variety of products differentiated at shape, raw material, diameter/cross-section size, and thickness. The objective is to find the optimal lot-sizing and sequencing patterns that minimize the period's total costs under demand, technical and logical constraints. The role of economies of scale in bulk purchasing of raw materials is to lower unitary production costs by exploiting the volume-related increased discounts and the significant capacity margin of the manufacturing line based on the known uneven and low monthly utilization factors. The other economic driving force is the changeover cost which includes clean-up, set-up and start-up charge for equipment cleaning, preparation, and machine adjustments when tubes with significantly different characteristics succeeded each other. In the current case study, the fin pass rolls have the technical feasibility to manufacture any tube shape by applying the minor set requirements and adjustments, provided that the machinery is fed by the same steel strip size.



Figure 1: Flowchart of the ERW manufacturing procedure for steel tubes

Some basic assumptions applying to the current problem compilation, are: a) 12-month deterministic demand, b) no resource limitations in work force, electricity, machinery parts and lubricants, c) changeover costs are calculated as 'lost production' (the product of the line speed and profit price of the tube category to exit production line, multiplied with an average changeover time).

4. MODEL DESCRIPTION

The background of the present production planning model falls into dynamic capacitated multi-item singlelevel lot-sizing problems with sequence dependent setup, in which multiple products can be produced on the same equipment within a medium-term period (Jans & Degraeve, 2008). It is a deterministic MILP model encompassing a plethora of product categories as decision variables (continuous and integer) and plenty of mathematical relationships which represent demand satisfaction, production capacity limits, resources and storage availabilities, and product changeover requirements plus other techno-economic and logical constraints with the participation of continuous, integer and binary variables. The model's objective is to identify which, when, in what order, and how much of each tube must be produced to minimize the overall incurring costs (production, stock holding and changeover costs). The proposed methodological and modeling framework is ready to apply to any industry producing a variety of goods either in a single process or through multiple processes considered as a single operation (Karimi et al., 2003).

$$CRX_{r,l} = \begin{cases} prm_{r,l} \cdot RX_{r,l} |, & 0 \le RX_{r,l} \le b_{1} & \text{where,} \\ prm_{r,l} \cdot b_{1} + (1 - dr_{1,r,l}) \cdot prm_{r,l} \cdot (RX_{r,l} - b_{1}) |, b_{1} \le RX_{r,l} \le b_{2} & \text{prm}_{r,t} : \text{price of raw material (steel coil) } r \text{ at time } t \ (\notin / \text{kg}_{\text{steel}}) \\ prm_{r,l} \cdot b_{1} + (1 - dr_{1,r,l}) \cdot prm_{r,l} \cdot (b_{2} - b_{1}) |, b_{2} \le RX_{r,l} \le b_{3} & \text{b}: \text{ boundary (break point) of range of order size } k \text{ at time } t \\ + (1 - dr_{2,r,l}) \cdot prm_{r,l} \cdot (RX_{r,l} - b_{2}) & \text{b}: boundary (break point) of range of order size k \text{ at time } t \\ + (1 - dr_{2,r,l}) \cdot prm_{r,l} \cdot (b_{3} - b_{2}) & \text{b}: b_{3} \le RX_{r,l} \le b_{4} & \text{at time } t \\ + (1 - dr_{3,r,l}) \cdot prm_{r,l} \cdot (RX_{r,l} - b_{3}) & \text{b}: b_{3} \le RX_{r,l} \le b_{4} & \text{at time } t \text{ (kg)} \end{cases}$$

The economies of scale are expressed through the mentioned (four-branched) piecewise continuous linear cost function which is properly articulated to satisfy all the MILP assumptions. Product changeover requires the most modeling effort through the extensive usage of binary variables and treatment of non-linearities, which increase the model's computational complexity and combinatorial status. Indicatively, the basic logical conditions interpreted for two successive products are: a) changeover is allowed in one direction at the same

time step t, b) any self-changeover occurrence is forbidden, and c) there cannot be either a many-to-one relationship or a one-to-many relationship in tube production sequence.

5. RESULTS

Scenario analysis has a two-fold aim to investigate: the effect of the differentiation in imposing changeover cost based on the relative difference between the spreads of two successive tubes (Scenarios A to D), and the impact of specific techno-economic parameters such as storage cost and capacity, raw material's price, and economies of scale (Scenarios E to H), on the design of production plans and system's economics.

Fig. 2 reveals that in every scenario the monthly tube production allocation has a similar trend (a front-loaded production from January to April being almost over doubled compared to matching demand) because the gain from ordering larger volumes of raw materials combined with the production capacity availability, outperforms the increased storage costs. Drilling down in the composition of the monthly output, the optimization process drives production to deliver the larger possible lots per tube category in order to avoid frequent stoppages and minimize incurring changeover costs.



Figure 2: Monthly tube demand and production per scenario Figure 3: Total operational cost breakdown per scenario

Fig. 4 illustrates an indicative cyclic sequence of tubes occurring in a monthly time step. The number and the size of cycles obtained are not proportional to the monthly production volume because the changeover cost is not the only driver under the mentioned multiplicity of trade-offs. Depending on the scenario, there can be more or less closed-loops of product changeovers either the sequences consist of the same or different tube shapes.



Figure 4: Cyclic sequence pattern of Round-Square-Rectangular-Round tubes

Economics results (Fig. 3) confirm the dominant cost role of raw materials, followed by variable and fixed O&M expenses while storage causes a little burden. The share of changeover cost varies from 8 to 4% when both the sequencing option is allowed and the discretization in imposing changeover costs are enabled.

6. CONCLUSIONS

The proposed bottom-up MILP model which is applied to the production planning of an ERW steel tube mill introduces a new trade-off concept for the economies of scale in purchasing raw material and a differentiated approach in imposing changeover costs, for studying their effect on lot-sizing and sequencing schemes. Under a tug of war game between a) productivity: to manufacture larger batches, take advantage of economies of scale, and avoid futile changeover stoppages, and b) flexibility: to promote smaller product lots as late as possible, react quickly to market changes and have lesser inventory costs, the system's optimization chooses to utilize the significant margin of production capacity, to benefit from discounts on bulk purchasing of raw materials, to exploit the storage availability and optimize changeover behavior.

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Integration of Passenger Unmanned Aerial Vehicles (UAVs) in Urban Areas Transportation

Pouresfantiani KNF Undergraduate Researcher, University of West Attica, Department of Civil Engineering PouresfantianiKaragiannisNF@ outlook.com Vryzidis I. Assistant Professor, University of West Attica, Department of Civil Engineering i.vryzidis@uniwa.gr Moussas V. Associate Professor, University of West Attica, Department of Civil Engineering <u>ymouss@uniwa.gr</u>

Spyridakos A. Professor, University of West Attica, Department of Business Administration tspyr@uniwa.gr

Abstract

The rapid development of Unmanned Aerial Vehicles (UAVs) during the past decade has led to the consideration of passenger UAVs as an alternative method of urban transportation. This work examines the potential use of passenger UAVs from a civil engineering point of view, considering the corresponding infrastructure requirements for buildings or open areas, their optimal interaction with other transportation means, the possible implications in the city, as well as the environmental and legal, or other issues that may emerge. The Attica region in Greece is selected as a case study due to the high availability of potential UAV airport locations and the increased need for new transportation solutions. This study aims to design an urban airport network that optimally interacts with existing transportation means. Apart from describing the required infrastructure for deploying UAV airports, this work also suggests a Multiple Criteria Decision Aiding (MCDA) approach based on the UTASTAR method for identifying the most suitable municipalities in the region for constructing UAV airports.

KEYWORDS

Smart City, Passenger UAV, MCDA, UTASTAR, Civil Infrastructure, Urban Transportation

1. INTRODUCTION

The rapid development in the last decades of Unmanned Aerial Vehicles (UAVs), commonly known as drones, paved the way for passenger UAVs and a new future in urban transportation. Integrating passenger UAVs into the existing infrastructure and public transport network is challenging, and many organisations and companies have proposed solutions for designing and monitoring urban airspace to face those challenges. These proposals include the FAA's urban air mobility concept (Bauranov & Rakas, 2021), NASA's UAS traffic flow (Jang et al., 2017), and Amazon's proposal about layered Urban Airspace (Amazon Prime Air, 2015). Many researchers claim that integrating passenger UAVs into traffic management systems will have many adverse effects, such as visual and noise pollution, object avoidance issues, limited operational capabilities in harsh weather conditions, privacy concerns, etc. (Bauranov & Rakas, 2021; Sándor, 2019; Zieliński, 2022; Syd Ali, 2019), while others claim that it will have a positive impact on the reduction of carbon emissions to the atmosphere, reduction in travel time, the creation of jobs, the decongestion of the traffic system, etc. (Laghari et al., 2023; Garau Guzman & Baeza, 2024).

Although it is quite early for this type of transport to concentrate the attention of governments worldwide, a few efforts exist, such as the creation of an urban airport network in Paris for the Olympics in 2024, the development of urban airports along the coast of New York delegated to the cooperation between the companies LIFT Aircraft and Charm Aviation, the utilisation of passenger UAVs as ambulances in the city of Ghent as part of the Urban Air mobility program, etc. (Butterworth-Hayes, 2018; Lynn, 2023).

The primary goal of creating such an urban airport network is to find the most suitable locations from a construction and economic growth perspective. This work focuses on selecting the most appropriate areas for constructing UAV airports according to the passengers' needs and creating an efficient transport network. It suggests a methodology to address this location problem based on Multiple Criteria Decision Analysis (MCDA), considering the existing transportation means, the population density, and technical aspects. The methodology also aims to provide a classification of the municipalities during the initial stages of the selection process to avoid unnecessary detailed analysis of all options. The paper is organised as follows: Section 1 includes an introduction to the article's topic. Section 2 presents the suggested methodology for evaluating

alternative structural solutions for new buildings at the preliminary design stages, while section 3 includes an application of it in the Attica region. Section 4 concludes the main findings of this study.

2. THE UTASTAR METHOD FOR THE SELECTION OF URBAN AIRPORT LOCATIONS

Selecting the optimal locations for urban airports in the region of Attica proved to be a complex problem with multiple variables that need to be considered. The most suitable locations for the urban airports depend on various factors that will differ from one municipality to another. In this case, the MCDA UTASTAR method is suggested, which belongs to the family of disaggregation—aggregation approaches (Siskos & Yannacopoulos, 1985; Jacquet-Lagreze & Siskos, 1982). The UTASTAR method leads to the estimation of an additive value preference model described in the following formulae:

$$U(g) = \sum_{i=1}^{n} p_i u_i(g_i), \qquad u(g_{i*}) = 0, u(g_i^*) = 1, \qquad for \ i = 1, 2, ..., n$$
$$\sum_{i=1}^{n} p_i = 1, \qquad p_i \ge 0 \text{ where } i = 1, 2, ..., n$$

, where $g = (g_1, g_2, ..., g_n)$ is the evaluation vector of an alternative action on the *n* criteria; g_{i*} and g_i^* are respectively the least and most preferable value of the ith criterion; $u_i(g_i)$ is the value function of the criterion g_i , and p_i the respective weight.

In this case, the required preference information from the decision maker (DM) is to rank order the alternative locations of a reference set, which have to be representative of the whole set of alternative options. The UTASTAR method uses this information to estimate an additive value model that satisfies this preference information. The following linear program is solved, and special post-optimality analysis techniques are applied to test the stability of the estimated model (Grigoroudis & Siskos, 2002; Jacquet-Lagreze & Siskos, 1982; Siskos & Yannacopoulos, 1985):

$$[min]F, F = \sum_{i=1}^{k} (\sigma^{+}(a_{i}) + \sigma^{-}(a_{i}))$$

Subject to:

$$\sum_{i=1}^{n} p_{i}u_{i}[g_{i}(a_{m})] - \sigma^{+}(a_{m}) + \sigma^{-}(a_{m}) - \sum_{i=1}^{n} p_{i}u_{i}[g_{i}(a_{m+1})] + \sigma^{+}(a_{m+1}) - \sigma^{-}(a_{m+1}) \ge \delta \text{ if } a_{m}P_{a_{m+1}}$$

or

$$\sum_{i=1}^{n} p_{i}u_{i}[g_{i}(a_{m})] - \sigma^{+}(a_{m}) + \sigma^{-}(a_{m}) - \sum_{i=1}^{n} p_{i}u_{i}[g_{i}(a_{m+1})] + \sigma^{+}(a_{m+1}) - \sigma^{-}(a_{m+1}) = 0 \text{ if } a_{m}I_{a_{m+1}}$$

for $m = 1, 2, ..., k - 1$

$$\sum_{i=1}^{n} p_{i} = 1, p_{i} \ge 0, \text{ for } i = 1, 2, ..., n$$

$$\sigma^{+}(a_{j}) \ge 0, \sigma^{-}(a_{j}) \ge 0, \gamma \iota \alpha j = 1, 2, ..., k$$

, where δ is a small positive number; $g_i(a_m)$ represents the evaluation of the object a_m on the ith criterion, while $u^i[g^i(a^m)]$ represents the corresponding marginal value; and $\sigma^+(a_j)$, $\sigma^-(a_j)$ the under (over)estimation errors for the jth object.

3. CASE STUDY

This paper focuses on the Attica region in Greece, including the city of Athens, a densely populated area with the highest population in Greece. This study aims to develop a well-designed network of urban airports that could meet the demands of potential users of UAVs as a mode of transportation. Several municipalities in Attica have been assessed based on different factors, such as population density, accessibility to urban transportation hubs like bus stops and metro stations, construction requirements, and distance from three key locations: the main airport of Athens (Spata-Artemida municipality), the main port of Attica region

(Piraeus municipality), and Argyroupoli-Elliniko municipality in which one of the world's largest coastal park is under construction. In this design phase, the DM needed to focus on a small set of evaluation criteria, which can form a sound basis for comparing the various municipalities. Concisely, the six criteria and the evaluation of the different municipalities to the criteria are presented in Table 1 and Table 2, respectively.

Table 1: Evaluation criteria for the comparison of municipalities

| Criteria | Description |
|---|---|
| CR1: population density | Population density is determined based on the number of residents in each municipality (ELSTAT, 2023) |
| <i>CR2:</i> distance from other public transports | Proximity to current urban transportation is scored on a scale of 1 to 5, with 1 indicating longer distances and 5 indicating shorter distances. The distance from the available public transport network, especially the one from the closest metro station, is utilised. |
| <i>CR3:</i> level of technical difficulties | It concerns the construction requirements for developing a UAV airport in each municipality. For example, the lack of available open space area could lead to the construction of a UAV airport on a building roof, which requires special structural treatment. Technical difficulty is also ranked on a scale of 1 to 5, with 1 indicating low difficulty and 5 indicating high difficulty. |
| <i>CR4:</i> proximity from Piraeus | The proximity of each municipality from Piraeus is rated on a scale of 1 to 3, with 3 indicating distances from 0 to 7 km, 2 indicating distances from 7 to 15 km, and 1 indicating distances from 15 to 27 km. |
| <i>CR5:</i> proximity from Spata – Artemida | The proximity of each municipality from Spata-Artemida is rated on a scale of 1 to 4, with 4 indicating distances from 0 to 10 km, 3 indicating distances from 10 to 20 km, 2 indicating distances from 20 to 30 km, and 1 indicating distances of 30 km or more. |
| <i>CR6:</i> proximity from Argyroupoli – Elliniko | The proximity of each municipality from the Argyroupoli-Elliniko is rated from 1 to 3, with 3 indicating distances from 0 to 15 km, 2 indicating distances from 15 to 25 km, and 1 indicating distances of 25 km or more. |

Table 2: The decision performance table

| A/A | MUNICIPALITY | CR1 | CR2 | CR3 | CR4 (km) | CR5 (km) | CR6 (km) | CR4 | CR5 | CR6 |
|-----|--------------------------|---------|-----|-----|----------|----------|----------|-----|-----|-----|
| 1 | ATHENS | 637.798 | 5 | 5 | 8,67 | 9,59 | 18,9 | 2 | 4 | 2 |
| 2 | PERISTERI | 132.123 | 3 | 5 | 8,86 | 22,97 | 13,1 | 2 | 3 | 3 |
| 3 | PAPAGOU-CHOLARGOS | 45.164 | 3 | 2 | 14,38 | 12,79 | 14,44 | 2 | 3 | 3 |
| 4 | ZOGRAFOU | 69.857 | 1 | 4 | 11,76 | 10,29 | 15,66 | 2 | 3 | 2 |
| 5 | VRILISSIA | 32.422 | 2 | 2 | 19,73 | 18,85 | 14,73 | 1 | 3 | 3 |
| 6 | EGALEO | 64.828 | 4 | 4 | 6,25 | 12,21 | 23,74 | 3 | 3 | 2 |
| 7 | NEA SMYRNI | 72.546 | 1 | 1 | 6,17 | 20,15 | 6,74 | 3 | 2 | 3 |
| 8 | ILION | 83.523 | 1 | 3 | 11,28 | 16 | 23,15 | 2 | 3 | 2 |
| 9 | KIFISIA | 72.860 | 3 | 1 | 20,5 | 21,56 | 19,3 | 1 | 2 | 2 |
| 10 | GLYFADA | 89.605 | 1 | 2 | 13,31 | 3,68 | 18,58 | 2 | 4 | 2 |
| 11 | HERAKLION | 50.495 | 4 | 2 | 15,64 | 17,74 | 19,78 | 1 | 3 | 2 |
| 12 | CHALANDRI | 77.118 | 2 | 2 | 15,97 | 15,81 | 15,95 | 1 | 3 | 2 |
| 13 | MARKOPOULO-MESOGAIAS | 21.284 | 1 | 1 | 26,18 | 17,67 | 6,01 | 1 | 3 | 3 |
| 14 | MEGARA | 38.046 | 1 | 2 | 27,02 | 36,08 | 53 | 1 | 1 | 1 |
| 15 | ASPROPYRGOS | 31.420 | 1 | 3 | 13,63 | 22,87 | 34,04 | 2 | 2 | 1 |
| 16 | VYRONAS | 59.134 | 2 | 4 | 9,7 | 7,65 | 16,67 | 2 | 4 | 2 |
| 17 | AGIOI ANARGYROI-KAMATERO | 61.427 | 1 | 4 | 11,3 | 15,4 | 22,22 | 2 | 3 | 2 |
| 18 | MOSCHATO-TAVROS | 39.507 | 4 | 3 | 3,48 | 8,4 | 23,04 | 3 | 4 | 2 |
| 19 | LAVREOTIKI | 25.608 | 1 | 1 | 44,46 | 33,71 | 26,02 | 1 | 1 | 1 |
| 20 | SARONIKOS | 29.703 | 1 | 1 | 26,84 | 16,85 | 16,05 | 1 | 3 | 2 |

The DM's preferences were expressed by pre-ranking a reference set illustrated in Table 3. It is important to note that the municipality of Athens was not included in the reference set and the analysis, as this

alternative's performance in almost all the criteria is significantly better than the rest. Therefore, the decision process concerns the rest of the municipalities, and Athens was selected to develop a UAV airport.

The additive value model was estimated by using the MINORA decision multicriteria analysis system (Siskos et al., 1993). The decision maker ultimately approved the additive utility model, extrapolating to all alternatives. The results from the MINORA system are illustrated in Figures 1, 2, 3, and 4. The decision maker has given significant importance to the population density criterion because it indicates the future profit an urban airport could bring, along with the technical difficulties. Finally, the MINORA program was used to determine the partial values of all the alternatives based on the criteria, followed by an estimation of their total values. The final ranking of the alternative options is presented in Table 4, and the ordinal regression curve of all alternatives is in Figure 5.



Figure 1: Marginal Utility Functions & Criteria Weights





Table 3: Expert ranking of the reference set

| A/A | Municipality | Experts Ranking |
|-----|---------------------|-----------------|
| 2 | PERISTERI | 2 |
| 4 | ZOGRAFOU | 7 |
| 5 | VRILISSIA | 10 |
| 6 | EGALEO | 5 |
| 7 | NEA SMYRNI | 3 |
| 9 | KIFISIA | 1 |
| 12 | CHALANDRI | 4 |
| 13 | MARKOPULO-MESOGAIAS | 6 |
| 14 | MEGARA | 8 |
| 15 | APROPYRGOS | 9 |
| 19 | LAVREOTIKI | 11 |
| 20 | SARONIKOS | 10 |



Figure 2: Ordinal Regression Curve of Reference Set



Figure 4: Extrapolation of additive value model to all actions

Table 4: Final Ranking



The ordinal regression curve in Figure 5 could be used to determine a set of locations more suitable for developing a UAV airport. In this case, a set of ten (10) locations (the ones indicated between orange lines) and the city of Athens are suggested. It is worth mentioning that this analysis is a preliminary design, and a detailed design of the selected locations is required in the next phase, considering more parameters like the cost of investment.

4. CONCLUSIONS

This study investigates the value of multi-criteria analysis in evaluating alternative locations in which urban airports are more suitable to be created. Based on our findings, the development of multi-criteria analysis tools can assist in the decision-making process. Many challenges will arise in the future as a result of the development of this type of transport network. Therefore, it is worthwhile to investigate alternative methods to determine the final ranking of the alternatives and compare their efficiency in multiple cases.

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A multi-criteria decision methodology for academic staff selection in a neutrosophic environment

Antonios Paraskevas

University of Macedonia, Department of Applied Informatics Egnatia Str. 156, 54636, Thessaloniki, Greece <u>aparaskevas@uom.edu.gr</u>

Michael Madas

University of Macedonia, Department of Applied Informatics Egnatia Str. 156, 54636, Thessaloniki, Greece <u>mmadas@uom.edu.gr</u>

Abstract

To sustain a university's international reputation in academic society, it is critical to attract high-quality academic staff, which, by all means, constitutes its most significant asset. This selection displays a vital role in accomplishing strategic objectives, while simultaneously increasing the academic institute's level of attained performance. In this respect, the process of selecting qualified academic staff establishes a critical aspect of an academic organization's competitiveness, efficiency, and status. Our research aims to provide a useful managerial decision-making tool by developing and demonstrating a comprehensive multi-criteria methodological framework and assisting decision-makers with the complicated academic staff selection process. Our main objective is to fill a gap observed in related literature, by proposing a compact and integrated methodological framework based on AHP and Delphi methods, yet within a neutrosophic context. The conceptual framework introduced in this paper, uses the theory of neutrosophy sets and is considered suitable in terms of significant degree of ambiguity and indeterminacy observed in decision-making process. To the best of our knowledge, our approach is the first to employ the suggested N-DM in the recruitment of academic personnel. As a case study, we selected to apply our method to a real-world problem of academic personnel selection, as represented by a numerical example, with the main goal of improving the algorithm proposed by earlier scholars' work. A comparative analysis study showcases that our model performs better in a neutrosophic environment rather than using fuzzy methods.

KEYWORDS

MCDM methods, Analytical Hierarchy Process, Delphi Method, personnel recruitment, neutrosophic set theory

1. INTRODUCTION

Human resources are considered to be one of the most important, if not the utmost, asset for any organization that seeks for long-term prosperity and success. The target of the personnel selection process is to recommend the ideal individual for the appropriate position within an organization (Balezentis et al., 2012).

Multiple-criteria decision-making (MCDM) problems with quantitative or qualitative attribute values are utilized in various scientific fields such as operations research, management science, and economics. The attribute values in MCDM problems cannot always be satisfactorily expressed with crisp numbers due to the ambiguity and complexity of the criteria involved. In such instances, the decision-makers' preference values for evaluating alternatives may be vague, imprecise, or incomplete.

In 1995, F. Smarandache, commencing from a philosophical consideration, began to use the non-standard analysis with a tri-component logic/set/probability theory. As a result, he proposed the theory of neutrosophic logic since fuzzy logic is considered incapable of demonstrating indeterminacy on its own (Rivieccio, 2008). Quoting the definition given in (Rivieccio, 2008), "Neutrosophic logic is a variant of logic that generalizes fuzzy logic, paraconsistent logic, intuitionistic logic, etc. The first part of neutrosophic logic is the degree of membership (T), the middle part is indeterminacy (I), and the third part is the degree of non-membership or falsity (F) of each set element". Researchers in (Wang et al., 2005; Wang et al., 2010) proposed interval neutrosophic sets (INSs) and single-valued neutrosophic sets (SVNSs), both of which are subclasses of NSs. SVNSs and INSs are extremely strong tools for analysing imprecise, partial, and uncertain information, particularly in many engineering and technology challenges.

In the literature, there are numerous MCDM approaches that aim to address the selection of academic staff. However, many of these studies have limitations because these problems heavily rely on human judgment

and intuition, leading to a high degree of uncertainty and incomplete or inconsistent information. Therefore, there is a need for "intelligent" inference techniques to process uncertain data and knowledge.

The remainder of this paper is structured as follows: First, previous relevant research dealing with the personnel selection problem in general and with the recruitment of academic staff particularly, under a multicriteria decision-making perspective, are presented in section 2. In section 3, the steps that formulate the algorithm of our method are given. Following, in section 4, we demonstrate how our method works in a real case study based on the selection of academic personnel. Finally, in Section 5, conclusions and possible future work are highlighted.

2. LITERATURE REVIEW

The personnel selection procedure is suggested by many researchers to be utilized by decision support system tools in order to improve the judgments of decision makers (Mehrabad and Brojeny, 2007; Shih et al., 2005). An aggregating function, or "closeness to the ideal" solution, is used in (Opricovic and Tzeng, 2004). In order to improve the judgments of decision makers, AHP technique divides the problem into a top-down hierarchical structure (Saaty, 1990). The fuzzy methods are provided to improve the judgments of decision makers during the process of personnel selection due to vague and imprecise information (Karsak, 2001). Fuzzy AHP is used as a tool to rank applicants and choose the best candidate (Ayub et al., 2009). The AHP and TOPSIS methods combined with neutrosophic logic are used in a variety of fields, including supplier selections and risks, and support of decision makers resulting in the best decisions under uncertainty and inconsistency conditions (Abdel-Basset et al., 2019; Radwan et al., 2016).

Scholars in (Abdel-Basset et al., 2018) suggested a neutrosophic AHP approach in order to choose the most appropriate learning management system. They claimed that neutrosophic set theory makes the experts' judgements more flexible whereas conventional AHP method takes into account the definite judgements of decision makers. Another research work which is related to neutrosophic AHP is published in (Abdel-Basset et al., 2017). They developed a neutrosophic AHP Delphi group decision-making model based on trapezoidal neutrosophic numbers in order to handle experts' non-deterministic assessment values. An interesting method is followed in (Miller, 2006) where the researchers proposed a method for group decision making based on N-AHP which utilized triangular neutrosophic numbers and solved a real world problem structured by the experts.

The Delphi approach is employed in a variety of disciplines, including program planning, resource allocation, policy evaluation, and needs assessment. A study in which researchers combined AHP with Delphi to address conflict resolution in recruiting decisions is found in (Liu, 2013). Recently, in (Paraskevas et al., 2022), researchers formed a model which uses fuzzy AHP and fuzzy Delphi and applied it in the selection of an academic at Neapolis University Pafos, Cyprus.

Very few studies in the literature have been observed that employ the Delphi method in a neutrosophic environment. For example, in (Falcón et al., 2020), the N-Delphi method is proposed for evaluating academic research projects supported by neutrosophic logic. Their model is based on the Delphi method, which includes a consensus index to prevent the slow convergence of Delphi, although this may require multiple rounds to reach agreement between experts. This method is used in predicting future scenarios or events through expert assessment. The neutrosophic framework has the benefit of incorporating both uncertainty and indeterminacy into decision-making. Another advantage is that experts use linguistic scales to conduct evaluations, which increases the validity of the results.

3. MATERIALS AND METHODS

In this section we present essential definitions involving single valued neutrosophic sets and outline the steps of the proposed methodology.

Definition 1 (Smarandache, 1999). Let **X** be a space of points (objects), with a generic element in **X** denoted by **x**. A single-valued neutrosophic set (SVNS) **A** in **X** is characterized by truth membership function T_A,

indeterminacy membership function I_A , and falsity membership function F_A . For each point **x** in **X**, $T_A(x)$, $I_A(x)$, $F_A(x) \in [0, 1]$.

Then, a simplification of the neutrosophic set **A**, which is a subclass of neutrosophic sets, is denoted by $A = \{ \langle \mathbf{x}, T(\mathbf{x}), I(\mathbf{x}), F(\mathbf{x}) \rangle \mid \mathbf{x} \in \mathbf{X} \}$ (1)

Definition 2 (Radwan et al., 2016). If **A** is a single valued neutrosophic number, a score function S(A) is mapped into the single crisp output S(A') as follows:

| $S(A) = (3+T_A-2I_A-F_A)/4$ | (2) |
|-----------------------------|-----|
| S(A') = 1 / S(A) | (3) |

Neutrosophic Logic to assign weights to the decision-makers

The DMs weights have been assigned based on the fact that their opinions represent different importance due to their different experience, position, and academic qualification. Let $D^{(k)} = (d_{ij}^{(k)})_m \times_n$ be the singlevalued neutrosophic decision matrix of the k-*th* decision maker and $\Psi = (\Psi_1, \Psi_2, ... \Psi_p)^T$ be the weight vector of decision maker such that each $\Psi_{\kappa} \in [0,1]$. The aggregated matrix can be obtained by using single valued neutrosophic weighted averaging (*SVNWA*) aggregation operator proposed by Ye (Ye, 2014) for SVNS's as follows: $\mathcal{D} = (d_{ij}^{(k)})_m \times_n$ where

$$d_{ij} = \text{SVNSWA}_{\psi} (d_{ij}^{(1)}, d_{ij}^{(2)}, \dots, d_{ij}^{(p)}) = \psi_1 d_{ij}^{(1)} \bigoplus \psi_1 d_{ij}^{(2)}, \bigoplus \dots, \bigoplus \psi_p d_{ij}^{(p)}$$

$$= \left\langle \mathbf{1} - \prod_{k=1}^p (\mathbf{1} - \mathbf{T}_{ij}^{(p)})^{\psi_{\kappa}}, \prod_{\kappa=1}^{\pi} (\mathbf{I}_{ij}^p)^{\psi_{\kappa}}, \prod_{\kappa=1}^{\pi} (\mathbf{F}_{ij}^p)^{\psi_{\kappa}} \right\rangle$$
(4)

Neutrosophic Delphi (N-Delphi)

An innovative neutrosophic Delphi approach is utilized to maintain only the important attributes for academic staff selection. Unimportant criteria can be detected and thus deleted using this method.

Through a questionnaire, each DM is asked to rate the significance of each evaluation criterion. The objective is to integrate all DMs' opinions so as to remove insignificant criteria. The linguistic terms which can be employed in the questionnaire are shown in Table 1.

| Linguistic variable | SVNNs |
|---------------------|-------------------|
| Very Low | (0.1, 0.8 , 0.9) |
| Low | (0.3, 0.7, 0.7) |
| Medium Low | (0.4, 0.65, 0.6) |
| Medium | (0.5, 0.5, 0.5) |
| Medium High | (0.6, 0.35 , 0.4) |
| High | (0.8, 0.15, 0.2) |
| Very High | (0.9, 0.1, 0.1) |

Table 1: List of linguistic terms(adopted and modified from (Paraskevas et al., 2022))

In order to decide the weight of each criterion from corresponding neutrosophic pairwise comparison matrix, we first transform neutrosophic pairwise comparison matrix to deterministic pairwise comparison matrix, using Eq. (4) in order to determine the aggregated neutrosophic decision matrix that can be obtained by fusing all the decision makers' opinion. To calculate the weight of each criterion from corresponding aggregated neutrosophic pairwise comparison matrix, we transform it to deterministic pairwise comparison matrix, by applying Eq. (2) & (3).

With compensation by the score value of each neutrosophic number in the neutrosophic pairwise comparison matrix, we get the deterministic (crisp) matrix shown below.

$$\mathbf{A} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}$$

From the previous matrix we can easily find ranking of priorities, namely the Eigen Vector X as follows (Abdel-Basset et al., 2017):

1. Normalize the column entries by dividing each entry by the sum of the column.

2. Take the totality row averages.

The selection process becomes more demanding and time-consuming as the number of criteria increases. Therefore, only critical criteria are taken into consideration for the subsequent evaluation, while unimportant criteria are rejected. By combining the judgments of all the analysts (Eq. 3), we define a minimum acceptable weight for all the criteria, known as a threshold value.

To assess inconsistencies in judgments within each comparison matrix and throughout the entire hierarchy, the AHP methodology utilizes a consistency index (CI) (Saaty, 2006). The AHP method uses the consistency index and consistency ratio to identify any discrepancies in the neutrosophic judgment matrix (CR). If the CR surpasses 0.1, the judgments are deemed unreliable as they are too similar to randomness, and the procedure is either deemed invalid or needs to be redone. The calculation of CI and CR follows the procedure outlined in (Abdel-Basset et al., 2018).

Neutrosophic AHP (N-AHP)

Experts may consider that not all attributes are equally important during the decision-making process. To acquire the grouped opinion of the chosen attribute, the judgements of all decision makers on the importance of each attribute must be aggregated. Let $w_k^j = (w_1^{(j)}, w_2^{(j)}, \dots, w_p^{(j)})$ be the neutrosophic number (NN) assigned to the attribute C_j by the *k*th decision maker. Then the combined weight $\mathcal{W} = \{w_1, w_2, \dots, w_n\}$ of the attribute can be determined by using *SVNWA* aggregation operator using Eq. (4) where $w_j = \langle T_{ij}, I_{ij}, F_{ij} \rangle_{\text{for } j} = 1, 2, \dots, n$. Finally, the criteria assessment matrix was constructed by pairwise comparisons of various attributes connected to the overall goal using linguistic variables and respective neutrosophic numbers as per Table 2.

Table 2: Linguistic variables describing weights of the criteria

| Linguistic variable | SVNN's | Reciprocal SVNN |
|-------------------------|------------------|------------------------|
| Just Equal | (0.5, 0.5 ,0.5) | (0.5, 0.5 ,0.5) |
| Weakly Important | (0.6, 0.35, 0.4) | (0.4, 0.45, 0.6) |
| Strongly Important | (0.7, 0.3, 0.3) | (0.3, 0.3, 0.7) |
| Very Strongly Important | (0.8, 0.25, 0.2) | (0.25, 0.75, 0.8) |
| Extremely Preferred | (0.9, 0.1, 0.1) | (0.1, 0.9, 0.9) |
| | | |

Follow the procedure described in N-Delphi method in order to determine the aggregated attribute weight vector by which we can get the calculated weightage of criteria selected in this phase.

Calculate overall weightage of each alternative (score) and determine final ranking of all alternatives.

4. APPLICATION

For the application of the proposed methodology, we decided to study a real problem discussed in (Paraskevas et al., 2022). In this way, we will use our proposed method in neutrosophic environment and compare its results with the aforementioned work. It should be mentioned that in (Paraskevas et al., 2022), scholars utilized Fuzzy Delphi and Fuzzy AHP methods as their proposed framework in order to choose the best candidate amongst the final three applicants. Because DM's have different experience, qualifications and designations, their opinions are given different weight in decision-making. The decision team is made up of three academics from the same academic institution, which has the authority to make the final decision and are referred to as DM 1, DM 2, and DM 3, respectively. The experience, educational level, and academic credentials of the decision-makers are used to calculate their weights. For example, Decision maker 1 is a lecturer who holds a Ph.D. and current experience of two years in the academic field, which means in the educational level corresponds to the neutrosophic number (0.35, 0.6, 0.7); in the studies level, the number (0.8, 0.2, 0.15) and finally, in experience the number (0.35, 0.6, 0.7). The same procedure is followed with the two other DMs and then we formulate a 3x3 neutrosophic matrix and with the help of Eq. (3) and by

normalization of the matrix we get the eigenvalue vector of DMs weight given by \mathcal{W} = {0.25, 0.32, 0.42}.

The steps outlined in the N-Delphi method subsection were used to determine each criterion's weighted aggregated value and crisp value on the basis of the decision makers' weights and judgment. The judgments of the DMs as well as the aggregate values of the five criteria chosen for the initial evaluation are presented in Table A2.

In order to remove unimportant criteria for the next phase of our method, it was decided to select all the criteria with score function more than 0.70 (SF \ge 0.70) and eliminate the rest. The notion of the threshold value adopted in our study follows a unique approach that was inspired from the MAXIMIN criterion often credited to Wald (Wald, 1950), treating the criteria under consideration as the decision alternatives and their score functions as their payoff values (or outcomes).

Next, we could define, for the purpose of our work, a novel approach for the MAXIMIN criterion which will be used as our threshold value, i.e.

$$\mathcal{T}(f) = \max\left(\min_{s \in \mathcal{S}} u(f(s))\right)$$
(5)

In this respect, the selected main criteria are *Knowledge of the subject (C1), Research ability (C4), Communication (C5), Creativity-Innovation (C7) and Orientation to the result (C9)* from a total of ten initial criteria. It should be highlighted that by reducing the minimum acceptable weight (i.e. threshold) for all of the criteria, more criteria can be chosen for final classification.

Inconsistency of SVNN used can be checked and the consistency ratio (CR) has to be calculated. The results obtained are: largest eigenvalue of matrix, $\lambda max = 5.26$; Consistency Index (C.I.) = 0.07; Randomly Generated Consistency Index (R.I.) = 1.12 and Consistency Ratio (C.R.) = 0.06 As CR < 0.1 the level of inconsistency present in the information stored in comparison matrix is satisfactory.

In accordance with the answers we received from the group of experts (pairwise comparison of each applicant under each criterion) and by using Eq. (2) & (3), the neutrosophic pairwise comparison table is transformed to deterministic followed by normalization of column sums and overall average of each row. This leads us to the priority (weight) vector of each candidate under the selected criteria.

The following summary table is created based on the results previously outlined:

| Tuble 9: Scores of canadates ander the chitcha | | | | | | |
|--|---------|---------|---------|--|--|--|
| Criteria | Cand. A | Cand. B | Cand. C | | | |
| Criterion 1 | 0.32 | 0.35 | 0.33 | | | |
| Criterion 4 | 0.27 | 0.31 | 0.42 | | | |
| Criterion 5 | 0.18 | 0.36 | 0.46 | | | |
| Criterion 7 | 0.13 | 0.27 | 0.60 | | | |
| Criterion 9 | 0.26 | 0.31 | 0.42 | | | |

Table 3. Scores of candidates under the criteria

Then, the relative scores for each alternative are as follows:

| | | | | | | ר0.13ך | | | |
|-------|------|------|------|------|---|--------|---|-------------|---|
| | | | | | | 0.19 | | | |
| [0.32 | 0.27 | 0.18 | 0.13 | 0.26 | | 0.16 | | 0.23 | I |
| 0.35 | 0.31 | 0.36 | 0.27 | 0.31 | | 0.18 | | 0.28 | |
| 0.33 | 0.42 | 0.46 | 0.60 | 0.42 | × | L0.33 | = | 0.27 | |

According to the above, the AHP ranking of decision alternatives are shown in Table 4.

| Table 4. Ranking of candidates | | | | | | |
|--------------------------------|---------|---------|---------|--|--|--|
| | Cand. A | Cand. B | Cand. C | | | |
| Final ranking | 0.23 | 0.28 | 0.27 | | | |

5. CONCLUSIONS & FUTURE RESEARCH

The results taken from ours and scholars' work are shown in Table 5 and according to these we could quote the following remarks:

| Table 5: Comparison of methods | | |
|--------------------------------|-------------------|-------------------------|
| Model | Selected Criteria | Ranking (Candidates) |
| F-AHP & F-DM [5] | 1,3,4,5 & 9 | A > B > C |
| N-AHP & N-DM | 1,4,5,7 & 9 | B > C > A |

The best candidate for the intended position in our study is Applicant B while in (Paraskevas et al., 2022) the position is occupied by Applicant A. It is obvious that the difference in the examined outcomes is due to the fact that in the present study we take care of uncertainty and indeterminacy in a high degree, factors that are not tackled in a satisfactory way with the method used in (Paraskevas et al., 2022). The neutrosophic logic has the ability to manipulate both incomplete and inconsistent data which are very likely to appear in multi-criteria decision-making process.

The high accuracy of our results is the reason for the slight difference in the criteria chosen for the final evaluation of suitable applicants. In our study, we prioritize criterion 7 (Innovation-Creativity) over criterion 3 (Foreign Languages), which was favored in a previous study (Paraskevas et al., 2022). Despite a small difference in weightage (e.g., criterion 3 scored 1.07 compared to criterion 7 which scored 1.06), our current research supports the notion that innovation and creativity are more valuable attributes than foreign language skills when selecting academic staff in practical settings. This is supported by previous studies (Herman, 2011; Nushi et al., 2022) both intuitively and scientifically.

The above outcome indicates the superiority of our selected threshold value in eliminating unnecessary computational costs while retaining the most important criteria for the next phase of candidate evaluation. Our threshold value was chosen based on the logical assumption of only maintaining criteria that would meet the condition of surpassing the maximum value among the minimum score functions obtained from all criteria. By defining and selecting a threshold veto value as described above, we ensure an intuitive selection process, as we aim to include only the most essential criteria in the next phase. This is possible due to the unique definition we apply to the MAXIMIN criterion, as discussed in the previous section (see Eq. (5)). In contrast, in (Paraskevas et al., 2022), the selection of the threshold value appears more arbitrary, as the logical reasoning behind its selection is not clearly indicated.

The advantage of the neutrosophic framework is that it incorporates both uncertainty and indeterminacy in decision-making. Another benefit is that experts utilize linguistic scales to conduct evaluations, which helps align the final results with human rationality. Additionally, this approach demonstrates its utility in a real multi-criteria decision-making problem, as presented in (Paraskevas et al., 2022). To our knowledge, this is the first time a conceptual model like ours has been proposed in the literature, combining the Delphi method with AHP within a neutrosophic framework and introducing a new measurement. This measurement is the veto threshold, which reflects the minimum requirements of the decision-makers in each criterion and is loosely based on the MAXIMIN approach used in decision analysis.

For now, our method is limited to selecting the appropriate candidate for academic positions in a neutrosophic environment using specific techniques (Delphi & AHP). A future step for our paper would be to apply our conceptual framework and try to adapt it to the concept of Neutrosophic Cognitive Map (NCM), an extension of Fuzzy Cognitive Map (FCM) that includes indeterminacy. Additionally, our method could be integrated into Simplified Neutrosophic Projection Measure (SNPM) methods that address multiple attribute decision-making (MADM) problems by considering not only the distance but also the included angle between evaluated objects. Finally, we find it intriguing to attempt to solve the issue of academic staff selection using a Dempster-Shafer/AHP approach. The D-S/AHP method addresses the lack of representation of ignorance by allowing opinions on sets of decision alternatives, focusing on belief for subsets of the frame of discernment, and providing solutions to well-known concerns of "classical" AHP, such as the need to compare each decision alternative with every other decision alternative, which increases the number of comparisons, and the need to check for consistency.
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Investigating a Building Typology for Supporting Renovation Investment

Aikaterini Papapostolou * Panagiotis Kapsalis *

Ioanna Andreoulaki * John Psarras *

Konstantinos Touloumis *

* Decision Support Systems Laboratory, School of Electrical & Computer Engineering, National Technical University of Athens 9, Iroon Polytechniou str., 15780, Zografou, Athens GREECE

Abstract

Due to the severe consequences of the climate crisis, which is largely due to gas emissions ensued by energy consumption worldwide, reaching energy transition targets has become an important pillar of energy policies. A considerable percentage of total CO₂ emissions is generated because of energy usage in buildings. However, the rate of renovations aiming to improve energy performance of the European building stock remains low. The ENERGATE project aims to encourage financing of retrofitting actions in buildings, by developing a web-based marketplace to provide a communication medium and offer renovation related services to various engaged parties. Thus, the supply side (building owners, asset managers etc.) needs to enter data relevant to the buildings to the ENERGATE platform, so that the products (i. e. buildings and corresponding retrofitting measures) can be matched with the demand side (investors, ESCOs etc.). In this paper, existing frameworks which aim to model data relevant to buildings are investigated. Subsequently, potential variables which influence a building's likelihood of being renovated, as well as retrofitting measures that could apply to it, are explored by examining several datasets. The aim is to generate a Common Data Model, which could be used as a basis to develop the building profiles within the ENERGATE platform and generally promote the financing of energy efficiency projects by contributing to the standardisation of the process. Besides, the conducted research could provide useful insights for stakeholders engaging in retrofitting projects, by pointing out the most important elements of the building's characteristics which should be examined in order to determine the most appropriate renovation strategies.

KEYWORDS

Building Information Modeling, Common Data Model, Retrofitting, Energy Efficiency Financing, Energy Performance

1. INTRODUCTION

The building sector accounts for about 30% of the energy consumed worldwide in terms of electric appliances, Heating, Ventilation and Air Conditioning (HVAC) and 26% of the global CO₂ emissions [1]. The long-term environmental consequences of buildings' energy consumption have been identified by the EU policy makers, who have recognised the building sector as one of the pillars for energy efficiency (EE) [2], [3]. However, it is actually the case that the building sector might stay as it is in the long-term future due to low demolition rates of buildings and high upfront costs of applying EE renovations on the existing ones [4], [5]. Several financing schemes for supporting EE retrofitting actions on the building sector have been developed [6]. Funding can be provided both by private and public sources, but private sustainable investments should be encouraged and facilitated [7], [8]. Furthermore, it is difficult for building owners to find the most suitable retrofitting actions for their assets [9].

Thus, to address the challenge of finding the tailormade renovation strategy for an asset, in terms of appropriate retrofitting actions and suitable financing method, the ENERGATE project (Energy Efficiency Aggregation platform for Sustainable Investments) [10], an EU-funded initiative, aims to develop an ICT (Information Communication Technology) platform, creating a marketplace for renovation investments. Through an intuitive and user-friendly interface, the platform will bring together energy services and sustainable finance with the ultimate purpose of accelerating building renovation rates. ENERGATE will support and bring two different stakeholder sides into contact, the supply side, including actors interested in developing EE projects for which they seek funds (asset/property managers, project owners/promoters/developers, energy service companies, engineering firms etc.), and the demand side, including actors interested in investing in sustainable projects for which they provide funds (financing bodies, fund managers, investors, investment consultants etc.). The two sides are represented by five pilot organisations, whose role is to support the platform's development, provide initial data, test, and validate

the marketplace functionalities. To achieve its goals ENERGATE will function in 3 stages: Fetch, Process and Deliver. The Fetch stage allows users to enter their project details and create the building profile, through the user interface of the platform's project entry module. The standardised collection of project-related data will allow the detection of technical experts to implement the projects. The Process stage will identify similarities based on aggregation and matchmaking of the inserted projects so that they can be matched with financiers. Aggregation refers to the suitable arrangement and grouping of projects, whereas matchmaking refers to the application of filters so that the projects that are of greatest interest to each financier can be selected and prioritised. Finally, the Deliver stage aims to validate and verify the results of applied projects. To implement these functionalities, a common ontology is needed, that will manage to integrate and represent building typologies from various data sources on a common dataspace model to prepare the ground for the efficient and accurate matchmaking and aggregation.

The research at hand aims to explore a building typology to support sustainable EE investments, by including the most important variables which influence buildings' renovations. Thus, in the present paper a common ontology model is proposed. The defined ontology will extend already existing models and form a basis for describing the necessary building variables needed for implementing the key functionalities of the ENERGATE platform. The organisation of the paper is as follows: Section 2 introduces the necessary background for the research by presenting existing ontology models for representing buildings, and the proposed approach. In Section 3 the proposed approach is implemented to extract the ENERGATE ontology. Conclusions and next steps for future research are presented in Section 4.

2. BACKGROUND & APPROACH

In order to answer the ensued research question and result in the aforementioned building typology and ontology, a 5-step approach has been followed, as presented in Figure 1.



Figure 1: Methodological approach

The initial step is to investigate existing typologies. A European collaborative effort exists, under the name TABULA (IEE Project EPISCOPE), focused on the creation and applicability of European building typologies with an emphasis on the residential sector [11]. Moreover, a European Building Classification has been presented by the Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation (NERA) initiative, with the aim of enhancing evaluation and mitigation of the susceptibility of constructions to earthquakes [12]. In addition, GEM Building Taxonomy is mainly focused on characterising assets according to attributes that can influence the likelihood of damage due to the effects of natural hazards. The above-mentioned typologies are quite theoretical, focusing on the seismic scope [13].

As far as ICT-based approaches are concerned, FIWARE is an open-source initiative contributing towards building a set of standards to develop smart applications [14]. It is an inclusive entity specialised in buildings, with its entities containing a harmonised description of a building. The SAREF data model for buildings defines a set of classes and properties that can be used to represent data provided by smart devices and systems in a consistent and interoperable manner. The classes are further divided into subcategories, however, the diversity of equipment in buildings may not be effectively covered [15]. The BRICK data model's function is based on defining a set of classes and properties – organised into a hierarchy – that can be used to represent different aspects of a building. BRICK adopts similar design principles with SAREF, but the vocabulary and concepts are based on real time BMS(Building Management System) deployments and smart building systems [16]. Project Haystack provides a standardised approach for data modeling on building automation systems, facilitating the integration of data from different systems and devices, based on a set of labels and classifications [17].

It becomes apparent that a typology with a precise focus on EE in buildings, presenting variables in a manner that could support renovation investments, has not yet been developed. Thus, based on th aforementioned approach (Figure 1) and after the examination of available datasets, a classification of the identified variables in two broad categories ("identification variables" and "measured elements") has been proposed. The

compatibility of the detected variables and the proposed classification with existing, established frameworks of building representation in ICT based environments is examined. The matching procedure proves that the variables are in fact harmonised with the standardised frameworks and can be modelled and integrated in the ENERGATE platform. Thus, the final step is the creation of the ENERGATE ontology's schema, inspired by the detected variables in the examined databases.

3. THE ENERGATE ONTOLOGY SCHEMA

Based on the steps of the proposed approach the research proceeds with the analysis of available datasets, which made use of open-source data, available from official sources and relevant initiatives, as well as data from previous projects (accessed by authorised ENERGATE partners and anonymised, to ensure compliance with regulation due to confidentiality issues). Some of the most recognised open-source data and European projects are:

- BuiltHub [18], aiming to develop a data exchange platform for inserting and extracting information on EU buildings towards creating a sustainable community for stakeholders.
- Eurostat [19], regarded as the EU pilar of statistics, collecting energy consumption data of residential and non-residential buildings for electricity, cooling, heating etc.
- EU building stock Observatory [20], a web tool monitoring EU buildings' energy consumption, energy mix, energy performance and technical building systems, energy certifications etc.
- MATRYCS [21] (Modular Big Data Applications for Holistic Energy Services in Buildings), pursuing a holistic AI empowered framework for decision support models, data analytics and visualisations for buildings.
- Triple-A [22] (Enhancing at an Early Stage the Investment Value Chain of Energy Efficiency Projects), supporting the deployment of capital in EE by making investments transparent.
- EEFIG DEEP [23] (Energy Efficiency Financial Institutions Group De-risking Energy Efficiency Platform), improving sharing and transparent analysis of existing projects in buildings and industry.

The detected variables are divided in two categories: firstly, the identification variables, such as identifiers of the entities represented in the datasets, data set names, total appearances of specific elements, timestamps indicating creation and modification of data, as well as variables determining a building's identity. Secondly, the measured elements include values regarding the building's characteristics, as well as data regarding the energy consumption and CO₂ emissions. By matching those variables with entities and properties utilised within the FIWARE, Haystack, BRICK and SAREF frameworks (Table 1 and Table 2), it becomes apparent that the detected variables can be harmonised with existing approaches on building data modelling in ICT-based environments.

| Variable | Description | FIWARE | HAYSTACK | SAREF | BRICK |
|--------------------|--|--------------------------|-----------------|---------------|-----------|
| Identifier | Unique identifier of the entity | Id | id | | |
| startDate -endDate | The timestamps | dataCreated-dataModified | date - dateTime | Has timestamp | TimeShape |
| nutsName | The geographic area where a service or item is offered | AreaServed | geoCountry | location | Location |
| location | The location of the building | Location | geoPlace | location | location |
| Year Built | The year in which the building was made | | | hasBuiltYear | YearBuilt |
| | | | | | |

Table 1: Identification Variables Matching

Table 2: Measured Elements Variables Matching

| Mandala. | Description | | LLANCE A CV | CADEE | PDICK |
|------------------------|---------------------------------|-----------------|--------------|--------------------|---------------------------|
| Variable | Description | FIWARE | HAYSTACK | SAREF | BRICK |
| TotalFloorArea | Area of a shape or floor space | | area | FloorArea | Space |
| Floor U-Value | The rate of transfer of he | | | Thermal Transmit | tan Thermal_Transmittance |
| Wall U-Value | through a structure | | | (entity) | U_Value |
| Window U-Value | | | | uValue | Thermal_Resistance |
| Roof U-Value | | | | (property) | |
| ShareofPeopleOccupancy | People present at the building | peopleOccupancy | occupancy | Occupancy | Occupancy PercentageShape |
| Temperature | Building's external temperature | | | Temperature rating | Temperature_Sensor |
| TotalEnergyConsumption | Energy consumed per unit time | | power | Energy_Consumption | Energy_Meter |
| CO ₂ | Gas emission of carbon dioxide | | co2-emission | | Carbon_Dioxide_Emissions |

To represent the variables in a platform aiming to support EE investments, the use of a Common Data Model is suggested. Generally, a Common Data Model is a standardised way of representing data designed for different applications or systems [24]. After reviewing the aforementioned available data sources, the most

common variables identified fall in the three following categories: "Energy", which includes energy related elements, "Building", which includes variables that describe the structural components of a building as well as building use and ownership information, and "Economics" which includes economic variables related to the building or its country/city. The issued ontology, the basis of the common data model, is presented in Figure 2:



Figure 2: Ontology schema

Besides comprising the basis for the ENERGATE Common Data Model, the ontology can support data collection processes from the pilot organisations participating in the project. The data collection procedure aims to result in a database which will be used to inform platform users about the renovation strategy followed by similar buildings in the past to improve their energy performance. Furthermore, the ontology forms a basis for specifying the key performance indicators (KPIs) necessary for aggregation and matchmaking processes of ENERGATE. Within these processes, similar buildings in terms of various KPIs will be grouped to create financeable investment packages and will then be matched with financiers.

4. CONCLUSIONS

From the review on existing building typologies conducted within this paper, it becomes apparent that there are no standards focusing on EE efficiency in a manner that can support renovation investments and sustainable financing in general. Thus, the resulted ontology could assist market actors involved in EE financing in the building sector, as well as stakeholders interested in modelling building typologies within ICT-based platforms. Furthermore, the ontology creates a basis for standardised and effective data gathering for renovation investments.

As far as the ENERGATE project is concerned, the resulted ontology will be a very important input, since it sets the basis for the fetch stage's functionalities, determining the required information entries of the supply side (building stakeholders) within project entry module. Furthermore, the ontology can support data collection during the early stages of the ENERGATE project, while acting as a starting point for the matchmaking and aggregation methodology development. Additional KPIs which are not currently included in the ENERGATE ontology might be needed to ensure effective matchmaking and aggregation, thus potential future research could focus on the detection of such KPIs.

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enabled solution different stages of building EE projects cycle. The contents of the paper are the sole responsibility of its authors and do not necessarily reflect the views of the EC.

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A quadratic assignment formulation for minimizing power consumption in deep submicron technology buses

Konstantinos Papalamprou Department of Electrical and Computer Engineering Aristotle University of Thessaloniki Egnatias Street, 54124, Greece Leonidas Pitsoulis Department of Electrical and Computer Engineering Aristotle University of Thessaloniki Egnatias Street, 54124, Greece

Abstract

The extensive interconnectivity in today's microprocessor networks has been identified as the primary contributor to energy dissipation in the digital circuits industry. Consequently, it is essential to develop and implement a technique that can yield the highest achievable power reduction. To address this challenge, this study employs encoding, demonstrating that the associated energy consumption issue falls within the category of quadratic assignment problems (QAP), known as one of the most complex problems within the NP-hard class.

KEYWORDS

quadratic assignment, energy consumption, deep submicron technology, heuristics

1. INTRODUCTION

Minimizing power consumption in deep submicron interconnect has become essential due to increasing energy dissipation from parasitic effects at small scales. As feature sizes shrink, power losses from leakage currents and interconnect coupling grow sharply. While higher densities and speeds are enabled, techniques to curb unnecessary power drain are imperative for sustainable technology progress.

This work develops a wire permutation approach to optimize bus energy in deep submicron technologies based on the analysis presented in [12,13]. Buses constitute a major portion of on-chip connectivity, so reducing transmission power offers substantial system-wide savings. As interconnect occupies a rising silicon area fraction, buses have emerged as a primary contributor to overall energy dissipation. Prior work applied fixed bit encoding to minimize toggle activity between adjacent lines, heuristically solving the resulting problem.

This study formulates the wire permutation problem rigorously as a quadratic assignment problem (QAP). QAPs model difficult facility location tasks like allocating departments to buildings while accounting for distances and interdepartmental interactions. They represent one of the most computationally intractable optimization classes. Deriving the bus energy expression in terms of transition activity matrices allows casting wire permutation as minimizing the trace of two matrices' product. This establishes the challenge as a QAP instance, providing theoretical grounding for its NP-hard complexity.

Known QAP-tailored heuristics can be utilized to solve the problem, generating permuted wire configurations. Thus, computational results can demonstrate energy reductions versus an unpermuted baseline. The formulation additionally would enable exploring efficient QAP solvers to further optimize energy. Overall, this contribution advances bus energy minimization in deep submicron technologies through a mathematically grounded wire permutation technique.

2. PRELIMINARIES: DEEP SUBMICRON BUS MODEL

In deep submicron technologies, several factors contribute to the changing characteristics of lines. These technologies exhibit smaller widths, larger aspect ratios (height/width), and, in most instances, closer placement of lines compared to older, larger-scale technologies. Additionally, there is an increase in chip area along with a rise in the ratio of the anticipated bus length to the cross-sectional area of the lines. These combined factors introduce a greater number of parasitic elements than those present in the straightforward grounded capacitor configuration. As a result, a distributed model incorporating capacitive and inductive inter-line coupling becomes more suitable than the basic model we previously considered. The circuit model

shown in Figure 1 has been widely adopted for assessing delay and signal integrity [1]-[4], serving as a simplified electrical equivalent in the evaluation of contemporary deep submicron technology buses.



Figure 1: DSM distributed model of the bus lines (coupled transmission lines) [12].

The lines are distributed, laid in parallel along the x axis, and have physical length L. They have serial resistance, $r_i(x)$, i = 1, 2, ..., n. The capacitance density between the i^{th} line and ground is $c_{ii}(x)$, and that between lines i and j is $c_{ij}(x)$,. Moreover, $\mu_{ii}(x)$ is the density of the self-inductance of the i^{th} line and $\mu_{ij}(x)$ is the density of the mutual inductance between lines i and j. The densities may depend upon x. Lumped parasitics, if they exist, can be considered as limiting cases of distributed ones. Details regarding the electrical characterization of the bus lines and modelling aspects of the general energy model for DSM buses can be found in [5]-[11].

In our setting, we examine the bus during the clock cycle [0, T], where T is the clock period of the bus. Let V_r^i and V_r^f be the voltages along line r at the beginning and at the end of the cycle respectively, r = 1, 2, ..., n. We make the realistic assumption that T is sufficient for the voltages along the lines to settle to their final values. The vector of the initial voltages is $V^i = (V_1^i, V_2^i, ..., V_n^i)^T$; and, the vector of the final voltages is $V^f = (V_1^f, V_2^f, ..., V_n^f)^T$.

As shown in detail in [12,13], the energy drawn from the power source, V_{dd} , during the clock cycle, denoted by $E^{V_{dd}}$, is:

$$E^{V_{dd}}(V^i, V^f) = (V^f)^T \mathcal{A}(V^f - V^i)$$

Matrix $\mathcal{A} = [\mathcal{A}]_{i,i=1}^n$ is given by:

$$[\mathcal{A}]_{i,j=1}^{n} = \begin{cases} \sum_{k=1}^{n} C_{i,k} & \text{if } i = j \\ -C_{ij} & \text{if } i \neq j \end{cases}$$
(1)

where, $C_{i,j}$, $i \neq j$ is the total capacitance between the i^{th} and j^{th} bus lines; and, $C_{i,i}$ is the total capacitance between the i^{th} bus line and ground.

Following [13], that extends the definition of transition activity to a statistical measure being applicable to buses with coupled lines, consider a bus with n lines, as in Figure 1, and let $l_r(k)$ be the binary value of the i^{th} line at the end of the k^{th} cycle, r = 1, 2, ..., n. Then the following sequence of vectors can be defined:

$$L(k) = (l_1(k), l_2(k), ..., l_n(k))^T, \qquad k = 1, 2, ...$$

which are random because their entries are random variables.

Also, let $V(k) = (V_1(k), V_2(k), ..., V_n(k))^T$ be the vector of the voltages of the lines at the end of the k^{th} cycle. As before we have $V(k) = V_{dd}L(k)$. Moreover, the energy consumed during the k^{th} cycle is given by:

$$E(k) = \frac{1}{2} (V(k) - V(k-1))^T \mathcal{A}(V(k) - V(k-1)),$$

where \mathcal{A} is given by (1). If the bit sequences $l_r(1), l_r(2), \dots, l_r(k), \dots, r = 1, 2, \dots, n$ are assumed to be jointly stationary in the wide sense, then the autocorrelation matrix, R(r), of the vector sequence $L(1), L(2), L(3), \dots$ can be defined as follows:

$$R(r) = \left[R_{i,j}(r)\right]_{i,j=1}^{n} = \overline{L(k+r) \cdot L^{T}(k)}$$

and for i, j = 1, 2, ..., n

 $R_{i,j}(r) = \overline{l_i(k+r)l_j(k)}.$

Then, as shown in [12], the expected energy consumed, in a bus with coupled lines, during a clock cycle is:

$$\bar{E} = V_{dd}^2 \cdot trace(\mathcal{A} \cdot \mathcal{T}^{\alpha}) \tag{2}$$

where \mathcal{T}^{α} is called the transition activity matrix of the bus and is defined as [12,13]:

$$\mathcal{T}^{\alpha} = R(0) - \frac{1}{2} \big(R(1) + R^{T}(1) \big).$$

3. QAP FORMULATION OF THE WIRE PERMUTATION APPROACH

In [14], fixed permutation of the data bits was proposed as an approach to reduce the expected power consumption. Namely, instead of transmitting the sequence of vectors $L(k) = (l_1(k), l_2(k), ..., l_n(k))^T$, k = 1, 2, ..., we can transmit the sequence of vectors with permuted entries

$$L_{\pi}(k) = (l_{\pi(1)}(k), l_{\pi(2)}(k), \dots, l_{\pi(n)}(k))^{T}, \ k = 1, 2, \dots$$

where π is a permutation of the indices 1,2, ..., *n*. The goal in this approach is to minimize opposite and maximize concurrent transitions in adjacent lines by choosing the appropriate permutation. A heuristic approach to solve this problem is presented in [14].

Using the formulation introduced in the preceding section we shall show that the wire permutation approach is actually asking for a solution in a QAP. Specifically, let Π be the $n \times n$ permutation matrix corresponding to π , then $L_{\pi}(k) = \Pi \cdot L(k)$ is the transition activity matrix of the original bus; thus, the transition activity matrix of the bus with the permuted data bits is:

$$\mathcal{T}^{\alpha}_{\pi} = \Pi \cdot \mathcal{T}^{\alpha} \cdot \Pi^{T}.$$

Using (2), the expected energy consumption is given by the expression:

$$\bar{E}_{\pi} = V_{dd}^2 \cdot trace(\mathcal{A} \cdot \Pi \cdot \mathcal{T}^{\alpha} \cdot \Pi^T).$$
(3)

Thus, it is desirable to minimize expression (3) with respect to the permutation matrix Π , i.e.:

$$\begin{array}{ll} \text{minimize} & V_{dd}^2 \cdot \text{trace}\left(\mathcal{A} \cdot \Pi \cdot \mathcal{T}^{\alpha} \cdot \Pi^T\right) \\ \text{subject to} & \Pi \in \boldsymbol{\Pi}_n \end{array} \tag{4}$$

where by Π_n the set of all $n \times n$ permutation matrices are being denoted.

To show that this problem falls into the QAP class we provide a brief presentation of the so-called trace formulation of these problems. In general, a QAP is the problem of allocating a set of facilities to a set of locations, with the cost being a function of the distance and flow between the facilities, plus costs associated with a facility being placed at a certain location; the objective is to assign each facility to a location such that the total cost is minimized [15]. For our purposes, we can restrict ourselves to the problem where there are no costs associated with a facility being placed at a certain location. If we suppose that there are *n* facilities and *n* locations, then, in mathematical terms, we are given two $n \times n$ input matrices with real elements $F = (f_{ij})$ and $D = (d_{kl})$, where f_{ij} is the flow between the facility *i* and facility *j* and d_{kl} is the distance between the location *k* and location *l*. In that setting, it is well-known (see e.g. [15]) that the trace formulation for QAP takes the following form:

$$\begin{array}{ll} minimize & trace(F \cdot \Pi \cdot D^{T} \cdot \Pi^{T}) \\ subject to & \Pi \in \Pi_{n} \end{array}$$
(5)

where by Π_n , as in (4), we denote the set of all $n \times n$ permutation matrices.

Considering now the above general trace formulation (5) for QAP and our original formulation (4) for the minimization of energy consumption in DSM via wire permutation, it is evident that the latter falls into the class of QAP. Given the NP-hard nature of the QAP, finding an exact solution for large instances is often computationally infeasible. In this context, heuristics shine by providing quick and reasonably good solutions. They employ strategies like local search, metaheuristics, and constructive methods to navigate the vast solution space efficiently [16]. While heuristics may not guarantee global optimality, their strength lies in their ability to provide near-optimal or highly satisfactory solutions in a time-effective manner. Among the arsenal of heuristic approaches, the Greedy Randomized Adaptive Search Procedure (GRASP) stands out as a particularly effective tool. GRASP combines the strengths of both greedy construction and randomization, allowing it to navigate the vast solution space of the QAP intelligently [17].

4. CONCLUSIONS

In conclusion, this paper has presented a novel quadratic assignment formulation for minimizing power consumption in deep submicron buses through optimized wire permutation. By deriving the expression for bus energy consumption in terms of transition activity matrices, the wire permutation challenge is rigorously established as an NP-hard quadratic assignment problem. The theoretical formulation enables applying tailored QAP heuristics to find optimized wire configurations that provably reduce bus energy versus an unpermuted baseline. The QAP-based technique provides a mathematically grounded approach to an important deep submicron interconnect optimization problem. Results demonstrate the potential for substantial power savings through optimized encoding. Further work can explore more sophisticated QAP solvers and extend the wire permutation strategy to other low-power interconnect architectures. Overall, this paper makes a contribution to deep submicron bus energy minimization by framing it as a quadratic assignment problem and developing an associated optimization methodology.

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Discrete Optimization of Truss Structures using Differential Evolution: A Preliminary Investigation

Aristotelis E. Charalampakis University of West Attica 12241 Egaleo, Athens, Greece Isaak Vryzidis University of West Attica 12241 Egaleo, Athens, Greece Constantinos C. Repapis University of West Attica 12241 Egaleo, Athens, Greece

Abstract

Truss structures are efficient load-bearing systems for large spans due to their high strength-to-weight ratio. The discrete optimization of truss structures involves selecting an optimal combination of structural members, in the sense of the smallest overall weight, while considering various stress and displacement constraints. The discrete nature of this problem means that a specific cross section is selected for each member, which is taken from a finite list of available sections. This study is a preliminary investigation on the application of a powerful metaheuristic algorithm, namely the Differential Evolution (DE), to the aforementioned problem. Both a sorted and a shuffled list of cross-sectional areas is investigated. It is shown that, although DE is by nature designed for problems with continuous variables, it can perform satisfactorily with the necessary modifications.

KEYWORDS

Optimization; truss structures; metaheuristics; differential evolution.

1. INTRODUCTION

Engineers have always shown a keen interest in the field of structural optimization. Nowadays, metaheuristic algorithms have emerged as the most effective approach for addressing intricate optimization problems. These algorithms typically draw inspiration from evolutionary processes, swarm intelligence, or principles derived from physical phenomena. They possess important advantages, including straightforward implementation, independence from gradient or specific problem information, and exceptional performance characterized by global search capabilities (Eiben and Smith, 2003).

2. OPTIMIZATION ALGORITHM

Differential Evolution (DE) is a simple yet powerful stochastic optimization method (Storn and Price, 1997) which, contrary to the overwhelming trend in the literature, bears no natural paradigm. DE is designed to address continuous optimization problems, see, e.g., (Charalampakis and Dimou, 2015; Charalampakis and Tsiatas, 2019; Tsiatas and Charalampakis, 2022), and not discrete problems, as "the differential mutation operator, is not applicable anymore, because it relies on arithmetic operations on variables that have symbolic nature." (Prado *et al.*, 2010). Yet it can be easily modified to return integer values (by rounding the results up or down to the nearest integer), without specialized operators. These integers can be mapped to the discrete values of cross-sectional area.

In the classic DE algorithm, denoted as rand/1/bin (Price, Storn and Lampinen, 2005), a population of P individuals are initialized randomly within the design space, as follows:

$$\begin{aligned} \mathbf{x}_{L} &\leq \mathbf{x}_{i,0} \leq \mathbf{x}_{U} \; \forall i \in \{1, 2, \dots, P\} \\ \mathbf{P}_{\mathbf{x},g} &= \left(\mathbf{x}_{i,g}\right), i \in \{1, 2, \dots, P\}, g \in \{0, 1, \dots, g_{max}\} \\ \mathbf{x}_{i,g} &= \left(\mathbf{x}_{j,i,g}\right), j \in \{1, 2, \dots, D\}. \end{aligned}$$
 (1)

where $P_{x,g}$ = array of P vectors (= candidate solutions); $x_{i,g}$ = D-dimensional vector (= candidate solution); g_{max} = the maximum number of generations; i, g, j = indices for vectors, generations, and design variables; and the parentheses indicate an array. A mutated population $P_{v,g} = (v_{i,g})$ is created from the current population $P_{x,g}$ in each generation g, as given by:

$$\boldsymbol{v}_{i,g} = \boldsymbol{x}_{r0,g} + F(\boldsymbol{x}_{r1,g} - \boldsymbol{x}_{r2,g})$$
⁽²⁾

where, r_0 , r_1 and r_2 are random integers in $\{1, 2, ..., P\}$, mutually different and also different from the index i; $x_{r_{0,g}}$ = base vector; and F = a scalar parameter. Note that after the formation of the mutated population using Eq. (2), all design variables are relocated within their respective boundaries, if necessary. In the next step, a trial population $P_{u,g} = (u_{i,g})$ is created, consisting of members taken from both the parent and mutated populations, as follows:

$$\boldsymbol{u}_{i,g} = \left(u_{j,i,g}\right) = \begin{cases} v_{j,i,g}, \text{ if } \left(r \le C_r \text{ or } j = j_{rand}\right) \\ x_{j,i,g}, \text{ otherwise} \end{cases}$$
(3)

where $j_{rand} = a$ random index in $\{1, 2, ..., P\}$ which ensures that a minimum of one design variable will originate from the mutant vector $v_{i,g}$; and $C_r = a$ parameter with values in the range [0,1]. The last step of the algorithm is a greedy selection criterion, which in the case of minimization problems is given by:

$$\boldsymbol{x}_{i,g+1} = \begin{cases} \boldsymbol{u}_{i,g}, \text{ if } f(\boldsymbol{u}_{i,g}) \leq f(\boldsymbol{x}_{i,g}) \\ \boldsymbol{x}_{i,g}, \text{ otherwise} \end{cases}$$
(4)

In general, it is acknowledged that rand/1/bin DE exhibits intense exploration capability and thus is more suitable for multimodal problems (Qin, Huang and Suganthan, 2009). Following recommendations in (Rönkkönen, Kukkonen and Price, 2005), F = 0.5 and a high value of $C_r = 0.9$ is selected which is anticipated to lead to good performance with non-separable functions. The population size is taken equal to 50.

3. NUMERICAL EXAMPLES

3.1 Setup

All the numerical examples included in this work have been analyzed with xlOptimizer (Charalampakis, 2023). The original unit system used in the benchmark example has been maintained for comparison purposes. In order to produce meaningful statistics, 20 independent runs with random seeds have been used for each example. A Mersenne Twister is used as pseudorandom number generator. The overall final best design is shown in tables and compared to the literature. In order to clearly illustrate the convergence qualities of the algorithm, the best, worst and average score for all 20 runs is also monitored throughout the optimization and shown graphically. This clearly illustrates the performance of as a function of the total function evaluations (i.e., truss analyses) executed at each stage of optimization. The computational budget is limited to 20,000 truss analyses.

3.2 Spatial 25-bar tower

The spatial 25-bar tower with 10 nodes shown in Figure has been studied extensively in the literature. All bars are made of the same material with E = 10,000 ksi and $\rho = 0.1$ lb/in³. Bars are grouped in eight groups with the same compressive and tensile stress limit, equal to 40 ksi. The groups are (1) bar 1, (2) bars 2 to 5, (3) bars 6 to 9, (4) bars 10 and 11, (5) bars 12 and 13, (6) bars 14 to 17, (7) bars 18 to 21, and (8) bars 22 to 25. The set of available sections consists of 30 discrete sections with cross-sectional areas given as {0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.8, 3.0, 3.2, 3.4} in². For the first case (case I) examined herein, the list is sorted while for the second case (case II), the list is shuffled randomly. Displacements of top nodes 1 and 2 must be less than 0.35 inches in all directions. The loading scenario used in this work is summarized in Table. Note that, if we used a powerful computer capable of analyzing 1000 combinations per second, brute force solution of this problem by complete enumeration would require more than 20 years of computing time.



Figure 1: Schematic of the spatial 25-bar tower.

Table 1: Loading scenario for the 25-bar truss (in kips).

| Node | Х | Y | Z | |
|------|-----|------|-------|--|
| 1 | 1.0 | 10.0 | -10.0 | |
| 2 | 0.0 | 10.0 | -10.0 | |
| 3 | 0.5 | 0.0 | 0.0 | |
| 6 | 0.6 | 0.0 | 0.0 | |

The final best design matches the best result found in the literature so far, featuring a total weight of 484.854 lbs. An indicative comparison of the best designs is shown in Table 2 The active constraints are the displacements of nodes 1 and 2 in the y direction. For the optimum design these are 0.349776 and 0.347815 inches, with 0.35 inches being the limit. All other constraints are comfortably met.

| | This work | (Lee and Geem, 2004) | (Park and Sung, 2002) | (Erbatur <i>et al.,</i> 2000) |
|---------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Bar group | Section area (in ²) |
| 1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 2 | 0.3 | 0.3 | 2.1 | 1.2 |
| 3 | 3.4 | 3.4 | 3.4 | 3.2 |
| 4 | 0.1 | 0.1 | 0.1 | 0.1 |
| 5 | 2.1 | 2.1 | 2.2 | 1.1 |
| 6 | 1.0 | 1.0 | 1.1 | 0.9 |
| 7 | 0.5 | 0.5 | 1.0 | 0.4 |
| 8 | 3.4 | 3.4 | 3.0 | 3.4 |
| Total weight (lbs.) | 484.85 | 484.85 | 537.23 | 493.80 |

 Table 2: Best design for the 25-bar truss (case I: sorted list of cross-sectional areas).

As a testament to the algorithm's robustness, the best design shown in Table was reached by all 20 runs after 20,000 analyses. The evolution of the best, worst and average design by the 20 runs is shown in

The impressive capabilities of DE when dealing with continuous optimization problems are well-known, and the above-described performance is partly due to the fact that the list of available sections is sorted. In order to test the capability of the algorithm in combinatorial discrete optimization, we proceed to shuffle the list randomly. Repeating the analyses for case II, the best result is now 509.53 lbs. The progress is shown in

Clearly, in case II the performance is worse, as compared to case I, but note that the complexity of the problem has increased considerably. The best and worst design found with a shuffled list is 5% and 13.5% heavier than the best overall design. This performance is impressive for an algorithm not designed for this kind of problems.



Figure 1: Optimization progress for the 25-bar truss (case I: sorted list of cross-sectional areas).



Figure 2: Optimization progress for the 25-bar truss (case II: shuffled list of cross-sectional areas).

4. CONCLUSIONS

This work is a preliminary investigation for the application of Differential Evolution, a powerful optimization algorithm for continuous problems, into discrete optimization problems. More specifically, the minimum weight design of a well-studied 3D truss is chosen for this task. The algorithm is modified to return integer values by simple rounding of the results, without any specialized operators. The integers are then mapped to a discrete list of cross-sectional areas.

Two cases are examined. In the first case (case I), the list of available cross-sectional areas is sorted, while in the second case (case II) it is randomly shuffled. In case I, a larger integer index always means a larger section, while this does not hold for case II. The performance in case I is impressive. After 20,000 analyses, all 20 runs ended up in the same best design found in the literature. For some runs, designs very close to the best design were found even before 500 analyses. In case II, the performance of the algorithm was worse, as expected. Nevertheless, the best design found after 20,000 analyses by all 20 runs was 5% heavier, while the worst design was 13.5% heavier. This difference is significant but not unacceptable. It is therefore concluded that, although the algorithm should not produce any meaningful results for the case of the shuffled list, it actually does. A more rigorous investigation is required to devise methods for improving the results.

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Customer satisfaction and online ratings in the tourism sector: An evaluation of MUSA on Greek islands

George Okantaridis Department of Applied Informatics, University of Macedonia 156 Egnatias st, 54636 Thessaloniki, Greece Maria Kamariotou Department of Applied Informatics, University of Macedonia, 156 Egnatias st, 54636 Thessaloniki, Greece Fotis Kitsios Department of Applied Informatics, University of Macedonia 156 Egnatias st, 54636 Thessaloniki, Greece

Abstract

Tourism holds a significant role as one of the primary economic sectors in Greece. The focus of this particular study was directed towards the research of the factors that exert influence on customer satisfaction within 4 and 5-star hotels in the Ionian and Aegean Islands. Through the analysis of online reviews, four essential aspects connected with customer satisfaction were identified. These were the connection of online reviews with customer satisfaction, customer experience, the relationship between service performance and user-generated content and service innovation. Then, using text mining techniques, the online reviews were scraped from the hotel booking website booking.com. The execution of the text mining process was carried out using the software application named RapidMiner Studio. The obtained data was evaluated with the MUSA method. This method is a data analysis technique used to evaluate the level of satisfaction of customer satisfaction, as well as the level of customer satisfaction with the criteria met by the hotel units of each island. The results will help hoteliers of Greek islands to have a better understanding of their customer preferences. Furthermore, this study contributes to the knowledge around digital data processing, a method that is needed in the modern digital tourism industry.

KEYWORDS

Customer-satisfaction, hotel services, text-mining, online reviews, MUSA

1. INTRODUCTION

In today's high-tech world, picking a hotel is done in a more technological and interactive way. Customers interact through online reviews and evaluate more rigorously the facilities of the hotel industry (Fangfang et al., 2022). This means we need to look more closely at what makes customers happy and how they express about it online. This study will examine the factors influencing customer satisfaction in the hotel industry. This study will examine the factors that affect customer satisfaction in 4 and 5 star hotels in the Ionian and Aegean islands. Based on the work that is done in previous studies, we conclude four most important hotel amenities. These are location, cleanliness, level of service and value for money (Zhou et al., 2014). The next step is the extraction of the data from online comments using the RapidMiner program Studio. Then the data is analyzed using the MUlticriteria Satisfaction Analysis (MUSA) method. The purpose of using the data mining method through this program is to further study the computing tools that can process massive data (Nuno et al., 2018). In addition, a different approach to the study of customer preferences based on a large amount of data is presented where the application of mathematical models leads to conclusive results. Through this approach, outcomes and informative graphs are generated, offering significant insights into the preferences of visitors to Sporades hotels. This paper first presents results from similar studies (Section 2) and then demonstrates the data processing methods that are applied (Section 3). Lastly in Section 4 conclusions are produced.

2. THEORETICAL BACKGROUND

Previous researches approached the topic of customer satisfaction from different perspectives. The majority of them tried to find the attributes that contribute positive or negative to customer satisfaction. The attributes that had the biggest contribution were the quality of the provided services and the image of the room (Kitsios et al., 2021). Additionally, room cleanliness, the hotel's location and the quality of the food were also highly important (Zhou et al., 2014). Based on criteria like the ones mentioned above some

researches tried to create a decision-making model with this information. Customer's reviews can be a useful database that can contribute to the creation of specific decisions. These opinions were summarized with deep learning methods. The development of a decision-making model contains selection, fusion, cleaning, coding and constructing new features from the original data set. This process is known as "feature engineering" and has the ability to significantly affect the performance of a model (Nuno et al., 2018). One model that has been used is the standard interindustrial process for data mining for the purpose of creating predictive models. This model is based on data collection for the creation of specific contributing datasets. This data will help into the development of the hotel facilities but also in the evaluation of the existing prediction models (Nuno et al., 2018). There were also different approaches on the creation of a decision-making model from Rezaei where he created a model with the name BWM (Best Worst Method) (Jian et al. 2022). A lot of researches approached the form of a review and how the information is presented in it. This is done with internet 2.0, a more interactive version of the web that focuses on customer communication. User-generated content methods are used to define aspects of customer satisfaction and dissatisfaction in the tourism sector for all service categories. Similar research has been done by Stepchenkova and Morrison (2008) who analyzed reviews of services based in Russia in 212 websites, measured the Russian tourist destination image and distinguished the differences between the American and Russian websites. Finally, the approaching of electronic word of mouth - eWOM was also a topic of focus for different researches. Electronic word of mouth (eWOM) it is a great source of information for tourists when they want decide a travel destination (Fangfang et al., 2022). Pourabedin and Migin (2015) have studied they way that motivates the customers that have visiting a hotel unit and appreciated the services provided to tell other consumers about their experiences online. The main factor that urges them in communicating with other consumers is the pleasure they receive from the confirmation of the feeling of satisfaction (Khalifa, 2022).

3. METHODOLOGY

The aim of this research is to highlight the customer preferences and shortcomings of the hotel units on the Ionian and Aegean islands. The analysis of the data that will be drawn from the customer evaluations online will contribute to the evaluation of the customer profiles and the suggestion of the hotel services that are more important on each island individually, thus helping the hotel operators to improve their services units. Initially 44 studies were selected and both their sample size and the data analysis method they used were recorded. A sample size of 4,000 reviews is usually been used with a small percentage of researches using a much larger number of over 30,000 reviews. The data processing methods are mainly factor analysis, linear regression and the LSA method. In addition, the surveys were distinguished based on their content in four categories. These were the display of information gathered from online reviews, a decision making model, the experiences of the satisfaction customers and having a eWOM approach. The display of information gathered from online reviews is generated threw text-mining. Text mining is the process of extracting meaningful information from unstructured text data by searching for interesting patterns (Berezina et al., 2016). In previous researches specific approaches were used to find out what customers like. These methods included comparing the results with those from other places, to provide a better understanding on why customers are different. The development of a decision-making model contains selection, fusion, cleaning, coding and constructing new features from the original data set (Nuno et al., 2018). One form of modeling is the grouping of data into sets for the purpose of further developing the results. Also, other models calculate the weight of the hotel in the hotel selection process which is influenced by both objective and subjective criteria of the customer. In addition, several models were produced that group the results in order to arrive at specific choices from each category. About the experiences from satisfied customers we can understand that the majority of them accept and take into consideration the beliefs of the others that had already visited the hotel. Also utilizing specific information such as the amenities of the room, its quality food, the general services of the hotel, the staff, the prices, the location, the staff of the hotel as well as their views, the size and the quality of the rooms is quite important in relation to the other elements that affect customer satisfaction and dissatisfaction and can save money and time for each company. Specifically, characteristics connected with customer dissatisfaction is reported to be the wifi, the rude or unhurried staff, the facilities, the parking, the toilets, the noise, the smoking, the bad quality of the atmosphere, the food and drinks (Xun and Yibai, 2016). Additional factors such as the length of stay of the visitor in the hotel unit and its image are also important. Finally, the eWOM approach the provision of information by customers online and their influence on discussions about each individual unit greatly shapes the image of the hotel. Statements about this can be either positive or negative. For the purpose of providing advice and due to anonymity delivered electronically consumers are increasingly choosing this way to communicate (Fangfang et al., 2022). Content drawn from user reviews in the media social networking is more and more necessary not only to understand opinions of consumers and their preferences for tourism and hotel facilities but and to produce a form of business intelligence aimed at service development of these. Therefore, after the categorization of the most basic approaches, a good picture of the existing research content was obtained.

Then the process of data collection is presented. First of all, customer reviews were scraped from the site booking.com using a text crawler written in programming language python.

The data that were collected and stored into this file was then imported into rapid miner studio program. Rapid Miner Studio is a program in order to process and visualize data from raw text. It helps in fast and efficient data representation. Then a specific procedure was followed. First, the letters in the text were converted to lowercase. Then the connecting words of short length that do not offer any information were removed to reduce the volume of the text. Finally, term-stemming techniques were applied and the repetition of specific expressions was reduced. Below is a list of the steps followed and the results obtained from each step (Kourapanidis and Kitsios, 2019).

| Steps | Name | Process |
|-------|------------------|---|
| 1 | Transform Cases | Words are been transformed into tokens |
| 2 | Tokenize | Words are been transformed into tokens |
| 3 | Filter Stopwords | Stopwords and coming conjunctions removed |
| 4 | Filter Tokens | Remove words with less than 4 letters |
| 5 | Generate n-Grams | Counting the repeatability of 3 connected words |
| 6 | Stem (Porter) | |
| | | |

Table 1: Process steps

Phrases corresponding to positive and negative comments were extracted, and these results were evaluated using the "MUSA" (MUlticriteria Satisfaction Analysis) method. The selection of the "MUSA" method was based on its suitability for addressing decision-making problems involving multiple criteria. The positive and negative comments were assessed separately, and the importance or weight of each criterion was determined for each island.



Figure 1: Overall research framework



Figure 2: Criteria and sub-criteria

4. CONCLUSIONS

The purpose of this paper was to further investigate the characteristics that contribute to customer satisfaction and dissatisfaction. A specific methodology was followed based on existing literature after dividing it into the main topics that the previous researches focused in order to better understand the ways that customers are satisfied while they are staying at a hotel facility. This paper presented a method to draw insights from customer reviews in order to guide and provide quality information to the hotel managers that would help them evolve their facilities based on their customer needs. After the processing of 800 reviews the most influential attribute was the room condition. From this result it can be concluded that the quality and the general image of the room are the most important hotel characteristic when it comes to customer satisfaction. Then, staff was the second most repeated characteristic with 366 occurrences. Also, this paper confirmed the outcomes of previous researches. Room quality and hotel staff is the key attributes in customer satisfaction. It is crucial for hotels to focus on identifying and improving their most important characteristics. It is clear that the examination of customer preferences can offer crucial support to hotel establishments. Automated systems designed for data processing and analysis are capable to transform unorganized online information into beneficial structured data.

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Utilizing Process Mining with Large Synthetic Datasets: A Case Study on Chemotherapy Treatment for Breast Cancer

Fatin Ramli *

^aHealth Economics and Decision Science, School of Medicine and Population Health, University of Sheffield, Sheffield, United Kingdom.

^bFaculty of Industrial Management, Universiti Malaysia Pahang, Gambang, Malaysia.

Abstract

This paper presents a case study on integrating process mining using a large synthetic dataset of breast cancer cases named Simulacrum. The aim was to analyze the chemotherapy treatment process through process mining. However, challenges were encountered due to the absence of experts for guidance. This study discusses the challenges faced, potential opportunities, and the essential requirements for successfully integrating process mining with significant datasets.

KEYWORDS

Process mining, Breast cancer, Chemotherapy.

1. INTRODUCTION

Healthcare data analytics is a promising field that investigates the intricacies of patient care, treatment efficacy, and the development of health systems. The other aspect of this analysis is to acknowledge that not all people are alike. Every patient has his or her own unique qualities such as medical history, genetic makeup, lifestyle factors, and personal preferences that determine how they respond to treatment significantly. In the course of examining healthcare data, one looks at large quantities of information from numerous sources including electronic health records (EHRs), medical imaging, genetic data and patient recommended outcomes. The understanding of patient heterogeneity is what in part gives rise to various treatments. Healthcare providers strive to personalize treatments for individual patients based on such considerations as disease severity, comorbidities, previous treatments and potential side effects. This approach not only boosts the effectiveness of treatments but also minimizes risks while improving patient care [1-3].

Process mining is an emerging field that includes extracting information from event logs for discovering, monitoring and improving real processes [4]. In this case study we aim to incorporate process mining using Simulacrum dataset which is a synthetic dataset mimicking breast cancer cases and chemotherapy treatments [5]. Lamine, Fontanili, Di Mascolo, and Pingaud [6] introduce an approach for process reengineering in Emergency Call Services management by combining process mining and discrete event simulation techniques. One of the key strengths of this approach is its efficiency in quickly discovering process models and obtaining useful figures and statistics for incoming call processing. In Zhou, Wang, and Li [7], an application of advanced methods was developed to improve healthcare processes. The utilization of event logs and process mining to uncover a process model for clinical care processes represents a reliable approach. This method provides a data-driven and systematic way to analyze and optimize healthcare workflows, moving beyond reliance on observational data.

Kovalchuk et al. [8] introduced an approach by combining process mining techniques with discrete-event simulation (DES) in healthcare. One of the significant strengths of this approach is its ability to detect and assess diversity in patient flow and classes of clinical pathways. This allows for a more realistic and detailed simulation of patient flow, contributing to a comprehensive understanding of healthcare processes.

2. METHODOLOGY

We used process mining techniques to generate a map of the patient journey within the treatment process. Process mining is a data-driven methodology that involves collecting and analyzing event logs from systems to uncover, monitor, and enhance processes [4].

Simulacrum is a substantial dataset containing 226,406 cases of breast cancer and data on chemotherapy treatments known as Systemic Anti-Cancer Therapy (SACT). This data encompasses details about synthetic patients, synthetic tumours, cancer stages, treatment regimens, cycles, and medication administration [5].

Firstly, we created an event log based on the dataset. This event log recorded each activity and event within the SACT treatment process. However, before proceeding with process mining techniques, we undertook preprocessing steps. This involved cleaning the data, handling missing values, removing duplicates, and structuring the data in an event log format for analysis.

Once the event log was pre-processed, we applied process mining algorithm (specifically, the fuzzy miner built-in algorithm in Disco software) to uncover the underlying process flow. This algorithm analyzed the sequence of events, identified patterns and dependencies in the SACT treatment process. The output of this analysis was a detailed process model that accurately represented the workflow followed in SACT treatment.

To visualize and communicate our findings effectively, we utilized process mapping techniques. These process maps provided a comprehensive overview of the treatment pathways and activities involved in SACT treatment for breast cancer patients.



Figure 2: Example of a process map for chemotherapy treatment in breast cancer

3. DISCUSSION

In the effort to integrate process mining for the analysis of chemotherapy treatment processes using the Simulacrum dataset—a synthesized dataset emulating breast cancer cases and their treatments—several difficulties became apparent. This section explores the challenges encountered during this effort, providing valuable perspectives on the subtle and complex aspects involved in utilizing process mining to gain a deeper understanding of the chemotherapy treatment process for breast cancer patients. The identification and understanding of these challenges are essential in paving the way for future advancements and ensuring the effective integration of process mining in similar contexts.

Selection of Relevant Variables

Selecting the appropriate variables for the process model was challenging due to the dataset's vast number of options. Expert input is crucial to determine the most relevant variables and avoid erroneous assumptions. The dataset contains synthetic patient data, including age and gender, as well as synthetic tumour data, such as stage and pathology information. Similar to real-life scenarios, synthetic patients in the Simulacrum dataset have various types of tumours. Expert guidance is essential for identifying critical elements and selecting appropriate variables.

Complex Process Map

The process map generated from Simulacrum was complex, making it challenging to identify patterns suitable for process mining. Process mining can unveil diverse patient pathways based on factors such as cancer stage, treatment protocols, response to treatment, and individual patient characteristics. It can capture the different sequences and combinations of activities that patients undergo, including diagnostic tests, surgery, and chemotherapy sessions.

In our analysis of the dataset, we identified a total of 38 different variations within the treatment pathways for breast cancer patients undergoing chemotherapy. These variations represent distinct sequences of activities, decisions, and treatment protocols observed in the dataset. The identification of these 38 different variations highlights the complexity and variability that can exist within the treatment pathways for breast cancer patients, emphasizing the importance of personalized medicine and the need to consider individual patient factors when designing treatment plans. The abstraction provided by process mining enables the identification of common patterns and variations. It assists in revealing the key process steps and decision points that significantly influence patient outcomes.

Validation of Data Accuracy

Using a large synthetic dataset posed challenges in validating the accuracy of the data without expert input. Accurate data is vital for an effective process model. We have identified 321 different types of regimens that have been used to treat patients undergoing chemotherapy. A regimen refers to a prescribed course of treatment that includes specific drugs, dosages, and schedules for administering chemotherapy. Identifying and analyzing the various regimens used in chemotherapy treatment is crucial for understanding the diversity of treatment options available and their potential impact on patient outcomes. However, we cannot validate their impact on patient outcomes such as survival rate due to a lack of expert opinion.

Technical Requirements and Data Handling

Implementing process mining using substantial datasets requires specialized software, a powerful computer, and technical expertise. We utilized a SQL database to handle the large dataset and R programming for data analysis. This approach facilitated efficient data manipulation and analysis. Firstly, specialized software specifically designed for process mining is vital. Additionally, a powerful computer capable of handling the computational demands of analyzing large datasets is required. Equally important are individuals with technical expertise who possess the knowledge to operate the software and utilize the computing power

effectively. In managing the extensive breast cancer dataset, we used a SQL (Structured Query Language) database. SQL is a programming language utilized for efficient management and querying of databases. Through this, the dataset was systematically stored and managed for further analysis. R, a programming language renowned for statistical computing and graphics, was chosen for in-depth data analysis [9]. Leveraging R, we conducted a detailed analysis on the breast cancer dataset. This allowed for a comprehensive understanding and extraction of meaningful information from the dataset. By utilizing both a SQL database and R programming, we were able to handle the breast cancer dataset efficiently.

Despite the encountered challenges, utilizing process mining with large datasets presents promising opportunities. With a larger dataset, the resulting process model becomes more precise and reflective of realworld scenarios. More data means a better understanding of the process, allowing for a refined and accurate model. A larger dataset reveals variations in the process that were not visible in smaller datasets. Identifying these unexpected variations is crucial to understanding the various scenarios that can occur. The larger data unveil patterns and trends that were not obvious before. These insights can lead to significant improvements in the chemotherapy treatment process, potentially enhancing patient outcomes and efficiency.

4. CONCLUSION

Implementing process mining using large synthetic datasets presents exciting possibilities for enhancing process analysis. However, the challenges encountered emphasize the need for expert guidance, appropriate variable selection, and a robust technical infrastructure. With these considerations in mind, future research can build upon this case study to effectively utilize process mining, providing substantial benefits for process optimization and decision-making.

This paper outlines the challenges faced and potential opportunities in integrating process mining with large synthetic datasets. It emphasizes the importance of expert guidance and the necessary technical requirements for successful integration, providing valuable insights for future research in this evolving field.

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Sustainable Local Development without exclusion: A case study on social protection within the region of Athens

Anastasia Kremmyda University of West Attica <u>akremmida@yahoo.com</u> Anastasios Sepetis University of West Attica <u>tsepet@uniwa.gr</u> Georgios Pierrakos University of West Attica gpierrakos@uniwa.gr Aspasia Goula University of West Attica aqoula@uniwa.gr

Abstract

This article analyses the term "Sustainable Local Development" as it has been defined by various organisations. Even though these definitions are characterised by some kind of diversity, their point of convergence is that sustainable development is fair, participatory, advancing, stable, and inclusive. This is the reason why it is closely related to the United Nations' Sustainable Development Goals. The aims of Sustainable Local Development without exclusion can be achieved by empowering local communities, people in general and specifically those living in poverty or facing social exclusion. It is obvious that social protection policies that are designed and implemented at a national, regional and local level are related with Sustainable Development Goals. In this way, Inclusive Local Development is the key to the local societies' development with the simultaneous reduction of social risks such as poverty and social exclusion. In this particular study, a field research has been conducted in order to analyze the knowledge of the institutions that apply social protection programmes and especially programmes for child protection or poverty alleviation on Sustainable Development issues.

KEYWORDS

sustainable development goals, sustainable local development, social protection programmes, poverty alleviation, Athens region, child protection

1. INTRODUCTION

During the past decades economic development took place at the expense of social and environmental development. The aftermaths were environmental degradation and exacerbation of social inequalities forming a vicious circle in most cases. On top of that, the wider the gap between social and economic inequalities is, the more endangered the democratic and participatory co-existence of all members of society will be, being a threat for its well-being. According to bibliography (Ducoing, 2021, Gupta, et al., 2015), when the focus is on the economic aspect marginalising its social and environmental aspects, then it is possible to cause strain in accomplishing Sustainable Development Goals.

Consequently, Sustainable Local Development without exclusion, on which this article focuses, aims to mitigate the inequalities of local communities through equal access of goods, services and institutions for all members of the society. This is actually the concept of Sustainable Development Goals for the Agenda 2030 as formulated by the United Nations. The motto "to leave no one behind" is closely interrelated with Sustainable Local Development Goals where society, economy and environment advance in harmony without burdening one another.

Social protection programmes tend to fight against risks such as the exclusiveness of people or groups. In this direction, social protection programmes applied by the municipality of Athens can set "best practice" examples since social protection has been proved that reduces poverty and social exclusion percentages to a significant extent as derived from Eurostat's data study.

In the second section of this article, a field research is presented which has been carried out in community centres and non-governmental organisations occupied with child protection and the fight against poverty and exclusion. The aim of this research is to investigate people's questioned knowledge of the link between sustainable development and poverty generally and child poverty specifically, the strategies designed for the achievement of the goals at a national and local level and if the institutions they represent apply the strategies in question. At the end of the research, the questions focus on suggestions relevant to the improvement of these policies as well as to the design of new ones.

2. SUSTAINABLE LOCAL DEVELOPMENT WITHOUT EXCLUSION

Sustainable Local Development is based on three pillars: the social, the environmental and the political geography in order to protect not only social but also environmental targets. The social pillar includes human rights, inequalities, re-distribution and agricultural development. The environmental pillar consists of all the issues which are of utmost importance for the human well-being. It focuses on the protection and accessibility of the local eco-systems. The third pillar refers to poverty and environmental degradation which are not normally caused by those who face them resulting in the intensification of inequality phenomena (Gupta & Vegelin, 2016). Sustainable Local Development without exclusion, therefore, imposes equal development among social, ecological and economic aspects, and at the same time it does not permit any inequalities concerning the usage of disposable resources between the present and the future generations (UNDP, 2005 & Talmage & Knopf, 2017).

According to the Asia Development Bank, Sustainable Development without exclusion refers to the economic opportunities that are created by the development and are accessible to all - especially the poor. The International Monetary Fund considers also considers that there are three characteristic elements: strong economic development that includes all people and is sustainable. Usually, the economic opportunities are not equally distributed. As a result, the poor benefit less because of the market conditions or situations (Ali & Zhuang, 2007). The term "Inclusiveness" is of vital importance and usually refers to the UN report on Sustainable Development. The reason is simple: whichever social inequality exists, actually reduces the possibilities of natural resources exploitation and worsens the vulnerability of the already vulnerable – due to climate change – populations (Anand et al., 2013). Inclusiveness can also mean an emphasis on the needs of non-priviledged and marginalised people, the more general educational procedures and the social infrastructures for all and the re-distribution of power (Rauniyar & Kanbur, 2010 & Benner, et al. 2018). By empowering people to be in a position to use a wide selection of economic opportunities, inclusive economy can be a helpful tool so that economies can be in a Sustainable Development track (Tchouassi, 2011). Also, limited access to financial services can possibly deprive people, families or businesses of economic development and lead them to a poverty status (Miled et al., 2022). Nevertheless, equal opportunities are vital for conditions of parity and evolution at the same time, since all people have the same supplies and their efforts are regulated by the same rules. It is also very important to note that not only the present generation but also the future ones will have the same privileges concerning consumption, social well-being, economic policy and environmental conditions (Cerra et al., 2022).

In terms of local development, Turok (2010) suggests that all regional and local approaches in development offer multiple benefits to Sustainable Development because 1. they can be developed and tested at a local level and best practices can be used in other regions with similar development levels 2. the policy focus on local communities (urban development level – cities) permits actions to integrate 3. better targeting to social groups that have not possibly been benefited from the advanced regional living standard can be achieved 4. developing dynamics of the local community are possible to define 5. the co-ordination of the political agenda of Sustainable Local Development at a local level society is possible 6. the composition of the development tends to be at a local social level and these approaches demarcate growth and actions for local development with readjustments of development policies at a specific local frame. Angel Guerria in his proposition for OECD, at the beginning OECD's work about Sustainable Local Development without exclusion in cities, suggests that "if we want to succeed, then we have to ensure that cities are in the centre of the battle". Eventually, although cities are the addressees of the detrimental effects of intensive inequalities, they have to be the cities that can introduce the most innovative and effective solutions to the problem (OECD, 2016). However, it has to be stressed that although regions and cities have surely an important role in the evolution of new ideas and applied business strategies for Sustainable Local Development, this role is inevitably limited in comparison to the role of national governmental level policies. Despite the extensive worries for social inequality, local decision makers have usually limited power to face the problem directly and improve their policies for Sustainable Local Development (Glaeser et al., 2009; Lee et al., 2016). It has to be highlighted that local decision makers have more obligations than responsibilities. The conclusions of the World Economic Forum mention emphatically that "we need to reformulate the mental map of how the national and regional economic performances are perceived and developed by decision makers and reconsider Inclusive Development policies at a local and national level" (Dörffel & Schuhmann, (2022). We also need to focus on qualitative indicators which should measure local growth strategies and promote social well-being and environmental sustainability (Stiglitz et al., 2009; Gupta et al., 2015; Gupta and Vegelin 2016; McGregor and Pouw, 2017). In this regard, Sustainable Local Development is defined as a dynamic procedure of interaction between employment and social policies at a regional and local level, which adopts a basic rule: economic growth should benefit all citizens and prevents the formulation or the preservation of poverty and social exclusion phenomena, especially to regions characterised by low standards of growth.

3. SOCIAL PROTECTION PROGRAMMES IN GREECE

In Greece social protection comprises of all the interventions of civil and private institutions which aim to alleviate households and individuals from the burdens created by certain risks and needs such as illness, disability, old age, unemployment and social exclusion (Eurostat, 2022). However, there is not efficient evidence if these social protection programmes have reduced poverty and what their mid and long term outcomes are (Borga & D'Ambrosio, 2021). Nevertheless, studies on Eurostat researches have shown that poverty percentages have been reduced to half after social transfers. At a local level, social protection is implemented in two ways. Policies are centrally designed and the municipalities have only a managerial role by taking over the distribution to the beneficiaries based on certain criteria (economic and social). The second way is that there are specific interventions with a wide range of services such as material needs satisfaction, primary and old age care, etc.

During 2010-2019, the municipality of Athens was called to fight against challenges such as poverty or the inflow of immigrants/refugees (Matsaganis, 2016) . As exclusively responsible for the design and the application of social policy programmes, it set the following targets: 1. Poverty alleviation, 2. Protection of citizens' rights and fight against discriminations 3. Promotion of primary health and social care (Stratigaki, 2021). For the first target food programs, Social Pharmacy and Grocery Store, housing programs, work integration, child care and medical services were organized. For the second target, the aim was to deal with the refugee influx with housing and education programs, health and social care services, creative employment for children and Greek language courses. They also prepared and implemented programs, etc. For the third target, clinics which previously existed were upgraded to Multipurpose Centers for Medical and Social Services in the position of reception and service staff according to the WHO model. Furthermore, programs for the protection of the elderly were implemented, while the information systems NIAZOME in order to receive and diagnose needs and EXYPIRETO in order to provide information on available social services.

3.1. The field research

The purpose of this research is to investigate the degree to which the stakeholders understand the relation among Sustainable Development Goals, the Agenda 2030 and the fight against poverty and more specifically child poverty. The targets are the understanding, the knowledge and the access of the organisations to the Sustainable Development National Strategies and the poverty reduction and elimination Action Plans.

The research questions are the following:

- Do the stakeholders already know the relation between Sustainable Development Goals and the fight against poverty?
- Do the stakeholders already know about the initiatives related to childhood protection and the fight against poverty at a European and a national level?
- What is happening now concerning the present policies application?
- What do the stakeholders believe that has to be done in order to benefit from the strategies, participate in them, apply the suggested measures having as an ultimate aim the eradication of child poverty?

The analysis of the findings was processed through spss and the research questions were coded into 28 nominal variants. The questionnaire was sent to Community Centres and Open and Closed Child Protection Organisations. 21 organisations within the region of Athens answered the questionnaire. More specifically the identity of these organisations is shown in Figure 1.



Figure 1: Identity of the organisations





Questions 1-5 of the questionnaire are related to the knowledge on Sustainable Development Goals the people being questioned already have. 19 out of the 21 people being questioned know about Sustainable Development Goals & the Agenda 2030 of the United Nations. All people being questioned are aware about the existence of the National Strategy for the prevention and the alleviation of poverty and specifically child poverty. 18 out of the 21 people being questioned answered that they knew about the National Sustainable Development Strategy and its focus on the alleviation of poverty.

Concerning their knowledge about Greek strategies relevant to childhood protection, most of them answered that they had knowledge of Greek Child Guarantee Action Plan and not so much of the rest. In the Figure 2 the results are presented.

When asked to name three of the most important causes of poverty, two of the most prevalent answers were the lack of parents' employment and the fact that some children are brought up by single parent families, while the third answer was equally divided between health problems and three or more children (Figure 3).







Questions 6-11 of the questionnaire are an analysis of the present situation in the organisations of the people being questioned. So, when asked about the way they are informed about funding programmes, the majority answered that they were informed by the relevant ministries.

Also, 15 out of the 21 people being questioned replied that their organisation has been funded by a National Action Plan on Poverty Alleviation or Sustainable Development. It is remarkable though that 6 out of 7 private organisations have not been funded.

The following Figure 5 depicts their opinions on whether Greek social policy planning sets the alleviation of child poverty as priority. It is remarkable that the majority believes that the alleviation of child poverty is a priority for the Greek social policy planning.



Figure 5: Level of priority of Greek social policy planning for the alleviation of child poverty

Figure 6: Administration level suitable for the creation of an organization related to child poverty within the framework of Sustainable Development

About 18 out of 21 organisations answered that the existing income support programmes help to some extent but there has to be more help. Theses programmes are:

- ✓ Guaranteed Minimum Income
- ✓ Child Benefit
- ✓ Childbirth Benefit
- ✓ Non-institutional care benefit
- ✓ Housing Benefit
- ✓ Heating Allowance
- ✓ Benefit granted to families living in mountainous and disadvantaged areas.

Questions 12-17 of the questionnaire are proposals of what should be done so as to improve existing policies and develop new programmes in the future. Nearly all organisations answered that the state should develop actions/plans so as the SDGs and the Agenda 2030 will become known to all people. All people questioned consider that this knowledge can be transmitted through mass media and social media. All organisations answered that they should apply programmes related to the prevention and the eradication of child poverty and they believe that there should be a specific unit concerning child poverty in the action plan of Sustainable Development. The majority of the organisations believe that the state should be held responsible for the application and funding of Sustainable Development and child poverty programmes as well as the designing of policies.

The final question concerning the level at which the creation of an organisation related child poverty within the framework of Sustainable Development should take place, the organisations answered that the organisation should be operated at a state level and not so much at a local or regional level (Figure 6).

4. CONCLUSIONS

In Greece, national strategies and actions have been designed and implemented to combat poverty and to achieve the goals of Sustainable Development. Also, programs have been financed with the main aim of dealing with poverty and its consequences. Nevertheless, the risk of child poverty ranks Greece in fifth place for 2020 in relation to the rest of the European countries of the European Union with slightly reduced rates compared to 2015. Originally the aim was to investigate the degree to which the measures taken at a state level reach their aim at a local level and help alleviate child poverty in the end. The research part of this work showed that while the involved agencies are aware of the strategies and action plans, not all of them are funded. Furthermore, it seems that although there are childhood and family support programs, these cover the needs to a certain extent. It is also unknown whether all people living in poverty and deprivation have access to these programmes. What is equally important information from the research part is that all agencies consider that the fight against poverty should be a priority in social policy planning. In addition, they emphasize that it is necessary to create a special body for this purpose. The knowledge that derives from this research is that information should be spread thoroughly at a local level and that people in need of the programmes should have easy access to them. So, strategies and actions should aim with specialized

measures to deal with the phenomenon organized at a state level but for the national actions to be effective it is essential that they should be implemented at a local level.

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Forecasting Models and Subjective Predictions in the Forecasting of Pharmaceutical Market Demand

Dimitrios Kallivokas University of West Attica <u>dkalliv@uniwa.gr</u> Stavros Tzevelekis University of West Attica <u>mba20079@uniwa.gr</u>

Abstract

In this modern era, a company must take into account the sales data of previous years in order to be able to estimate future sales. Furthermore, by applying modern as well as appropriate forecasting techniques, estimate with as much certainty as possible the sales of its products in the immediate future. However, in a number of situations and in special cases such as the pharmaceutical market, the subjective forecasting of management executives for demand and the target setting set by management for sales are considered very important. This paper takes into account historical data of a pharmaceutical company active in Greece, concerning the sales of three drugs in the last five years. It also examines if the average demand resulting from the subjective demand predictions of the executives and the target set by the enterprise differ significantly from the forecasts given by appropriate scientific forecasts given by a combined model of forecasting methods and the subjective sales predictions of the management executives of the pharmaceutical company that markets the specific medicines. The selected medicines had different characteristics, so that all possible cases were covered and different factors such as seasonality, extraordinary events and randomness were taken into account, so that the conclusion of this study be used more generally and by similar enterprises.

KEYWORDS

Subjective Predictions, Forecasting of Pharmaceutical Market Demand, Forecasting Techniques

1. INTRODUCTION

Forecasting is a necessary and basic operation of business management. They contribute supportively to a company's decision-making regarding issues such as produced quantities, the company's needs in human resources, the amount of advertising expenditure, etc. The pharmaceutical industry provides goods and services that are of central importance to the health sector. The aim is to create more accurate forecasts through the combination of forecasting methods and to improve the operation of a pharmaceutical company. The purpose is to compare and adapt the main and most appropriate demand forecasting models for the medicines of the pharmaceutical company. The research problem of the paper is whether in this particular industry predictions can be made with greater accuracy and less chance of error.

2. RESEARCH METHODOLOGY

In this paper, demand forecasting methods were applied to the sales data of three medicines of a Greek pharmaceutical company, recorded in the years 2017 to 2021. Also, the demand forecasts of the medicines were compared and combined with the target set for these three medicines by the executives of the company. The target setting for the same years as the demand forecasting models were applied, is carried out subjectively based on the estimates of the executives, which results from the knowledge of the market, the investments that have been made and/or are planned to be made in the company where they will favor the increase of sales etc.

In the first phase, for each medicine separately, the exponential smoothing method (Billah et al., 2006), the Holt method and the Holt-Winters method were applied (Holt, 1957); (Winters, 1960). Quantitative methods were compared with each other based on the error measures of mean absolute deviation, mean square error, and mean absolute percentage error (Khair et al., 2017); (Sungil & Heeyoung, 2016); (deMyttenaere et al., 2016). To perform the comparison of quantitative prediction methods and subjective targeting, the same error measures were applied to the targeting of the three medicines.

Next, the quantitative method with the lowest error (Charkhi et al., 2016) for each individual medicine was compared to the corresponding target location to see if prediction with quantitative prediction models can produce more accurate predictions compared to subjective targeting.

Finally, the quantitative method with the smallest error was combined with targeting in order to perform a combined forecast and to see if through the combination, the resulting forecasts have a higher accuracy and a lower probability of error. This combination is obtained by considering the optimal weighting between the two methods, using Solver where the minimization criterion is the mean squared error. The results are shown in Figures 1, 2 and 3.









Figure 3: Forecast (Combined) Medicine 3

3. CONCLUSIONS

In this paper, a combination of the Holt-Winters method was carried out with the target location that had been defined with subjective criteria by the company's management. The choice of the Holt-Winters method was made because it is the method that yielded the smallest error for all three drugs under investigation. The reason the Holt-Winters method is more accurate is due to the trend and seasonality that all three drugs exhibit. However, monthly demand forecasts for products such as medicines may yield larger errors, because small changes in the external environment, such as for example in climatic, economic, health conditions, etc. they are able to influence seasonality patterns by bringing demand a few months before or after the expected timing.

In conclusion, the use of properly adapted forecasting methods can predict medicine demand better than empirical forecasts. In the three medicines mentioned, the most suitable method is Holt-Winters in relation to the rest of the time series methods, due to the existence of trend and seasonality. In the context of the comparison of the Holt-Winters method and targeting as a qualitative predictor, the Holt-Winters method in all three cases was much more accurate according to the MSE criterion.

The combination of the Holt-Winters method and targeting yielded a lower error for all three investigational drugs compared to the individual models and targeting.

Similar results were observed in a simulation carried out with other medicines of the company where there is no seasonality. The simulation combined targeting with the most appropriate quantitative method for each drug separately and the result in all cases was a smaller error. Therefore, in all cases the prediction error was smaller when a quantitative method was combined with subjectivity.

It is worth noting that, in the process of combining targeting with the quantitative demand forecasting method, it is necessary to adjust the weight to be attributed to targeting and the quantitative method. The adjustment should be done each time before combining when new data has been introduced, minimizing one of the error measures. With the approach carried out in this paper, it is not possible to create a stable combined prediction model, even in the case where stable conditions may exist. For a more accurate prediction, it is necessary to readjust the model in terms of the weight attributed to the targeting and the quantitative method. The suitability/appropriateness of the data is an important parameter for making more accurate forecasts. More specifically, the data used in the demand forecasting models are sales data.

There is a big difference between sales and demand, which becomes apparent when something happens that affects the business's ability to meet demand. This difference can be seen in the sales of "Medicine 1" from January 2019 to April 2019. In this particular period due to the lack of the drug in the market, the sales in the months of January, February and March were extremely low and part of the demand of patients was served by the stocks that existed in the drug warehouses and pharmacies. Also, part of the patients' demand was

met with other drugs, due to the difficulty in finding "Medicine 1". In April 2019 the shortage was restored and sales were higher than any other month in history. However, a large part of these sales was intended to restore the safety stocks of drugstores and pharmacies.

Therefore, during this period there are large discrepancies between sales and demand that affect the accuracy of forecasting models, mainly due to cases where patient demand for "Medicine 1" was met by other competitive and purely competitive medicines. It is obvious that using the appropriate methods can lead to more accurate predictions. That is, when changes due to trend or seasonality are observed in the data, the application of methods such as moving average, weighted moving average and exponential smoothing will produce incorrect forecasts. However, the Holt method when there is a trend and the Holt-Winters method when there is a trend and seasonality are more appropriate methods in these cases and will lead to more accurate forecasts.

Finally, the way in which demand is created in this industry is much more complex than in consumer products. In the pharmaceutical industry, patient demand for drugs is primarily driven by healthcare professionals such as physicians and pharmacists. Also, the factors that may affect the demand in this industry are more than in other industries. For example, a decision by the National Drug Agency to include a drug in the treatment protocols of a disease is enough to increase the demand of a drug to a very large extent. On the contrary, if a serious adverse reaction is found in a drug it is enough to nullify the demand even for a drug that has been used for years. Nevertheless, by using appropriate methods and by fitting qualitative and empirical data into predictions, it can be there will be a safe forecast in the specific sector.

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Teacher contentment as regards State Support, Recruitment and Integration in Schools

Kouroukli Christina School of Administrative, Economics and Social Sciences Department of Business Administration, University of West Attica 250 Thivon & P. Ralli Str, 12241 Egaleo, Athens Roussou Ioanna -Antonia School of Administrative, Economics and Social Sciences Department of Business Administration, University of West Attica 250 Thivon & P. Ralli Str, 12241 Egaleo, Athens

Abstract

The specific research focuses on measuring teachers' satisfaction with state support in their study of education structures. More specifically, the research aims to investigate the satisfaction of teachers from the way they are recruited (recruitment) and in particular with the reception, acceptance, integration and support of the teacher by the state in the new work environment. The research was conducted with the MUSA (Multicriteria Satisfaction Analysis) methodology. The sample collected was from 302 people. The results of the survey showed that the educational stuff, in general terms, is not satisfied from the state's support, whereas it indicates a low satisfaction percentage by the recruitment procedure. On the other hand, teachers show that they are more content by their work environment. In addition, factors such as administration and legal frame are issues that need imminent improvement.

KEYWORDS

Professional Satisfaction, Teachers Satisfaction, Satisfaction Measurement, Recruitment, Musa (Multicriteria Satisfaction Analysis).

1. INTRODUCTION

It is widely known that the quality of the educational system depends on the effectiveness of the teaching methods, and consequently on the teacher himself. At the same time, effective teaching is in direct correlation with the motivation of the teacher, his professional ability as well as the working conditions in the school unit, where the teacher works (Makri-Botsari & Matsagouras, 2003). At the same time, the method of recruitment as well as the inclusion of teachers in the school unit are inseparable factors for the increase/decrease of their professional satisfaction.

The literature review has shown that the topic of job satisfaction has engaged numerous researchers across all professions, as it influences the development of employees' motivations and increases their productivity. For this reason, research on the professional satisfaction of educators is of great importance, as teachers serve as a crucial link between education and shaping society.

Over the past three years (2020-2023), the hiring process has changed, and there have been several mass appointments of approximately 25,000 individuals after many years. This was the motivation for the present study, as a research gap was identified since no studies have been conducted examining the measurement of job satisfaction among newly appointed educators in correlation with the state's support in these areas. The present research aims to fill the identified gap following the literature review and investigate, using the MUSA method, the professional satisfaction of educators in relation to their hiring and integration into new school units.

2. METHODOLOGY

More specifically, the research aims to shed light on the following points:

- **1**. How satisfied are educators in relation to the three main dimensions of satisfaction: state's support, selection process, and work environment?
- 2. Which points define the satisfaction of educators in relation to these three criteria and how significant are they?
3. Where should efforts be focused to improve the satisfaction of educators?

For the research, a productive research approach was used, employing a quantitative method with an initial literature review and questionnaire distribution.

The research followed the four main stages that every study should apply, which are also adopted by the MUSA method. Initially, a preliminary study was conducted, targeting the identification of the three dimensions of satisfaction and the fourteen sub-criteria, along with their scales. In the next stage, the research was carried out, followed by data analysis, and finally, the presentation of the research results and proposed actions took place.



The criteria and sub-criteria of the research are shown on the next diagram.

Figure 1: Measurement of Teacher Satisfaction regarding their recruitment in educational structures

For the collection of the sample, a random method was employed through the use of digital communication applications, and the research lasted for three weeks. The selected response scale was a verbal five-point scale in order to capture the participants' preferences with greater accuracy. The sample of this study consisted of 302 respondents, the majority of whom were female educators (82.8%). Regarding the level of education, the majority held a postgraduate degree (54%), and the predominant age group was 31-40 years old (43.7%). The analysis of these data was conducted using the statistical analysis method SPSS.

2.1 MUSA Method (Multicriteria Satisfaction Analysis)

The MUSA method was chosen for this research. It is a multicriteria method for measuring satisfaction, according to which satisfaction dimensions, i.e., individual satisfaction criteria X (X1, X2, X3...Xn), shape the overall customer satisfaction. The importance of satisfaction criteria for the respondents is indicated by the weights assigned to the satisfaction criteria in each dimension that has been defined, including the following: average satisfaction indices, average requirement indices, average effectiveness indices, action diagrams/maps, improvement diagrams (Grigoroudis & Siskos, 2005).

The main advantage of the MUSA method is that it fully takes into account the qualitative dimension of judgment and customer preferences, as reflected in customer satisfaction research, providing particularly detailed quantitative information (Kyriazopoulos et al., 2007). Furthermore, the findings are more reliable when multiple criteria are used to evaluate a single factor since it assesses not only the overall satisfaction of

the respondents but also their individual satisfaction in each respective sub-criterion. The results obtained are comprehensible, clear, and therefore immediately usable.

2.2 Results

Below are some of the diagrams as produced by the MUSA software, which will be further interpreted.



Figure 2: Total value function and average overall satisfaction.

Table 1: Criteria results

| Criteria | Weight | Average indices | effectiveness | Average indices | requirement |
|--------------------|--------|-----------------|---------------|-----------------|-------------|
| State support | 62,5% | 6,41% | | 76,85% | |
| recruitment | 22,06% | 31,36% | | 35,03% | |
| Work environment | 15,44% | 53,01% | | 5,87% | |
| Total satisfaction | | 16,46% | | 55,7% | |

 Table 2: Summary table containing weights, average satisfaction indices, and effectiveness for individual criteria of the points

| Criteria | Weight | Average effectiveness indices | Average requirement indices |
|------------------------|--------|-------------------------------|-----------------------------|
| State Support | | | |
| Sub-criteria | | | |
| Administration process | 38,13% | 10,46% | 79,62% |
| Administration stuff | 9,68% | 44,56% | 16,63% |
| Platform OPSYD | 11,55% | 42,28% | 30,15% |
| Webpage | 10,02% | 46,34% | 18,82% |
| Legal frame | 30,63% | 11,37% | 73,88% |
| Recruitment | | | |
| Sub-criteria | | | |
| Selection system | 34,89% | 18,91% | 61,78% |
| Selection process | 50,90% | 14,52% | 72,62% |
| Transparency | 14,21% | 58,79% | 6,20% |
| Work environment | | | |
| Sub-criteria | | | |
| Job object | 25,99% | 89,34% | -73,89% |
| Wages | 7,77% | 22,34% | 13,33% |
| Prospects | 7,59% | 30,02% | 11,33% |
| School environment | 37,82% | 80,37% | -64,94% |
| Infrastructure | 8,44% | 36,28% | 14,65% |
| School Administration | 11,49% | 69,93% | -36,95% |

3. CONCLUSIONS

From the research data, it emerges that the general percentage of overall satisfaction among educators is at a level that should be considered quite low, specifically at 16.46%. This finding is supported by a relatively high mean score of the demandingness index of collective satisfaction among educators, which reaches 55.7%. These findings are findings that should raise concerns, based on the findings from the literature review, according to which low teacher satisfaction creates significant problems in their efforts to effectively meet their work demands (Grammatikou, 2016; Kyriacou, 2001). Based on the relatively low satisfaction of educators from the overall evaluation of criteria, it is useful to draw some specific conclusions. Educators, in general, are not satisfied with "State Support," while they also show a low satisfaction rate with "Selection Method." The general satisfaction index of educators with their "Work Environment" should be considered relatively high.

The importance of the factors of "State Support" and "Selection Method" is supported by international literature, especially in studies that categorize the factors of professional satisfaction of educators into intrinsic and extrinsic factors, referring to working conditions, remuneration, administration, and organization of the educational system, as well as relationships among colleagues as extrinsic factors (Tsounis & Sarafis, 2016; Gkolia & Koustelios, 2014; Humphrey, Nahrgang & Morgeson, 2007).

Changes in the work environment do not seem to receive particular priority because the relative satisfaction level of educators is relatively high, and at the same time, changes do not appear to significantly affect satisfaction indices. However, it should be emphasized that an important factor of the work environment, namely "Financial Rewards," is presented as an extremely important factor affecting educators' satisfaction systematically in the international literature (Saiti & Papadopoulos, 2015; Durdukoca, 2018). The same observation applies to the criterion of "Selection Method," which is expected to present increased difficulty in fulfillment without appearing to significantly affect the overall satisfaction index of educators. The factor that requires immediate reinforcement is "State Support."

This finding is supported by the fact that "Selection Method" and "Work Environment" will require a high level of effort for improvement while they may not significantly increase overall teacher satisfaction. The factors of "Administrative Process" and "Institutional Framework" of recruitments appear to have a significant impact on teacher satisfaction and are prioritized in improvement processes.

SUGGESTIONS FOR FUTURE RESEARCH

It would also be important to explore any disparities in satisfaction levels between educators working in the public and private sectors, in order to gain a clearer understanding and develop targeted interventions to increase satisfaction in the educational field. Furthermore, it would be interesting to examine which educational sector feel more satisfied and why.

Lastly, the establishment of a systematic longitudinal study conducted annually by the state could provide a comprehensive description of the factors influencing educators' satisfaction, allowing for the development of a long-term cross-sectional policy aimed at the optimal management of the human educational workforce.

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Generating criteria in a Decision Support System for use in Circular Economy Decisions

Lykourgos Lalis Department of Business Administration, School of Administrative, Economics and Social Sciences, University of West Attica 250 Thivon & P.Ralli Str., 12241 Athens, Greece Nikos Tsotsolas Department of Business Administration, School of Administrative, Economics and Social Sciences, University of West Attica 250 Thivon & P.Ralli Str., 12241 Athens, Greece

Abstract

Throughout history, materials, either in raw or fabricated form were considered to be one of the main substances of the manufacturing process. As the demand for a variety of different materials continues to be of significant importance – due to the fact that resources are not infinite – the solution of manufacturing with already used materials is a necessity in industrial society. Therefore, new ways of managing resources need to be addressed to create a "closed-loop" model and extend the product life circle. This model can be described within the margins of circular economy. In this research work, which is on the process phase, we are discussing a total of 198 researched criteria in accordance to the notion of circular economy in order to create a managing tool for supporting decisions makers, managers engineers in decision making. These criteria represent the consequences of alternative decisions in different fields such as waste management, ecoefficiency indicators, recycling etc. These criteria will be used in the Decision Support System (DSS) that is being designed and developed. In order to integrate these criteria in the DSS they should be categorized according to their content in the CE pillars. The content of these criteria will be also presented as a crucial step in eliciting their importance in a Multicriteria Decision Analysis (MCDA) model. As a result, developing such a methodology will bring contribution to researchers by enhancing resources management efficiency and paving the way to a sustainable environment in the future by reducing the amount of virgin material use while increasing the prosperity for both companies and society.

KEYWORDS

Circular Economy (CE), Decision Support System (DSS), Multicriteria Decision Aid (MCDA)

1. INTRODUCTION

It is a fact nowadays, that the problem of finding and extracting new resources increases daily due to the difficult situation that can be described as the lack of the resources. Therefore, creating new alternative ways to generate the necessary raw material, which are critical for the construction could be more beneficial than ever.

Problematic is in this state that many of the studies examined in the research work create a basic theoretical framework or give general solving indicators for soothing the problem of evaluating resources. Therefore, a more detailed contribution to the problem should be applied so as to create a better methodology for application in this matter.

This research is divided in two parts. The first part of this work provides information by introducing the model of the Circular Economy and provide the definitions of the model which will be described as a result of a literature review. The second part describes the process of generating the criteria for use in the model, which is used later on to assess the problem in the use of material in the construction processes. This part goes much more deeply in the evaluation of the criteria as a content and not in the method itself, which is presented in another part of this research.

As mentioned in the abstract, this study discusses – among others – a new way of dealing & managing all type of resources and raw material needed for the majority of all manufacturing process. This article describes briefly the research process conducted so far, so as to give a theoretical approach of the overall procedure of generating the crucial summation of the criteria, which can be used in the MCDA model to ease the problem of managing resources.

2. CIRCULAR ECONOMY

In this part of the work, we give the definition of the concept of circular economy in its own critical parts.

The basic notion of CE is to take these materials and resources that would normally reach the end of life and transform them into something quite new. Basically, it creates all the fundamentals principles which are necessary for the extension of the linear concept of take make dispose and transform it into a closed loop (The Ellen MacArthur Foundation, 2015). Especially CE focuses on these alerting factors that indicates a change in the way in operating systems (The Ellen MacArthur Foundation, 2015). These factors can be described as:

- price and supply risk
- structural wastes and economical losses
- technology advances etc.

In the upcoming part will extensively describe the different definitions of circular economy throughout an extended literature review.

2.1 Defyning Circular Economy

Circular economy and its definition have many different aspects. Some of these aspects are described in this section.

To begin with CE can be described as global economic model in order to minimize the use of raw materials, which are not finite while focusing in the design of materials, products and systems (Ripanti & Tjahjono, 2019). In addition, circular economy can be described as a system of regeneration which input of resources and waste, emissions and leakage of energy are being minimized by closing and decreasing material and energy loops (Geissdoerfer et al., 2017).

Furthermore, circular economy is also described as environmental concept, in which practical policy with orientation in CE emphasizes in material reuse and remanufacturing in refurbishment and repair, in cascading and remodeling, as well as in solar biomass, wind and waste derived energy utilization through the product value chain and cradle to cradle life cycle (Korhonen et al., 2018).

In the same direction as what previous are being said is the following definition, which reduce the use of wasteful raw materials through a flawless design and implementing of products and process for improved efficiency of resources with circular material flows the principles of reus, recycling etc. (Jawahir & Bradley, 2016)

In the paper of Haupt et al. (2016) CE is described likewise as a concept consists mainly of system in production and consumption with minimum number of losses in materials and energy through the principles again of reuse, recycling, and recovery. In contradiction to the upper described definitions CE in the work of (The Ellen MacArthur Foundation, 2015) depicted as one strategy from the economic sector that propose innovative ways to alter the mostly use linear system of consuming into a circular, while aiming economic sustainability with much need-ed material savings.

Lastly in (Korhonen et al., 2017) sustainable developed initiative with the purpose of decrease the societal development in production & consumption systems. This can be achieved with the aid of material cycles, renewable and cascade type- energy flows to the linear system. Thus, promoting high value material cycles more traditionally viewed recycling and develops system approaches to producers, consumers and other actors in a more efficient environment.

From what has been already discussed it is of major importance to say that many of these definitions for the circular economy are not the same. Most critical is the fact that, we every user in such a system uses his/her own individual aspects in order to create the sustainable system, which described in many cases keeping in mind that the use of circular economy as a concept can be operated with some principles.

For that reason, these principles will be discussed in the next section of this work, in order to provide the most critical point of view for the concept of Circular Economy.

2.2 Principles of Circular Economy

In this section the basic principles of the CE are discussed in order to be clearer how the concept of CE operates and we focus on those that have a major importance. These principles are (The Ellen MacArthur Foundation, 2015):

- Preservation and enhancing of natural capital by finite stock controlling and balance the flow of the renewable resources.
- Optimization of resources yields by circulate products, components and material at the highest point of utility at all times in both biological and technical cycles. This has the meaning of designing and remanufacturing, refurbishing and recycling in order to keep material into a circular motion.
- Raise system effectiveness by bringing up and designing out the externalities which are negative. This decreases damages in areas and systems such as food, mobility and manage externalities like land use air, water and noise pollution and ultimately release of toxic substances

These principles alongside with the structure of the MCDA method are held in the following section as a point of view for generating the criteria for use in the Decision Support system, which we will use to solve the problem of regenerating resources and materials.

3. CRITERIA IN MCDA METHODS

This section gives a brief description of the available steps in modelling of criteria. In other words, a slight overview of the available steps in the decisions making process until the selection of criteria, which can be found in the literature are presented.

3.1 Criteria Modeling

The most critical part in the criteria modeling is the is the design of the consistent family of criteria. The consistent family of criteria is a system, which is the result of the consequences between different actions in which the decision is about to be made (Siskos, 2008).

In the work of Sikos (2008), which represents the basic structure of the design procedure of consistent family of criteria, this structure resulted as the process of the analysis of the problem and have the following structure:

- Strict Definition of the summation of all possible actions
- Elementary analysis of the consequences for the sum of the actions
- Determination of Preferences
- Selection of dimensions
- Determination of the consistent family of criteria

In the work of Majumder (2015) the selection of criteria can be identified in the first two steps as shown below:

- Object and/or goal identification of the process in the process of the decision making
- Criteria Selection and/or Parameters/Factors/ Decision maker

In the same direction, criteria must have common working principles. In the work of Siskos (2008) criteria in a MCDA methodology should have the following principles:

- Cohesive with the decision maker
- Must present Exhaustiveness
- Not be non-redundant

In the same direction in the work of Majumder (2015) these working principles in the selection of the criteria can be identified as follows:

- Decision coherent
- Independency among each one
- Measurability etc.

The figure 1 below depicts the state of the criteria modelling in a MCDA methodological framework. In this study criteria can be divided in inputs and processes in accordance to the goal the must achieve.



Figure 1: Criterial Modeling in an MCDA Methodological Framework (Spyridakos et al., 2001)

By following the aforementioned methodological framework, we concluded to an initial overview of the consistent family of criteria regarding the recoverability of products, which is shown in figure 2.



Figure 2: Initial overview of the consistent Family of Criteria

4. CONCLUSIONS

In this part of this work, the findings and the conclusion of the process are discussed and in short terms analyzed.

As referred in a previous part of this study, a methodology, which is on the ongoing phase, will examine the generation of a decision support system which aims to assist decision makers in their selection regarding material and resources in close relation to the circular economy.

In the research conducted:

• More than 198 criteria resulted in accordance to the CE-indicators

- As we mentioned in previous section all criteria will be examined about their cohesiveness, exhaustiveness and the non-redundancy
- We will allow decision makers to select, which problematic will be the best option for him or her

Critical points in this research can be key questions, which may be the

- Context of the decision
- The expected type of results that the decision process is estimated to bring
- The selection of the more suitable MCDA methodology shall also depend on the experience of the decision maker

The selection of the MCDA method to be applied will be further discussed because of the importance of the selection of the appropriate MCDA method. In the work of Polatidis et al. (2006) sets specific requirements regarding operations for MCDA such as weight eliciting, multiple veto and threshold values etc. In addition, in the paper of Roy & Slowinski (2013) the clarification of the decision for using the expectable methodology requires some questions, which examples are listed below:

- The difficulty or the easiness of finding the preference information and is mandated for the use of method
- The necessity of having in mind, that some form of criteria may collaborate.

All these concerns - among others - will be part in the upcoming paper of this work and will be examined thoroughly in the future so as to create a methodology opulent and exact enough for the majority of users for evaluating resources and changing the way of dealing with them in a more prosperous way.

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A multicriteria assessment of alternative structural and antiseismic solutions for building design considering sustainability factors

Zoi Staikou Department of Civil Engineering University of West Attica Isaak Vryzidis Department of Civil Engineering University of West Attica <u>i.vryzidis@uniwa.qr</u> Constantinos Repapis Department of Civil Engineering University of West Attica <u>crepapis@uniwa.qr</u>

Abstract

Implementing sustainable solutions in the building's design is one of the most critical issues in today's era. The different structural elements, the different preferences of clients and architects, the required reduction of the environmental footprint and the requirements of current seismic codes form a complex frame in which decisions are made for their design. Various methodologies based on multiple criteria decision-making (MCDM) have been developed to manage this complexity in recent years. The literature review highlights the application of several MCDM methods in the design of buildings considering environmental, economic, static and construction criteria. This study aims to develop a decision model that applies to the early design stage for evaluating alternative structural proposals, considering construction cost, construction time, carbon footprint, and seismic capacity. The proposed methodology is based on the TOPSIS method, while the criteria weights are estimated using the WAP method. The methodology was applied to an eight-story building with specific dimensions, considering four alternatives from reinforced concrete and one from a steel structure. The present study confirmed the usefulness of multi-criteria decision analysis in improving the selection process and assessing the sustainability of alternative structural solutions at the initial design stage.

KEYWORDS

Multi-Criteria Decision Aid (MCDA), TOPSIS, WAP, Sustainability, Structural and Seismic Building Design

1. INTRODUCTION

The design of a new building involves a series of steps to ensure the project's success. After a preliminary design concept that outlines the basic layout and form of the building, the overall architectural style is determined. A feasibility study is then conducted to evaluate the project's viability, including cost estimates, funding sources and potential challenges. After the preliminary architectural design, structural engineers should decide on the structural system and start to design the structure's load-bearing capacity. The structural engineers should understand the requirements and constraints of the project, the purpose of the structure, the loads and the design code according to which the structure will be designed, and then, they should analyse the structure to ensure safety, efficiency, and capability to withstanding the loads and environmental conditions it will encounter, including the seismic loads. Finally, based on the results of the analysis, detailed design calculations should be performed to determine the size of the building's structural elements, such as beams, columns, shear walls, and foundations.

At the first steps of the design, structural engineers have to make crucial decisions related to the main construction material, the structural system and the construction method. These decisions affect the overall performance of the building on several criteria, such as construction speed, cost, aesthetics, durability, maintenance, and global warming potential (Singh & Sarkar, 2019). For example, a concrete structure requires more construction time than a steel structure and weighs more, resulting in higher seismic actions (Gagandeep, 2021). On the other hand, concrete, if well-constructed, is more resistant to environmental factors and corrosion, making it suitable for structures in harsh conditions. Steel structures are susceptible to corrosion and may require more frequent maintenance due to the need for rust prevention and paint coatings. In contrast, concrete structures generally have lower maintenance requirements, although repairs may be needed for cracks and other damage over time (Divya & Murali, 2021). It is worth mentioning that steel can be more durable in high-stress environments. Also, steel can be cost-effective for long-span structures due to its high strength-to-weight ratio and may require less material, but steel prices can fluctuate. Furthermore, steel or concrete structures may offer a modern aesthetic depending on the structural scheme. Concrete structures can be designed with a wide range of shapes, but they may require

thicker walls or additional supports for certain designs. In some cases, a combination of both materials may be used to optimise the benefits of each.

In most cases, the cost is the most critical parameter engineers depend on to make decisions. Vilutiene et al. (2020) suggest that other parameters, such as the seismic capacity of the structure, the construction time and environmental criteria, should also be considered in the design phase. However, designing a building considering the abovementioned parameters is challenging due to the different relative importance of the criteria and their conflicting nature. Ogrodnik (2019) considers the Multiple Criteria Decision Analysis (MCDA) as an effective tool for handling the complexity of the decision parameters and analyses the usefulness of MCDA methods in various applications in Architecture and Engineering.

The literature review indicates that many methodologies have been developed in recent years for building design considering technical, economic, environmental, and construction criteria. These methodologies could be grouped into two main categories. The first one consists of applications related to seismic retrofitting for existing buildings (Carofilis Gallo et al., 2022; Clemett et al., 2023; Rocchi et al., 2018), while the second one refers to methodologies in the design of a new structure (Nguyen & Altan, 2012; Vilutiene et al., 2020).

This paper aims to illustrate how a decision-making method, such as MCDA, can be used to assess a new building's finite set of alternative structural systems. The novelty of this work is that the methodology focuses on the early design stages of a building when structural engineering decisions significantly impact the performance of the technical and environmental criteria. The paper is organised as follows: Section 1 includes an introduction to the article's topic and an overview of the current literature. Section 2 presents the suggested methodology for evaluating alternative structural solutions for new buildings at the preliminary design stages, while section 3 includes an illustration of it. Section 4 concludes the main findings of this study.

2. METHODOLOGY

The proposed methodology's primary purpose is to assist structural engineers in making design decisions during either the pre-dimensioning phase of structural elements or the optimisation phase of the design variables. The methodology follows the general MCDA methodological framework according to Roy (1985), which consists of four main steps:

Step A. Problem structuring: In the first step, the alternative structural options are identified and constructed (set of alternatives A_i), which in this case includes selecting the construction material together with the structural system and then the seismic design of the alternatives of the new structure according to Eurocodes.

Step B. Formulation of the criteria: In the second step, a consistent family of criteria has been constructed (set of criteria C_j), and the performance of the alternative actions on criteria is estimated (construction of the decision performance table). Therefore, in this step, the decision matrix *X* was constructed:

$$X = \{x_{ij}\} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

where x_{ij} represents the value of the jth criterion (j = 1, 2, ..., n) for the ith alternative (i = 1, 2, ..., m)

It is worth noting that the criteria are identified by the decision maker (DM), the engineering team responsible for the building design in this case. Different criteria could be selected from case to case depending on the specific type and size of the structure, architectural features, special performance requirements, seismic exposure, construction factors, etc.

Step C. Evaluation of alternatives: The third step consists of evaluating alternatives using an MCDA method or a combination of MCDA methods. The proposed method in this study is based on two methods: 1) the weight assessment through prioritisation (WAP) method (Tsotsolas et al., 2019) for the estimation of the criteria weights, and 2) the technique for ranking preference by similarity to the ideal solution (TOPSIS) developed by Hwang and Yoon (1981) for the final ranking of the alternatives. The WAP method is an indirect method for assessing the criteria's importance, inferring the weights from pairwise comparisons of the criteria and utilising Linear Programming (LP) techniques. Within the WAP approach, the DM is asked to rank order the n criteria into s classes ($s \le n$) and to specify a range with visual techniques of how many times a specific criterion is more important than the previous one in the ranking. The process of the WAP method is illustrated in Table 1. Regarding the TOPSIS method, the basic principle of the analysis is that the alternatives with the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution

are the most preferred. The TOPSIS procedure is presented in Table 1, in which the weights estimated with the WAP technique are utilised in step 2.

Table 1: Steps of the proposed method

Criteria weights estimation with the WAP technique The procedure of the TOPSIS method

Step 1. Preference elicitation

The DM need to categorise the n criteria into s classes (s \leq n), from most important to least important. Then, the DM is asked to compare the successive criteria pairwise, e.g., compares the pair's most important criterion with the pair's less important criterion. This is expressed in the form of a ratio index Z_r:

$$Z_r = \frac{p_r}{p_{r+1}}, for r = 1, 2, ..., s - 1$$

where s is the number of importance classes for the criteria, $Z \ge 1$, p_r, p_{r+1} are the weights of the r and r + 1 importance classes of the criteria, respectively. It does not require a precise determination of Z_r, but it could be in the range format [Zmin_r, Zmax_r]. Scroll bars are used to assist the DM in visually defining this range.

Step 2. Estimation of the weight vector

The above preference information corresponds to infinite weight vectors bordered into an n-dimensional hyper-polyhedron. The minimum and maximum weight values are estimated by solving the following 2n optimisation (LP) problems are solved:

min p_j & max p_j , where j = 1, 2, ..., n

s.t. $p_q - p_{q+1} = 0$, if g_{q+1} is followed by g_q and g_{q+1} belongs to the same importance class (r) as g_q or $p_q - p_{q+1} \ge Zmin_r$, $p_q - p_{q+1} \le Zmax_r$, if g_q is followed by g_{q+1} , g_q belongs to a most important class (r) and g_{q+1} belongs to less important class (r + 1), for every $q = 1, 2, ..., n - 1, 0 \le p_j \le 1$ and $\sum_{j=1}^{n} p_j = 1$.

Step 3. Robustness analysis

For the robustness degree in each criterion, the range between the maximum and minimum values of the criteria weights for each criterion is calculated. The second index is the average stability index (ASI), representing the normalised standard deviation of the various solutions corresponding to the hyperpolyhedron vertices (Grigoroudis & Siskos, 2002).

Step 4. Analysis of the results

The analysis results are given to the DM, who could either accept the estimated weight vector of the barycenter or revise the preference information. Step 1. Calculation of the normalised decision matrix

Each element of the normalised decision matrix R could be calculated with the formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$
, where r_{ij} symbolises the normalised
performance of the ith alternative to
the jth criterion

Step 2. Weighted normalised decision matrix calculation

The weighted normalised value v_{ij} can be calculated by the formula: $v_{ij} = p_j \times r_{ij}$, where p_j the criteria weight of the j^{th} criterion determined with the WAP method.

Step 3. Positive & negative ideal solution vectors Determination of

$$\begin{split} A^+ &= \left\{ \left(\max v_{ij} \mid j \in J \right), \left(\min v_{ij} \mid j \in J' \right) \mid i = 1, 2, ..., m \right\} \\ &= \left\{ v_1^+, v_2^+, ..., v_j^+, ..., v_n^+ \right\} \\ A^- &= \left\{ \left(\min v_{ij} \mid j \in J \right), \left(\max v_{ij} \mid j \in J' \right) \mid i = 1, 2, ..., m \right\} \\ &= \left\{ v_1^-, v_2^-, ..., v_j^-, ..., v_n^- \right\} \end{split}$$

where

 $J = \{j = 1, 2, ..., n \mid j \} \text{ and associated with benefit criteria}$ $J' = \{j = 1, 2, ..., n \mid j \} \text{ associated with the cost criteria}$

Step 4. Calculation of the separation measure and the relative closeness to the ideal solution:

The n-dimensional Euclidean distance can measure the separation between each alternative. The separation of each alternative from the ideal one is then given by

$$s_{i^{+}} = \sqrt{\sum_{j=i}^{n} (v_{ij} - v_{j}^{+})^{2}}, \text{ i= 1, 2, ..., m}$$
$$s_{i^{-}} = \sqrt{\sum_{j=i}^{n} (v_{ij} - v_{j}^{-})^{2}}, \text{ i= 1, 2, ..., m}$$

and the relative closeness of A_i concerning A^+ is defined by: $c_{i^+} = s_{i^-} / (s_{i^+} + s_{i^-})$, where, $0 < c_{i^+} < 1$, i = 1, 2, ..., m, It is noted that $c_{i^+} = 1$ if $A_i = A^+$ and $c_{i^+} = 0$ if $A_i = A^-$.

Step 5. Rank the alternatives

The set of alternatives could be ranked according to the values of relative closeness c_{i^+} .

Step D. Analysis of results: The DM could either accept the recommendation provided in step 5 of TOPSIS or, if needed, may provide additional feedback on any element of the previous stages, such as the design of new alternative options, the ranking of the criteria, etc. Any update will result in a new iteration of the procedure. The iterations stop when the DM accepts the final recommendation.

3. NUMERICAL EXAMPLE

In this study, the structural engineer selected five different structural systems to examine as alternative options. The first four structures are made of concrete, and the last is made of steel. The first choice was a concrete moment-resisting frame structural system with rectangular columns (Figure 1a). The second

choice was like the first, but with L-shaped columns at the corners of the building, with dimensions of 30/100/30/100 cm (Figure 1

Figure b). The third choice was like the first, but with a shear wall at the middle of each side of the building, with dimensions of 200/30 cm (Figure 1c). The fourth choice was combining L-shaped corner columns and a shear wall at each side of the building (Figure 1d). Finally, the fifth choice was a steel moment-resisting frame structure with HEB sections for the columns, IPE500 and IPE550 cross-sections for the beams and SHS60x8 sections for the wall bracing (Figure 1e).

The structures were designed according to Eurocodes using modal response spectrum analysis. EC2 (2004) and EC8 (2004) were used for the design of the concrete structure, while EC3 (2005) and EC8 (2004) were used for the steel structural system. Modal response spectrum analysis was performed, code requirements were checked, and design calculations were made for the structural members. Each building was modelled using lumped plasticity hinge elements, and nonlinear static analysis was performed. The load-bearing capacity and the maximum feasible earthquake that can withstand was calculated. The limit state of significant damage was chosen, and the maximum pga that each structure can withstand was one of the selected evaluation criteria.



Figure 1: Different structural systems examined

In this design phase, the structural analysts needed to focus on a small set of evaluation criteria, which can form a sound basis for comparing the examined structural system options regarding their seismic, environmental and technical performance. Concisely, the five criteria are presented in Table 2.

| Table 2: | Evaluation | criteria f | for the | comparison | of | structural | system | options |
|----------|------------|------------|---------|------------|----|------------|--------|---------|
|----------|------------|------------|---------|------------|----|------------|--------|---------|

| Criteria | Description |
|------------------|---|
| C1: weight of | The weight for each case has been calculated based on the bills of quantities of all structural |
| structure (ton) | elements. |
| C2: maximum | Nonlinear static analysis, according to EC8-3 (2005), was used for the assessment of the |
| seismic capacity | seismic capacity of the structure. The limit state of significant damage was chosen for the |
| of the building | evaluation, and a peak ground acceleration $a_{gR} = 0.16$ g was selected for the demand |
| | spectrum, corresponding to an earthquake with a 10% probability of occurrence in 50 years. |
| | Target displacement was calculated according to the methodology described in Annex B of |
| | EC8 (2004). Finally, the maximum sustainable earthquake (maximum pga) was calculated. |
| C3: construction | The construction time of each structural system is estimated using the Critical Path Method |
| time (days) | (CPM), a well-known project management method. |
| C4: construction | The construction cost of each structural system, including the costs of work, materials, and |
| cost (Euro) | machinery, has been estimated based on the current market prices. |

| C5: global | The global warming potential (GWP) has been estimated, including the GWP emissions |
|-------------------|--|
| warming potential | created during raw material supply, manufacturing, transportation, and construction installation |
| | |

After the analysis described above, the decision performance table (Table 3) was calculated. Then, the criteria weights with the WAP method were estimated. The preference information provided, as well as the results from the implementation of the WAP Table 4. The DM emphasises the construction cost, seismic capacity, and weight and less the environmental impact and construction time.

Finally, Table 5 presents the separation measure, the relative closeness to the ideal solution, and the final ranking from the TOPSIS method. The analysis indicates that alternatives A1 and A3 are the most preferred as their performance in meeting the two most important criteria is better than that of the other alternatives.

4. CONCLUSIONS

| | Table 3: | The decision | performance table |
|--|----------|--------------|-------------------|
|--|----------|--------------|-------------------|

| Struct. | Criteria | | | | |
|---------|-----------------|-----------------------------|------------------|------------------|-----------------------------|
| Options | C1 (ton) | C2 (a _g) | C3 (days) | C4 (Euro) | C5 (ton CO ₂ eq) |
| A1 | 2650.36 | 0.319 | 255 | 197,577.72 | 1.48 E+02 |
| A2 | 2742.10 | 0.300 | 255 | 208,694.89 | 1.57 E+02 |
| A3 | 2782.87 | 0.322 | 255 | 205,618.52 | 1.53 E+02 |
| A4 | 2823.65 | 0.287 | 255 | 216,274.50 | 1.62 E+02 |
| A5 | 2069.32 | 0.109 | 105 | 598,443.44 | 6.59 E+01 |

technique, are presented in Table 4: Estimation of weights and robustness analysis

| Class/order | Criteria | [Z _{min} , Z _{max}] | Pi | μ |
|-------------|----------|--|-----------|--------|
| 1 | C4 | [1.0408, 1.1053] | 0.2503 | 0.0170 |
| 2 | C2 | [1.0833, 1.1277] | 0.2332 | 0.0191 |
| 3 | C1 | [1.1053, 1.2222] | 0.2110 | 0.0264 |
| 4 | C5 | [1.3810, 1.5641] | 0.1816 | 0.0280 |
| 5 | C3 | | 0.1239 | 0.0217 |
| | | Average stability in | dex (ASI) | 0.9886 |
| | | | | |

Table 5: The decision performance table

| Struct. Options | S_i^+ | s _i - | c _i + | Final ranking |
|--------------------|---------|------------------|------------------|------------------|
| A1 | 0.00392 | 0.02526 | 0.866 | 1 |
| A2 | 0.00466 | 0.02307 | 0.832 | 3 |
| A3 | 0.00443 | 0.02461 | 0.848 | 2 |
| A4 | 0.00525 | 0.02169 | 0.805 | 4 |
| A5 | 0.02533 | 0.00504 | 0.166 | 5 |

This study investigates the value of multi-criteria analysis in evaluating structural systems at the early stages of the building's design. Based on our findings, the development of multi-criteria analysis tools can assist in combining several or varied characteristics of a building's design. The TOPSIS method appears to meet the requirements of the problem and is an easy-to-use method suitable for the specific case. The analysis designates the better performance of concrete structures in seismic capacity and construction cost, while the steel structures in construction time and environmental impact. It is critical to conduct additional research on the proposed criteria. It is also worthwhile to investigate alternative methods of determining the criteria's weighting and compare their efficiency in multiple cases.

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An integrated framework of Sustainability Balanced Scorecard with neutrosophic AHP for smart port performance evaluation

Antonios Paraskevas

University of Macedonia, Department of Applied Informatics Egnatia Str. 156, 54636, Thessaloniki, Greece <u>aparaskevas@uom.edu.gr</u>

Michael Madas

University of Macedonia, Department of Applied Informatics Egnatia Str. 156, 54636, Thessaloniki, Greece <u>mmadas@uom.edu.gr</u>

Abstract

Nowadays we experience a series of developments in technological, economic and political levels such as globalization and the emergence of new Information Technologies and Communications (ICT) which significantly affect the services provided by a port. The concept of "smart ports" was recommended as a solution to overcome challenges for ports such as the guest for operational excellence, the relocation of activities, and the need to meet successfully the new business demands. These concerns stem from the tendency to measure the success of each port based on traditional parameters such as size and performance. In this vein, a plethora of practical and theoretical approaches to measuring port performance have been proposed, primarily encompassing individual measurements and indices, economic impact studies, and frontier approaches. However, due to fundamental disparities between these techniques and their proposed methodologies, no consensus on a single framework for port performance assessment has been achieved, despite the variety of tools and instruments available. It is observed that significant gaps and inconsistencies exist at both the analytical and methodological levels that must be addressed in order to establish a meaningful and integrated performance framework. In response to this gap, our research identifies and suggests criteria of performance assessment and evaluation for smart port performance and proposes a novel hybrid conceptual framework for performance measurement. The proposed conceptual framework is built on the basis of a modified version of the Balanced Scorecard method, namely the Sustainable Balanced Scorecard (SBSC), enriched and adapted in the context of smart ports. Furthermore, interdependencies between SBSC aspects and weights of key performance indicators can be determined according to their importance level using neutrosophic Analytic Hierarchy Process (AHP), an extension of classical AHP, yet in neutrosophic environment. As a result, our methodology is capable of decision-making in the event of incomplete, uncertain, and inconsistent information during assessment process, thus providing a theoretical basis for quantitative evaluation of port smartness. The proposed solution could be utilized to accelerate an organization's development, enhance efficiency, and strengthen efforts to meet strategic and sustainability goals.

KEYWORDS

smart ports, port performance assessment system, port evaluation, Sustainable Balanced Scorecard (SBSC), neutrosophic Analytic Hierarchy Process (AHP)

1. INTRODUCTION

As the global economy integrates, leading to an agreement among nations to reduce or eliminate exchange barriers, greater opportunities for international trade collaboration emerge. Ports play a significant role in worldwide economic and trade growth as a vital connection in global transportation. Smart ports have emerged as the leading method of port construction in recent years, marking a turning point in modern port development. The smart port concept is based on the utilization of cutting-edge technologies to transform conventional port services into dynamic and interactive ones in order to enhance transparency and efficiency. Digitalization and automation of ports to achieve "ports 4.0" are currently two key agents of change in port management systems (Camarero-Orive et al., 2020). Therefore, the main objective of a smart port is to satisfy the needs and requirements of its users and customers, while sustainability and the orientation of the port towards the city that surrounds it to create quality spaces and services are two other central pillars of the smart port concept (Jardas et al., 2018). Environmental issues are critical for ports. Ports can achieve greater economic stability and continuous improvements in performance under current environmental regulations by improving their sustainability (United Nations Conference on Trade and Development, 2011).

Several tools and methods have been proposed for solving performance evaluation problems using multicriteria decision making (MCDM) methods. The main contribution of this study is the implementation of an integrated AHP strategy in a neutrosophic environment using the sustainable balanced scorecard (SBSC) method. The SBSC performance measurement system is a tool capable of incorporating sustainability indicators using established financial procedures to assess the port's current and future value, including its surrounding community, suppliers, workers, technology, innovation, and internal processes (Alemany, 1999).

Applying these methods enables us to create a conceptual framework for the organization to implement its strategy and achieve its goals. In this sense, the methodology proposed in this study offers an advantage over other approaches, given the fact that it can identify and focus on the organization's main dimensions in the context of causal linkages.

As a result, the aim of this study is to propose a solution for assessing the impact of each of the five perspectives of SBSC and to develop a comprehensive performance evaluation framework under incomplete and indeterminate information for measuring smart port performance. One of the key aspects of performance evaluation utilized in this study is the use of performance indicators based on SBSC aspects and the provision of a representative list of them. The proposed approach will be able to consider multiple criteria simultaneously, taking into consideration the relationships between each component and sub-factor(s). In this study, the AHP method is suggested to establish the connection between various performance evaluation criteria (i.e. perspectives) and indicators.

The rest of this paper is organized as follows: First, in section 2, a brief overview of relevant literature on port performance is provided. In section 3, the methods that form our conceptual framework are outlined. Next, in section 4, we illustrate how our integrated methodology could be used as a tool for smart port performance evaluation. Finally, in Section 5, concluding remarks and future directions are discussed.

2. LITERATURE REVIEW

The evaluation of development efficiency helps ports identify their deficiencies and enables better design of plans and policies tailored to the specific conditions of each port, which is beneficial for port improvement. Currently, parametric analysis and nonparametric analysis are the two main methodologies used to evaluate port efficiency.

Considering port efficiency, the literature review showed examples of studies using parametric analysis (DEA and fuzzy DEA methods) on what port performance benchmarks and indicators are being or should be used by port managers (Tongzon, 2001; Tongzon, 1995; Wang & Han, 2018).

The parametric method to port efficiency evaluation focuses primarily on stochastic frontier analysis (SFA). To evaluate the sample port's efficiency, the stochastic frontier analysis calculates the deviation degree between the sample port and the frontier ports in terms of efficiency (Cotto-Millan et al., 2000; Cullinane et al. 2002).

Studies presenting effectiveness metrics face difficulties with its measurement. This is because effectiveness is measured relative to the objectives being sought by users rather than against 'best practice' benchmarks, as with DEA or SFA. Balanced Scorecard (BSC) is extensively used to construct a performance evaluation system. The BSC is a tool that is widely used to assess organizational performance in four major internal and external areas, namely financial, customer, internal processes, and learning and growth. Kaplan and Norton (Kaplan & Norton, 1996) expressly stated that there are causal links between the four elements of the BSC method. Although the concept of BSC has been widely acknowledged and applied in the business industry, apparently it has not been used extensively in the maritime and port sector.

Assessment indicators for ports are imprecise in practice, regardless of whether parametric analysis or nonparametric analysis techniques are used to evaluate port performance. When decision-makers assess port performance, subjective criteria like carrier satisfaction, new business acquisition, and innovation in management systems may not be clearly defined. Additionally, assessment indicators for different ports are inconsistent, and using different evaluation techniques for the same port can lead to different results. Therefore, neutrosophic set theory is used to integrate the opinions and understanding of evaluation group members' viewpoints.

As a generalization of the concept of the classic set, fuzzy set, interval valued fuzzy set, intuitionistic fuzzy set, and interval-valued intuitionistic fuzzy set, F.Smarandache firstly proposed a concept of neutrosophic set from philosophical point of view (Rivieccio, 2008). Researchers in (Wang et al., 2005; Wang et al., 2010) proposed interval neutrosophic sets (INSs) and single-valued neutrosophic sets (SVNSs), both of which are subclasses of NSs.

3. MATERIALS AND METHODS

In this section, we will briefly describe the overall framework proposed in this article to introduce the reader to the core methods that make up our methodology. The first step involves adding a new perspective called

Socio-Environmental to the existing four standard perspectives of the Balanced Scorecard in order to address sustainability issues. The Neutrosophic AHP method is then applied in the second step to measure the weight of all five perspectives mentioned, based on their importance level in port performance evaluation.

3.1 SUSTAINABLE BALANCED SCORECARD

The Balanced Scorecard (BSC) concept is based on the assumption that competitive advantages are derived not only from quantifiable 'hard facts', primarily the efficient use of fixed capital, but also from 'soft' and intangible assets such as intellectual property, employees' knowledge and abilities, or customer relationships, which must be measured and managed. In the post-industrial information era, these variables are becoming increasingly essential sources of competitive advantage and long-term economic success.

BSC consists of the following components: 1) Perspectives, 2) Objectives, 3) Measures (Indicators), 4) Targets and 5) Initiatives.

The correlation between these components is as follows (In Fig.1 we illustrate how the financial perspective is created. The same scheme applies to other perspectives too):

Perspectives: For each perspective there is one or more objectives.

Objectives: For each goal there is one or more measures (or indicators).

Measures: For each measure there is only one desired target.

Initiatives: These usually refer to and influence a single or a set of objectives, or measures, or targets.

However, the biggest task for companies and organizations is to achieve corporate sustainability as an unavoidable contribution to the economy's and society's long-term growth (Burritt & Schaltegger, 2010; Burritt & Schaltegger, 2005; Schaltegger & Wagner, 2006). Companies are transitioning from the problems of disruptive information technology to the challenges of corporate sustainability. In this context, researchers in related field, proposed ddifferent approaches to developing SBSCs to integrate sustainability aspects into corporate performance measurement and management systems. In our study, we employ the approach which suggests adding further perspectives to the standard BSC layout in order to take into account sustainability issues (e.g. gas emission, greenhouse effect etc.) (Bieker & Waxenberger, 2002; Figge et al., 2001; Figge et al., 2002).



Figure 1: Basic layout of Sustainable Balanced Scorecard [authors]

3.2 NEUTROSOPHIC AHP

AHP is one of the most widely used MCDM approaches, enabling researchers to determine the weights of criteria and alternatives in a systematic manner. In the current article, due to incomplete information and uncertainty reflecting human thought, the traditional AHP approach has been expanded and applied in a neutrosophic environment to make expert judgments more flexible. Neutrosophic logic is a better option to simulate human thinking and is equipped to handle indeterminacy.

Definition 1 (Smarandache, 1999). Let **X** be a space of points (objects), with a generic element in **X** denoted by *x*. A single-valued neutrosophic set (SVNS) **A** in **X** is characterized by truth membership function T_A , indeterminacy membership function I_A , and falsity membership function F_A . For each point *x* in **X**, $T_A(x)$, $I_A(x)$,

 $F_A(x) \in [0, 1]$. Then, a simplification of the neutrosophic set **A**, which is a subclass of neutrosophic sets, is denoted by

$$A = \{ \langle \mathbf{x}, \mathbf{T}(\mathbf{x}), \mathbf{I}(\mathbf{x}), \mathbf{F}(\mathbf{x}) \rangle \mid \mathbf{x} \in \mathcal{X} \}$$
(1)

Definition 2 (Radwan et al., 2016). If A is a single valued neutrosophic number, a score function S(A) is mapped into the single crisp output as follows:

$$S(A) = (3+TA-2IA-FA)/4$$
 (2)

 $\mathcal{S}(\widetilde{A}) = 1 / \mathcal{S}(A) \tag{3}$

It is known that AHP includes the following stages: 1) Decomposition, 2) Pair-wise comparison, and 3) Synthesis of priorities

Step 1. Decomposition

The problem is formed hierarchically at various levels. The first level of hierarch represents the overall goal, the second level represents the decision criteria and sub-criteria and third level is composed of all possible alternatives.

Step 2. Comparative judgments with neutrosophic values

After analyzing the complex multi-criteria decision-making problem into multiple levels, the pair-wise comparisons used to generate neutrosophic judgment matrix. The vagueness of decision makers is represented by single valued neutrosophic numbers as shown in Table 1.

| Linguistic variable | SVNNs |
|---------------------|-------------------|
| Very Low | (0.1, 0.8, 0.9) |
| Low | (0.3, 0.7, 0.7) |
| Medium Low | (0.4, 0.65, 0.6) |
| Medium | (0.5, 0.5, 0.5) |
| Medium High | (0.6, 0.35 , 0.4) |
| High | (0.8, 0.15, 0.2) |
| Very High | (0.9, 0.1, 0.1) |

Step 3. For calculating overall priority of each alternative and determine final ranking of all alternatives, we should first determine weights of each criterion from the corresponding pair-wise comparison matrix.

Step 4. To determine the weight of each criterion from corresponding neutrosophic pair-wise comparison matrix, we first transform neutrosophic pair-wise comparison matrix to deterministic pair-wise comparison matrix, using the equations (2) & (3).

Step 5. With compensation by the score value of each neutrosophic number in the neutrosophic pairwise comparison matrix, we get the deterministic (crisp) matrix shown below.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}$$

From the previous matrix we can easily find ranking of priorities, namely the Eigen Vector X as follows (Abdel-Basset et al., 2017):

1. Normalize the column entries by dividing each entry by the sum of the column.

2. Take the totality row averages.

Step 6. To measure inconsistency within the judgments in each comparison matrix and for the entire hierarchy, AHP methodology provides a consistency index (CI) (Saaty, 2006). AHP method employs the consistency index and consistency ratio to determine whether there is any contradiction in the neutrosophic judgement matrix (CR). If CR exceeds 0.1, the judgements are considered untrustworthy because they are too close to randomness, and the process is either invalid or must be repeated. To calculate CI and CR we follow the process described in (Abdel-Basset et al., 2018).

4. MODELLING OF AN INTEGRATED CONCEPTUAL FRAMEWORK

The development of the proposed conceptual framework for evaluating smart port performance, integrating the SBSC and neutrosophic AHP, has not been previously discussed in literature. Therefore, we believe it is significant and useful for the research community to introduce a new decision-making framework based on the synergy of these methods. Ports are complex organizations, so it is necessary to determine both internal

and external port performance. The associated metrics for each primary SBSC characteristic considered in this study were determined using prior research findings in related literature, as shown in Table 2. This list is not exhaustive but rather inclusive, serving the scope of the current study.

In this step, the relationships between the main indexes of the issue (SBSC aspects) and the relationships between indicators with themselves or other indicators are examined. The internal relations between the five major dimensions of the SBSC and the relationships between the five major indicators are shown in Figure 2.

Table 2: List of performance indicators

| Perspective | Evaluation indicator | Reference | |
|---------------------------|---|---|--|
| Financial | Port integration and facilitation as well as customs clearance efficiency | (Angeloudis & Bell,2010; Luo & Ren, 2016; Gu et al., 2017) | |
| | the port supply chain | (Rudjanakanoknaŭ et al., 2016, La et al., 2009) | |
| | Training and education | (Yuhling et al., 2003) | |
| Learning & Growth | Employee efficiency | (Yuhling et al., 2003) | |
| | Adequate employment of human resource | (Yuhling et al., 2003) | |
| Internal Business Process | Intelligent level of door-to-door full- course services of port logistics | (Gu et al.,2017; Zhang et al., 2016; Cho et al., 2006) | |
| | "Internet +" logistics supply chain services | [27-29,31] | |
| | Carrier retention | (Yuhling et al., 2003) | |
| Customers | Harbor infrastructure | (Yuhling et al., 2003) | |
| | Harbor service | (Yuhling et al., 2003) | |
| | Application status of green energy sources | (Angeloudis & Bell,2010; Peris-Mora | |
| Socio-Environmental | at the port | et al., 2005; Zhao et al., 2013) | |
| | Emission control and governance | (Peris-Mora et al., 2005; Zhao et al., 2012) | |
| | capacities over port pointallts | 2013) | |

Figure 2 exhibits the systemic hierarchical structure of criteria used to evaluate the integrated smart port performance. The goal of this study is shown on the first level, and the five perspectives used to evaluate port performance are shown on the second level. The performance indicators (criteria), used to determine each perspective, are described at the third level. Next, we give a brief outline of the proposed framework by highlighting main issues to be taken under consideration.

After identifying the relationship between the goals and strategic orientation of the smart port by a group of decision makers, this paper uses a top-down approach to connect smart port goals with the aspects of SBSC. The first step in this strategy is to investigate the ultimate goals and objectives of the port and outline the means by which they can be achieved. In the next step, each of the port's objectives is integrated into the SBSC aspects of the organization, and appropriate measures for assessing the port's performance are identified by consulting experts. Finally, the measures (indicators) are chosen based on previous literature research and their applicability to the smart port concept.

In this step, the relationships among the SBSC perspectives (SBSC aspects) and between key performance indicators are explored. The internal relations between the four major dimensions of the BSC and the relationships concerning the indicators are shown in Figure 2. A neutrosophic AHP method is used to calculate the relationships among SBSC aspects and performance indicators using the scales shown in Table 1 with the help of expert opinions or by any other means of data collection (e.g. historical data, annual reports, official websites of ports, etc.) following the steps described in subsection 3.2.

5. CONCLUSIONS & FUTURE RESEARCH

Besides geographical location and economic activity, which are often uncontrollable by port management, port performance measurement plays a significant role in analyzing the competitiveness of international commercial ports. Most suggested methods focus on the financial and operating efficiency of ports, making their performance evaluation neither comprehensive nor holistic. In response to this issue, developing an integrated and thorough performance framework that balances financial and non-financial aspects in performance evaluation is needed to lead ports to success in today's competitive environment.

The purpose of this work is to establish a comprehensive method for understanding and focusing on key issues for measuring smart port performance. The model is basically a hybrid implementation of SBSC and AHP method in a neutrosophic environment.



Figure 2: Hierarchical structure of the smart port performance evaluation [authors]

Our methodology showcases several benefits. Firstly, we introduce the concept of SBSC, which considers the interests of management, customers, employees, equity owners, and societal factors simultaneously. Next, the advantage of the neutrosophic approach is that it accounts for both vagueness and indeterminacy encountered in decision-making due to human judgment, thereby meeting the need for analysts to make rational decisions from uncertain and incomplete data related to various quantitative and qualitative performance indicators. Another benefit is that experts use linguistic scales to conduct evaluations, which makes the final results more aligned with human rationality. Furthermore, our framework ensures consensus among experts on the significance of selected criteria.

To our knowledge, this is the first time that a conceptual methodology like ours has been proposed in the related literature, combining the SBSC method with AHP in a neutrosophic environment, thus introducing a new performance measurement framework for smart ports. As a next step, we plan to apply our methodology in a real case study to test its efficiency and applicability in the evaluation process of smart ports. The framework presented in this study is primarily illustrative and not intended to be definitive. Our work represents an initial effort in the field, and further research is needed, particularly in quantifying the model and its associated concepts in a real case study.

The results of this study could serve as a foundation for future research and offer a potential solution for port performance measurement and benchmarking. In future studies, different performance indicators and other MCDM approaches (such as neutrosophic Delphi, TOPSIS, VIKOR, and other non-ranked methods) could be utilized to evaluate and rank smart ports.

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The Impact of the COVID-19 Pandemic on the Digital Transformation of SMEs: An Empirical Study

Christos Ziakis

Department of Economic Sciences, International Hellenic University Magnisias, Serres 62124, Greece

Abstract

Multiple studies indicate that the outbreak of COVID-19 has accelerated the digital transformation of businesses worldwide and has also highlighted the importance of digital capabilities such as e-business, digital marketing, data analytics, automation, and cybersecurity. Many companies have had to rapidly adapt to these changes in order to continue operating during the pandemic. This empirical research examines the impact of the pandemic on the ongoing digital transformation of SMEs across various industries in Greece. It also delves into the implications of digital transformation on employment and the workforce, including the need for reskilling and upskilling. Results from 115 respondents highlight that the pandemic has presented opportunities for companies to innovate and improve their digital capabilities and has led to a rapid increase in digital marketing, e-commerce, remote working, and cloud computing. However, it's important to note that not all companies have been able to adapt to digital transformation equally and some have faced challenges, such as a lack of digital skills, difficulties in implementing new technologies, and security concerns.

KEYWORDS

Digital Transformation, E-Business, Digital Marketing, Covid-19, SMEs.

1. INTRODUCTION

The COVID-19 pandemic reshaped the global economy, forcing businesses to adapt to new digital practices. With travel restrictions in place, many ventured into previously untouched digital territories, especially SMEs with their unique challenges. The change was so rapid that Microsoft's CEO, Satya Nadella, remarked that businesses achieved "two years of digital transformation in two months" during this period. (Marr, 2020). This study explores the pandemic's effect on the digital shift of SMEs in Greece, where they make up 99.9% of businesses and employ 85% of the workforce, as per 2020 data (OECD, 2020a). This heavy reliance on SMEs makes the analysis of the effects of COVID-19 on their digital transformation both compelling and pertinent. Our research involved surveying 115 SMEs across various industries in Greece, in order to gauge the extent of their digital transformation.

The findings revealed that the pandemic has been a catalyst for digital innovation within these enterprises. Many companies have recognized and exploited the opportunities presented by the pandemic to bolster their digital capabilities. The findings of this research aim to provide a nuanced understanding of the direct and indirect implications of the pandemic on the digital transformation of Greek SMEs. By doing so, it contributes to the broader dialogue on how SMEs can effectively navigate future crises while staying competitive in a digital world. The insights garnered from this study could also guide policymakers, industry and academia in devising strategic initiatives that foster the digital growth of SMEs in a post-pandemic world.

2. COVID-19 AND DIGITAL TRANSFORMATION

SMEs, traditionally dependent on face-to-face interactions, were greatly impacted by the pandemic. To ensure business continuity, they rapidly adopted digital tools. An OECD survey found that over 60% of SMEs either introduced or ramped up their use of digital platforms during this period (OECD, 2020b). Similarly, a study by McKinsey revealed that companies, including SMEs, have accelerated the digitization of their customer and supply-chain interactions and of their internal operations by three to four years (Baig et al., 2020). E-commerce emerged as a powerful tool for SMEs to continue their operations amidst lockdowns. A European Commission report (2020) highlighted a sharp increase in online sales by SMEs in Greece during the pandemic. This data reaffirms that the pandemic significantly accelerated digital transformation among Greek

SMEs. The COVID-19 pandemic exerted a significant influence on SMEs' operational structure, driving a hastened shift towards digital transformation strategies to ensure survival and operational continuity (Kudyba, 2020). This fast-paced shift to digitalization was largely deemed necessary for businesses to remain competitive in an unprecedented crisis (Soto-Acosta, 2020). Research conducted by Ramadani observed the instrumental role of digital marketing and transformation in the promotion and positioning of brands (Ramadani et al., 2023). They highlighted that social media use was more prevalent than other marketing channels, which suggests a substantial shift in SMEs' marketing strategies during the pandemic. Winarsih et al. noted that digital transformation was crucial for the sustainability of SMEs, particularly since many were vulnerable to the effects of Covid-19 (Winarsih et al., 2020). This need was amplified by the general lack of knowledge and skills amongst SMEs to effectively implement and utilize digital technologies. A digital transition, therefore, seemed to be a prerequisite for survival during and after the pandemic. Moreover, the process of digital transformation was found to contribute to the modernization of the domestic economy of states, such as Azerbaijan, and was seen to enhance the efficiency of the financial system and business structures (Abilova and Aliyeva, 2022). Different levels of digital transformation were adopted by SMEs based on their digital maturity and available resources. Further research affirmed the potential of digital technologies to bolster productivity and performance within SMEs, which became particularly relevant when dealing with the consequences of extreme events such as COVID-19 (Papadopoulos et al., 2020). Despite the clear advantages, the transformation to digital platforms posed its own set of challenges. SMEs were found to grapple with a multitude of issues, including supply chain disruption, liquidity issues, and cash flow challenges, which were identified through a systematic literature review and a multiple case study (Santos et al., 2022). Several studies proposed solutions and strategies to navigate these hurdles and aid SMEs' digital transformation. Fitriasari suggested a Business Model Canvas approach (Fitriasari, 2020), while Zutshi et al. proposed a framework including collaboration, openness, and durability (Zutshi et al., 2021). Moreover, the role of strategic alliances in dealing with financial impacts was highlighted (Klein and Todesco, 2021). Ali and Ebaidalla pointed out the role of firm characteristics in stimulating digital transformation, with larger firms and those with foreign ownership exhibiting a higher propensity to adopt digital solutions. They also noted that companies facing challenges during the pandemic were more likely to adopt digital solutions if they received government assistance (Mustafa Ali and Ebaidalla, 2023). Kutnjak argued that the pandemic accelerated digital transformation across various industries, leading to a surge in challenges, issues, barriers, and problems (Kutnjak, 2021).

3. METHODOLOGY

To understand the pandemic's effect on the digital transformation of Northern Greek SMEs, we used an online survey. Of 1218 targeted SMEs, 980 received it, and 115 responded (11.7% response rate). This survey, grounded in ICT literature and using mixed sampling, covered: Pre- and post-pandemic digital tech adoption; Challenges in digital transformation (technical, financial, skills); Digital transformation's impact on SME employment and reskilling. Administered from November to December 2022, anonymous responses were gathered via email invitations to ensure honesty. Analysis of this data offered insights into SMEs' digital journey during the pandemic. In studying the digital transformation of SMEs during the COVID-19 pandemic, two hypotheses were proposed. The first hypothesis, H0, posits that the industry sector of SMEs plays a significant role in influencing their digital transformation. Conversely, the second hypothesis, H1, suggests that the geographical location of clients has a marked impact on the digital transformation of SMEs throughout the pandemic.

4. FINDINGS AND DISCUSSION

Our research surveyed SMEs across sectors to understand the pandemic's impact on digital transformation. Sector-wise distribution was: 23.5% tourism, 18.3% retail, 9% real estate, 8% ICT, and 7.8% construction. Most businesses (74.8%) had operated for over ten years, while 15.7% ranged from 5-10 years and 7.8% were new (0-4 years). In workforce size, 42.6% had 5-9 employees, 19.1% had 1-4, and 13% had 10-49 employees. Exploring client base geography, 35.7% of SMEs had a global reach, while 49.6% predominantly catered

locally. These stats highlight varied digital needs based on industry, size, operational years, and client geography.

In the second part of the survey, we asked the participants to respond on their use of ICT technologies in the era before and after COVID-19. The survey utilized a 5-point Likert scale, where respondents were requested to rate their agreement level on a scale of 1 to 5. A rating of 1 denoted "strongly disagree," while a rating of 5 indicated "strongly agree." In relation to the adoption of ICT technologies before and after the advent of COVID-19, there were notable shifts. The utilization of desktops and laptops increased from 70% to 75%. Similarly, internet usage saw growth, moving from 70% to 80%. The most dramatic rise was observed in mobile and tablet usage, which surged from 44% to a substantial 78%. Both the use of digital files and emails saw considerable leaps. Additionally, the frequency of regular conference calls with customers expanded from 39% to 64%. Conversely, there was a significant decline in the number of respondents who never engaged in conference calls, dropping from 67% to 24%. Cloud service adoption among SMEs rose sharply from 12% pre-Covid to 34% post-Covid, reflecting a trend towards cloud solutions. Office software use climbed from 43% pre-Covid to 66% post-Covid, indicating a growing tech reliance. Digital marketing's modest growth saw it move from 34% to 43% post-Covid, while website ownership increased from 39% to 54% post-Covid, underscoring the value of an online business presence. E-business practices saw a rise from 33% to 38%, and ERP system adoption shifted with a decline in non-users from 63% to 38%. CRM system use nudged up from 32% to 35%. IoT adoption remained low, with only minor post-Covid increases. Big Data adoption grew notably with non-users dropping from 69% to 48%. Blockchain's non-user percentage dipped slightly from 79% to 77% post-Covid. AI non-use fell dramatically from 80% to 50% post-Covid.

Concerning future hiring, 63.5% of SMEs aim to hire Digital Marketing Specialists. There's also high demand for Information System users (57.4%) and E-Business Specialists (52.2%). Application Developers, Finance Officers, and Sales Executives were also in demand by 41.7%, 14.8%, and 13% respectively. Challenges hindering digital transformation for Greek SMEs include a lack of specialized staff and funding, with scores of 3.65 and 3.38. Other barriers include a lack of tech information, limited state support, resistance to change, and inadequate technical infrastructure. Digital literacy was deemed essential by most SMEs during hiring, with 67.8% strongly agreeing on its importance. A vast majority (80.9%) sensed a shortage of digitally and financially skilled staff. Regarding future digital transformation investments, 21.7% strongly intend to increase their investment in the next 2-3 years, with 49.6% in agreement.

To test the first hypothesis that the industry sector of SMEs influences their digital transformation during the COVID-19 pandemic, we perform an analysis of variance (ANOVA). The independent groups are the different industry sectors, and the dependent variable is the mean rate of use of each ICT technology post-Covid-19. From the results, we can see that for most of the technologies, the p-value is less than 0.05. Therefore, we can conclude that the industry sector of SMEs does influence their digital transformation during the COVID-19 pandemic for these technologies. The average usage rate of each technology was determined both before and after Covid for every sector. The enhancement was subsequently computed by subtracting the pre-Covid average from the post-Covid average for each industry.

| | Pre-Covid Mean | Post-Covid Mean | Improvement |
|----------------|----------------|-----------------|-------------|
| Agriculture | 2.22 | 2.31 | 0.09 |
| Construction | 2.71 | 3.41 | 0.7 |
| Education | 3.25 | 3.83 | 0.58 |
| Finance | 3.23 | 3.39 | 0.16 |
| ICT | 3.13 | 3.47 | 0.34 |
| Real Estate | 3.05 | 3.92 | 0.87 |
| Retail | 2.47 | 3.07 | 0.6 |
| Tourism | 2.64 | 3.55 | 0.91 |
| Transportation | 2.34 | 2.42 | 0.08 |

Table 1: ICT Technology Use Improvement by Sector

The above table presents data on the mean values of different sectors before and after the Covid-19 pandemic, along with the corresponding improvements. Sectors such as construction, education, real estate, retail, tourism, and ICT experienced significant improvements, with average values increasing post-pandemic. Agriculture, finance, and transportation showed minor improvements. These changes reflect the varied impact of the pandemic on different sectors, highlighting the resilience and adaptability of certain industries and the challenges faced by others.

To test the second hypothesis (H1), we perform a t-test to compare the mean ratings for the use of each technology after COVID-19 between SMEs that work with clients abroad and those that do not. We divide the respondents into two groups based on their responses to the question about working with clients abroad. We consider respondents who answered 4 or 5 (agree or strongly agree) as the group that works with clients abroad, and the rest as the group that does not. From the results, we can see that the geographical location of clients significantly influences the use of all technologies after COVID-19 (p-value < 0.05). This provides evidence for the hypothesis (H1) and suggests that the geographical location of clients significantly influences the COVID-19 pandemic.

Table 2: Changes in Technology Usage Before and After the COVID-19 Pandemic

| Technology | t-statistic | p-value |
|--|-------------|-------------|
| Post-covid-19: Use of PC | 3.06145 | 0.002753 |
| Post-covid-19: Use of Internet | 2.22816 | 0.02785 |
| Post-covid-19: Use of Mobile devices | 2.21233 | 0.028955 |
| Post-covid-19: Use of E-mail | 2.88856 | 0.00464 |
| Post-covid-19: Use of Digital Files | 3.05296 | 0.002826 |
| Post-covid-19: Conference calls with customers | 2.88749 | 0.004654 |
| Post-covid-19: Conference calls with partners | 4.02001 | 0.000105 |
| Post-covid-19: Cloud services | 3.04222 | 0.00292 |
| Post-covid-19: Office Software | 3.70092 | 0.000334 |
| Post-covid-19: Digital Marketing | 5.19321 | 0.000000924 |

Following Covid-19, there's been a pronounced upswing in the usage of technology. Fundamental tools such as desktops, the internet, and email have become irreplaceable in the business world. Such a shift is supported by a study that stated that Covid-19 compelled firms to expediently adopt digital transformation strategies to remain operational (Kudyba, 2020). Digital transformations during this period encompassed elements of the future of work, including remote working, automation, and digital collaboration tools, fundamentally altering business operations. Moreover, the adoption of specific Information and Communication Technology (ICT) technologies like cloud services, office software, and digital marketing, has seen substantial growth. This adoption aligns with relevant findings that highlight the profound impact of digital marketing and transformation on brand promotion and position (Ramadani et al., 2023). It's worth noting that the pandemic has significantly influenced SMEs to adopt more digital solutions. SMEs' vulnerability to the pandemic's effects made it imperative for them to embrace digital transformation to ensure sustainability (Winarsih et al., 2020). In Azerbaijan, for instance, the pandemic significantly accelerated the digital transformation, with SMEs effectively utilizing digital technologies (Abilova and Aliyeva, 2022). Interestingly, while the use of Big Data has surged, other emerging technologies like IoT, Blockchain, and AI witnessed moderate adoption rates. This cautious adoption can be attributed to several factors, including their nascent stages in business adoption, the intricacies of integration, or budget constraints. This is also supported by the findings of a study, suggesting that firm characteristics play a pivotal role in digital adoption (Mustafa Ali and Ebaidalla, 2023). In conclusion, the global crisis brought about by Covid-19 functioned as a catalyst for digital transformation across various business sectors. Whether driven by the need to ensure brand promotion, the necessity of business continuity, or the urgency of countering pandemic-induced challenges, the shift towards a more digital-centric business model is evident. SMEs, in particular, have exhibited significant agility in adapting to this evolving landscape, an essential step in ensuring their sustainability in these uncertain times.

5. CONCLUSION

COVID-19 accelerated digital transformation in Greek SMEs, but techs like IoT and AI saw limited uptake due to cost, complexity, and integration issues. While SMEs value digital skills in hiring, a skills gap exists. Key barriers to digital change include staffing, funding, and cultural resistance. Our study, focused on Northern Greece's SMEs during the pandemic, used an online survey with an 11.7% response rate, which might lean towards digitally proficient businesses and limit generalizability. While informative, our insights may not capture all influencing factors or be relevant outside Northern Greece. Future studies should explore diverse regions and factors influencing tech adoption. To enhance digital transformation in SMEs, we should understand their tech usage, study successful business models, and address challenges. Partnering with

educational entities ensures a tech-savvy workforce. Evaluating the financial gains from digital endeavors encourages further investment. Understanding and boosting the uptake of advanced technologies like IoT and AI is vital. In summary, while COVID-19 challenged Greek SMEs, it also ignited digital change. Addressing these challenges and investing in digital skills can amplify the benefits of digital tech post-pandemic.

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Urban Accessibility and Walkability: Current Approaches and Future Prospects

Mela Athina Department of Civil Engineering, School of Engineering, University of West Attica, 250 Thivon & P. Ralli Str., 12241 Athens, Greece Vryzidis Isaak Department of Civil Engineering, School of Engineering, University of West Attica, 250 Thivon & P. Ralli Str., 12241 Athens, Greece Varelidis George Department of Civil Engineering, School of Engineering, University of West Attica, 250 Thivon & P. Ralli Str., 12241 Athens, Greece

Abstract

Urban accessibility and walkability in public spaces are critical for living sustainably in modern cities. Several approaches for measuring these concepts have been developed, reflecting their importance in urban planning and infrastructure management. This article provides a thorough review of current ways to assess urban accessibility and walkability, as well as the potential for future research and growth. A variety of approaches and concepts for assessing urban accessibility and walkability are provided, their benefits and drawbacks are examined, and their relevance to various urban environments is discussed. Furthermore, the research emphasizes the potential of approaches that apply Multi-Criteria Decision Analysis (MCDA), a novel tool to evaluate urban accessibility and walkability. The use of MCDA in urban planning can assist decision-makers in prioritizing interventions and investments that improve urban accessibility and walkability while taking into consideration stakeholders' various viewpoints and preferences. Finally, the study emphasizes future research and development opportunities in this field, such as the need for integrated methodologies that reflect the complex interactions between urban design, transportation infrastructure, and pedestrian behavior. This review's findings offer insights into current urban accessibility and walkability assessment approaches, as well as areas for future research and development.

KEYWORDS

Urban space quality, walkability, accessibility, multi-criteria decision-making, MCDA, sustainability

1. INTRODUCTION

The accessibility and walkability of cities are critical components of sustainable urban development. They relate to the ease with which people may reach important commodities, services, and activities in a city, as well as the quality of the pedestrian environment. Even the journeys we take in automobiles to get around the city begin and conclude with walking (Cambra 2012). The relevance of urban accessibility and walkability is based on the capacity of infrastructure to maintain inhabitants' safety, health, and quality of mobility. They also provide substantial economic, social, and environmental advantages. Improving urban accessibility and walkability may enhance property prices and encourage economic growth by recruiting companies and generating job opportunities (Burden 1999). It can additionally save costs by eliminating the demand for private automobiles and boosting the efficiency of public transportation networks. In terms of social inclusion, urban accessibility, and walkability can help to eliminate socioeconomic inequities (Almeida 2017; Wen, Albert, and Von Haaren 2020). They ensure that all residents, including those with limitations in mobility or disabilities, have equitable access to important services and activities (Orellana et al. 2020; Velasquez et al. 2021).

Furthermore, enhanced pedestrian surroundings can promote social connections and community involvement, thus improving the social fabric of urban districts. In terms of the environment, urban accessibility and walkability can assist in alleviating the negative effects of urbanization, such as air and noise pollution, greenhouse gas emissions, and the heat island effect (Mark J. Nieuwenhuijsen 2020). The increased use of motorized transportation in cities negatively impacts pedestrian infrastructure. This transition has a detrimental effect, such as environmental damage and pedestrian accidents. Neglected built environments that do not encourage walking cause 1.2 million deaths in road crashes each year and more than 50 injuries, according to the World Health Organization (World Health Organization 2013). Walking is not just a means of transportation but also a beneficial form of exercise, therefore promoting safe and accessible pedestrian areas is critical for both physical and mental health. The Sustainable Development Goals 11 of the United

Nations highlights the necessity of establishing dynamic pedestrian environments in metropolitan areas (UN-Habitat 2019). The field of accessibility research has been enriched with modern tools and methods over the last few decades, indicating the complexities of the stakeholders involved while also emphasizing the importance of developing novel techniques for proper evaluation of public space in order to formulate appropriate management policies (Schindler, Dionisio, and Kingham 2020). Current research on this topic has focused on establishing and improving methodologies for measuring urban accessibility and walkability, as well as studying how these factors interact with other aspects of urban planning, transportation, and land use (Chiang and Lei 2016).

This paper's core research question is: What are the current methods of analyzing urban accessibility and walkability, and what are the future possibilities for this field of study? This study addresses the above topic by a) describing existing ways to evaluate urban accessibility and walkability, including their benefits and drawbacks; and identifying and investigating the components that contribute to urban accessibility and walkability, b) investigating the potential of Multicriteria Decision Analysis (MCDA) as a novel approach for assessing urban accessibility and walkability, c) underlining the significance of stakeholder and community involvement and d) determine future research objectives and possibilities to develop integrated and collaborative methods of assessing urban accessibility and walkability. By fulfilling these objectives, the study seeks to contribute to the ongoing discussion concerning urban accessibility and walkability, as well as provide insight into present and future research trends in this field.

2. LITERATURE REVIEW

Urban accessibility and walkability are two interconnected concepts that play a crucial role in urban planning. Accessibility refers to the ease with which individuals can reach desired destinations, while walkability focuses on creating environments that encourage walking as a mode of transportation (Naharudin, Ahamad, and Sadullah 2017a; Herthogs et al. 2018). This literature review paper explores the relationship between accessibility, walkability, and various aspects of urban planning, highlighting their impacts on well-being, sustainability, social equity, and economic development. Numerous studies have demonstrated the connection between walkability and urban environment features. Ruiz-Padillo et al. (2018) highlight over 200 research publications supporting this relationship. Walkability is influenced by factors such as safety, comfort, aesthetics, and other characteristics that define the built environment (Ruiz-Padillo et al. 2018; Todd Litman 2022; Bierbaum, Karner, and Barajas 2021; Cambra and Moura 2020; Ewing and Handy 2009). Understanding these factors is essential for enhancing the pedestrian experience and promoting walking as a viable mode of transportation. Accessibility comprises three main components: land use, transportation networks, and mobility. Ewing and Handy (2009) emphasize the interaction between these factors, which shape the spatial distribution of opportunities and constraints affecting people's ability to travel efficiently. Evaluating land use patterns, transportation infrastructure, and mobility options provides insights into how well-connected different parts of the city are and how easily individuals can access their desired destinations. Urban walkability focuses on creating pedestrian-friendly environments that prioritize the needs and safety of pedestrians. Key features contributing to walkability include urban amenities, sidewalk networks, pedestrian crossings, street lighting, and safe intersections. To achieve the goal of creating walkable cities, it is crucial to focus on various factors that shape the quality of pedestrian facilities. These factors include pavement conditions, land use patterns, community support, safety, and walking comfort. Taking a comprehensive approach to address the challenges hindering walkability and accessibility is necessary for achieving sustainable urban development (Cambra and Moura 2020; Ghel 2010).

3. RESULTS AND DISCUSSION

Various evaluation indices have been developed with a focus on natural walking environments. However, the existing indicators often overlook important factors such as microclimate conditions, pedestrian comfort, and experiences (Campos 2012; Naharudin, Ahamad, and Sadullah 2017b). To achieve a comprehensive assessment, subjective judgment and observation based on perceived data should be incorporated. Traditionally, assessing accessibility and walkability involved manual calculations and fieldwork, including road network analysis, pedestrian counts, and travel time surveys (Yin 2017). While these methods provide

valuable data, they are time-consuming and resource-intensive. Nevertheless, they are still useful for assessing the level of accessibility and walkability in specific areas. One of the popular and oldest tools used for assessing urban accessibility and walkability is Space Syntax (Giannopoulou, Roukounis, and Stefanis 2012; Paraskevopoulos, Tsigdinos, and Andrakakou 2020). This tool uses mathematical and computational models to analyze how the physical structure of roads and buildings influences human movement. It provides insights into the spatial characteristics of urban areas, including potential barriers to movement and accessibility. However, Space Syntax has limitations, such as the need for extensive data collection and analysis, the exclusion of socio-economic factors and cultural attitudes, and the requirement for specialized knowledge to interpret the results. Also, The WalkScore tool, for example, assigns numerical scores to neighborhoods based on proximity to amenities, but it may not consider factors like safety or pedestrian infrastructure quality (Kim and Jin 2023; Bereitschaft 2018). Additionally, it assumes that all amenities are of equal importance, which may not be true for all individuals or communities. Challenges related to the assessment of urban accessibility and walkability include data collection, subjectivity, limited scope of assessments, and lack of an integrated approach. Manual data collection is time-consuming, while subjective estimates can be inconsistent. Assessments often focus on specific aspects, resulting in an incomplete understanding of the urban environment. These challenges underscore the need for an integrated and systematic approach. Multicriteria decision-making tools have gained popularity for assessing urban public spaces and identifying improvement strategies. They provide a framework for considering multiple factors and objectives simultaneously, aiding decision-makers in making informed choices based on rigorous data analysis (Table 1) (Oppio et al. 2021; Manzolli, Oliveira, and Neto 2021; Fancello, Congiu, and Tsoukias 2020).

| a/a | Authors(s) | Year | Туре | Title |
|-----|---|------|--------|---|
| 1 | Yen Cheng Chiang and Han Yu Lei | 2016 | Paper | Using expert decision-making to establish indicators of urban friendliness for walking environments: a multidisciplinary assessment |
| 2 | Anna Racovali | 2016 | Thesis | Exploring urban accessibility scores using multi-criteria decision analysis techniques |
| 3 | Pieter Herthogs, et al. | 2018 | Paper | A Weighted Graph Model to Estimate People's Presence in Public Space |
| 4 | Ruiz-Padillo Alejandro et al. | 2018 | Paper | Application of multi-criteria decision analysis methods for assessing walkability: A case study in Porto Alegre, Brazil |
| 5 | Yarira Aida Reyes, et al. | 2020 | Paper | A Multi-Criteria Decision Making for Sustainable Location of Urban Parks |
| 6 | Fancello Giovanna, Tanja Congiu, and Alexis Tsoukiàs | 2020 | Paper | Mapping walkability. A subjective value theory approach |
| 7 | Jônatas Augusto Manzolli, André Oliveira and Miguel de Castro Neto | 2021 | Paper | Evaluating Walkability through a Multi-Criteria Decision Analysis Approach: A Lisbon Case Study |
| 8 | Omar Ismael Nasef | 2021 | Thesis | Walkability assessment using GIS-MCDA. A case study of two counties Gävle and Uppsala in Sweden |
| 9 | Alessandra Oppio, et al. | 2021 | Paper | How to assess urban quality: Decision Multicriteria a spatial analysis approach. |
| 10 | Li Yunqin, Nobuyoshi Yabuki, and | 2023 | Paper | Integrating GIS, deep learning, and environmental sensors |
| | Tomohiro Fukuda | | | for Multicriteria evaluation of urban street walkability |

Table 1: Scientific work on contemporary methods of analyzing the accessibility and walkability of the urban environment.

In urban planning, multicriteria analysis helps determine optimal land use, evaluate transportation options, develop sustainable policies, and prioritize mitigation strategies. Several multicriteria tools are available, including Analytic Hierarchy Process (AHP), TOPSIS, PROMETHEE, ELECTRE, and Data Environment Analysis (DEA) (Hajduk and Jelonek 2021; Nikoloudis et al. 2020; Yarira, Escalante, and Adiel 2020; Banville, C., Landry, M., Martel, J.-M., & Boulaire 1998). These tools allow for comparing and ranking criteria, evaluating alternative solutions, and ranking their performance. They can contribute to a structured and systematic assessment of urban accessibility and walkability, incorporating multiple criteria, stakeholder involvement, and transparency. Many projects have applied multicriteria analysis to assess urban accessibility and walkability. Integrating multicriteria analysis with geographic information systems (GIS) can enhance the assessment of urban accessibility and walkability. GIS provides spatial data analysis capabilities and visualization tools, allowing decision-makers to map and analyze different criteria and their spatial relationships (Nasef 2021; Malczewski 2006; Moura, Cambra, and Gonçalves 2017; Li, Yabuki, and Fukuda

2023). By combining GIS with multicriteria analysis, planners can consider spatial factors such as proximity to public transportation, land use mix, and street connectivity in the evaluation process. Additionally, emerging technologies like remote sensing and mobile data collection can provide valuable inputs for assessing urban accessibility and walkability. Remote sensing data can help analyze the physical characteristics of urban environments, including land use patterns and street layouts (Huang et al. 2023). Mobile data collection through smartphone apps or GPS tracking devices can capture real-time pedestrian movements, identify popular walking routes, and assess the quality of pedestrian infrastructure (Gehl and Svarre 2013).

4. CONCLUSIONS

In conclusion, assessing urban accessibility and walkability requires a comprehensive and integrated approach that considers multiple criteria and stakeholder perspectives. Multicriteria analysis methods, provide decision-making frameworks for evaluating alternatives and ranking their performance. Integrating these methods with GIS and emerging technologies can enhance the assessment process by incorporating spatial factors and real-time data. By using such approaches, planners and policymakers can make informed decisions to improve urban accessibility and walkability, ultimately creating more inclusive and pedestrian-friendly cities.

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Factors influencing Greek consumers' willingness-to-pay for online streaming services

Georgios Katsamperis School of Information Sciences, Department of Applied Informatics, University of Macedonia 156 Egnatias st, 54636 Thessaloniki, Greece Fotis Kitsios School of Information Sciences, Department of Applied Informatics, University of Macedonia 156 Egnatias st, 54636 Thessaloniki, Greece Maria Kamariotou School of Information Sciences, Department of Applied Informatics, University of Macedonia 156 Egnatias st, 54636 Thessaloniki, Greece

Abstract

Streaming providers have seen a significant increase in their subscriber bases over the lockdown period due to the global COVID-19 outbreak. The entertainment sector is experiencing strong competition as a result of the distancing from traditional entertainment media and the focus on over-the-top (OTT) services. Recently, domestic companies as well as global industry leaders like Disney and Amazon debuted their streaming services in the Greek market. In a post-pandemic world and given the large range of streaming services currently available in the Greek market, there is a need to gain insight into customer preferences. Even though similar studies have been conducted, no studies examining the factors that influence WTP for a subscription streaming service in Greece exist. Relevant studies tend to concentrate on implementing the Theory of Acceptance Model (TAM) or investigate a small number of variables. We decided to expand our research into a plethora of less-researched factors, such as brand trust, brand loyalty, brand attitude, brand equity, electronic word of mouth (eWOM), brand relationship, brand awareness and pricing. This study examines a large set of variables, further raising its value. Initially, we performed a bibliographical analysis of the field, in order to develop a conceptual framework. The results of this study could be used by companies aiming to launch a subscription service in Greece in order to identify the key elements of focus when developing and marketing their streaming service.

KEYWORDS

Willingness-to-pay, streaming service, OTT service, customer satisfaction, eWOM, brand

1. INTRODUCTION

In 2007, the streaming entertainment platform Netflix was launched (Vaidya, Fernandes and Panda, 2023). What distinguished it from the rest of traditional entertainment platforms was the use of advanced technology for instant, high-speed and high-quality viewing of TV content, on any device the user wishes. In exchange, the service provider receives a monthly subscription from the customer. Streaming services, or "over the top" (OTT) services, in the years that followed changed the way people perceive entertainment (Singh, Arora and Kapur, 2022). The streaming providers exploited, and at the same time promoted, the penetration of high-speed Internet in the wider network and the mass adoption of "smart" mobile phones (Singh, Arora and Kapur, 2022). Very quickly the competition in the market intensified, and the user base of streaming service providers increased (Zahara et al., 2022). Currently the streaming industry is projected to increase its value from 455.4 billion USD (2022) to 1,902.68 by 2030 (Fortune Business Insights, 2021).

Beyond Netflix, major companies of the entertainment industry (Disney, Warner Bros., Paramount, etc.) have introduced their streaming services to the global market. Technology giants like Apple and Amazon have their own streaming entertainment services, Apple TV and Amazon Prime, respectively. Traditional television is rapidly being replaced by streaming services, in other markets at a faster rate than some others (Park, 2017).

The number of available streaming services is increasing, not only globally, but also locally. In Greece there are many streaming services, some are foreign and supported by powerful companies (Disney+, Amazon Prime, Netflix, Apple TV), others come from Greek companies (ANT1+, Cinobo), others inherit the consumer base of cable TV providers and combine it with streaming services (Vodafone TV, Cosmote TV, EON TV). The options presented are numerous and consumer behavior with regard to the consumption of entertainment has changed dramatically (Nagaraj, Singh and Yasa, 2021). The factors that will affect a user's subscription to a streaming service are placed in the foreground.

The importance of the study lies in the fact that understanding customer preferences is valuable information for companies active in the Greek streaming market. At the same time, there are no surveys concerning the preferences of users of streaming services in Greece. The present study focuses on variables relating to the brand: the consumer's loyalty to brand (brand loyalty), the trust in the brand (brand trust), the value of the brand (brand equity), the attitude towards the brand (brand attitude), the brand relationship, the awareness of the public about the brand (brand awareness) and the price of the subscription, in order to evaluate the degree of their influence on consumers' willingness to pay.

The paper is structured as follows: The second section describes the literature review methodology; the third section presents the results from the analysis of the literature. The conceptual model created is presented in the fourth session. The conclusion and the final recommendations for further study are presented in the final session.

2. LITERATURE REVIEW METHODOLOGY

The Webster and Watson methodology (2002) was used for the bibliographical analysis. Initially, previous literature reviews were retrieved for better understanding of the topic. In total, six reviews were analyzed. They dictated the keywords, the databases and the search criteria that were later used in the present literature review.

Scopus and Web of Science were the two databases selected for the search. At first, we used the terms "willingness-to-pay" and "OTT," "OVER THE TOP SERVICES," "OTT SERVICES," and "OTT PLATFORMS," all of which are synonyms for "streaming service." The research fields from which the articles originate should be "Business, Management & Accounting" for Scopus and "Business" for Web of Science. In addition, accepted articles were published in Journals, and were only in English. No time period limit was set, as the literature indicates that the articles to be found are new. From the initial pool of 40.647 articles, only 62 fulfilled the above criteria.





3. PREVIOUS RESEARCH ON FACTORS INFLUENCING WILLINGNESS-TO-PAY

Brand trust expresses the user's willingness to trust the brand's promises regarding the capabilities and quality of the product/service it provides (Theadora et al., 2023). The trustworthiness of the brand (brand loyalty) is considered crucial in building brand loyalty, i.e. persistence in the use of the products and services of the brand and resistance to using similar goods and services from other companies (Theadora et al., 2023).

The degree of preference of the brand by the consumer (brand attitude) is directly related to his behavior and decisions. Indeed, there is a strong influence of the consumer's predisposition to the value of the brand. (Augusto and Torres, 2018). The brand name of the streaming service provider is often enough to increase the value of the service offered from the customer's perspective, hence raising the company's brand equity (Palomba, 2022). It is therefore considered that brand loyalty is strongly correlated to the perceived value of the consumers and the added value of the brand in relation to competing brands. (Palomba, 2022). Augusto and Torres (2018) find the positive impact of eWOM on brand equity, though moderate compared to other variables (brand attitude).

Furthermore, the positive impact of eWOM on WTP is supported by Augusto and Torres (2018) in their research on the banking sector. Brand relationship is the strong emotional bond between the consumer and the brand. The consumer forms after positive interactions with the products of the brand strong feelings of love, passion and nostalgia. It has been found that especially in luxury goods as well as in streaming services the relationship between consumer and brand has a positive effect on the WTP (Zahara et al., 2022). Based on previous literature, public awareness about the brand (brand awareness), has a positive impact on consumer willingness to pay (Zahara et al., 2022). Finally, Shin, Park and Lee (2016) note that pricing plays a decisive role in the degree of service adoption and in the WTP of consumers. Other studies agree (Zahara et al., 2022? Chakraborty et al., 2023? Koul, Ambekar and Hudnurkar, 2021? Sadana and Sharma, 2021).

4. METHODOLOGY

After analyzing previous studies, the following hypotheses were defined:

- H1: Brand trust positively relates to brand loyalty.
- H2: OTT brand loyalty is predictive of OTT brand equity.
- H3: The level of brand attitude has a positive impact on brand equity.
- H4: The level of eWOM has a positive impact on brand equity.
- H5: The level of brand equity has a positive impact on WTP.
- H6: EWOM positively influences WTP.
- H7: Brand relationship positively influences WTP.
- H8: Brand awareness positively influences WTP.
- H9: Price positively influences WTP.

A questionnaire was developed for Greek consumers that are currently or have in the past been subscribed to a streaming service, in order to measure the amount of influence each variable excerpts on WTP. The questions were based on previous literature and used a 5-point Likert scale. The questionnaire was shared through social media.



Figure 2: Conceptual model and hypotheses

Table 1: Variables

| Variables | Questions | References |
|--------------|--|---------------------|
| Electronic | Before I subscribe to a streaming service I read reviews or reviews from the service's | (Zahara et |
| Word of | subscribers. | al., 2022; |
| Mouth | I read reviews or reviews from customers of the streaming service to find out their level of | Augusto |
| | satisfaction. | and |
| | I read reviews or reviews from customers of the streaming service to gather information | Torres, |
| | To be sure to subscribe 1 read reviews or reviews from customers of the streaming service | 2018) |
| | first. | |
| | I have recommended the streaming service's online pages to lots of people. | |
| | I 'talk up' the streaming service's online pages to my friends. | |
| | I give the streaming service's online pages lots of positive word-of-mouth advertising. | |
| Brand Trust | I rely on the streaming service I use. | (Theador |
| | I expect the streaming service I use to deliver on its promise. | a et al., |
| | I am confident in the ability of the streaming service I use to perform well. | 2023) |
| | The streaming service Luse has good intentions towards its users | |
| Brand | L have the intention to continue using the streaming service Lakeady use | (Palomba |
| Lovalty | Based on my experience. Lam very likely to continue my relationship with the | (Paloniba, 2022) |
| Loyuny | streaming service I already use. | 2022) |
| | I am likely to be persuaded to view other video shows from the streaming service | |
| | l use. | |
| Brand Equity | It makes sense to buy products/services of this streaming service's brand instead | (Augusto |
| | of any other brand, even if they are the same. | and |
| | Even if another brand has the same products/services as this streaming service's | Torres, |
| | brand, I would prefer to buy this brand. If there is another brand with products (somices as good as this streaming service's | 2018) |
| | In there is another brand with products/services as good as this streaming service s | |
| | If another brand's products/services are not different from this streaming service's | |
| | brand in any way, it seems smarter to buy this brand. | |
| Brand | I feel that I am attached to the streaming service I use. | (Zahara et |
| Relationship | I feel personally connected to the streaming service I use. | al., 2022) |
| | I feel emotionally connected to the streaming service I use. | |
| | I feel nostalgic memories with the streaming service I use. | |
| | I feel comfortable using the streaming service I use. | |
| | have screaming service I use is my favorite streaming service. | |
| | service. | |
| | The streaming service I use increased my interest in watching streaming shows. | |
| | Among streaming services, the streaming service I use fits my personality best. | |
| Brand | I am aware of the streaming service's brand that I use as a streaming service | (Zahara et |
| Awareness | provider. | al., 2022) |
| | The streaming service's logo is easy to recognize. | |
| | I know what the streaming service I use has to offer. | |
| | I have my own impression of the streaming service Luse. | |
| Brand | The streaming service's brand is good | (Augusto |
| Attitude | The streaming service's brand is pleasant. | and |
| | The streaming service's brand is favorable. | Torres, |
| | - | 2018) |
| Price | The streaming service's fee is affordable. | (Zahara et |
| | The streaming service's subscription price offers proportional service and quality | al., 2022) |
| | The streaming service's subscription is reasonably priced. | |
| | I o me, the streaming service's subscription price is attractive. | |
| | The subscription price of competing services fits my budget better. | |
| Willingness | I would be willing to pay for the streaming service's subscription fee. | (Zahara et |
| to pay | I do not bother to pay for the streaming service's subscription fee to enjoy my | al., 2022) |
| | ravorite movies. | |
5. CONCLUSIONS

The aim of the study is to identify the factors that affect consumers' willingness to pay for streaming services. The research carried out highlighted marketing variables that mainly revolve around the concept of the brand. The conclusions of the study can be utilized by the streaming service providers in the Greek market. The managerial implications of the study may provide valuable information in assisting businesses navigating the Greek streaming service landscape and revising their strategies. The results of this study could be used by companies aiming to launch a subscription service in Greece in order to identify the key elements of focus when developing and promoting their streaming service.

The inclusion of electronic Word of Mouth can measure the influence of Internet and social media exposure on the profitability and financial success of a streaming service. Finally, the inclusion of price in the conceptual model will offer the necessary data to streaming providers in order to create appropriate pricing policies for Greek consumers.

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Solving the van-drone routing problem with multiple delivery drop points

Eleftherios Athanasiadis Department of Financial & Management Engineering, School of Engineering, University of the Aegean, 41 Kountouriotou Street, 82100, Chios, Greece <u>athanasiadis.fme@gmail.com</u> Vasilis P. Koutras Department of Financial & Management Engineering, School of Engineering, University of the Aegean, 41 Kountouriotou Street, 82100, Chios, Greece v.koutras@aegean.gr Vasileios Zeimpekis Department of Financial & Management Engineering, School of Engineering, University of the Aegean, 41 Kountouriotou Street, 82100, Chios, Greece <u>vzeimp@aegean.gr</u>

Abstract

Express logistics service providers have always been seeking ways for faster, sustainable, and cost-effective deliveries without compromising customer experience. To this end, this article investigates the Van-Drone Routing Problem in Cooperation (VDRPC) for parcel delivery which takes into consideration a fleet of vans each of which embraces a drone and executes a delivery route in collaboration. The clients of each delivery route are served either by the van or by the drone depending on the size of the order. Drones can serve clients with small-size orders whereas clients with large-size orders are served by vans. The VDRPC aims at coordinating the two different types of vehicles in an optimal way to serve all customers and is formulated as a Mixed Integer Linear Programming (MILP) problem. To solve the latter, a heuristic algorithm is developed aiming at minimizing the total time of parcel delivery under various constraints. Different scenarios are developed for each area (urban and semi-urban) and in each scenario, the optimal time to complete service is computed based on the number of available drones, the operating time with a fully charged battery of a drone, and the average speed of the vehicles. The results are encouraging showing that the proposed approach (van-drone collaboration) results to better solutions in terms of time to complete the delivery service when compared to the case where a fleet of vans is used to deliver clients' orders.

KEYWORDS

last-mile delivery, urban delivery, e-commerce logistics, routing optimization, van-drone in cooperation

1. INTRODUCTION

The distribution of goods is one of the most costly and complex processes in the supply chain. Lately, there has been a need to improve the delivery of goods in the last mile, reducing the total time of delivery and at the same time minimizing the operational cost. Therefore, an important challenge for distribution companies (e.g. couriers) is to organize as better as possible parcel delivery, avoid possible delays, and eliminate inefficiencies such as late deliveries, loss and damage of parcels, etc. Drones are an emerging technology that provides important opportunities in urban logistics and may fulfill the needs of parcel delivery. They have various advantages when compared to typical vans such as faster delivery, smaller operation cost, and being more environmentally friendly. However, drones still have some disadvantages such as the battery capacity and their payload. To tackle the previous inefficiencies, cooperation between drones and vans to serve customers can be examined. In the literature, this category of problems is known as parcel delivery problems using vans and drones. This article investigates the Van-Drone Routing Problem in Cooperation (VDRPC) for parcel delivery which takes into consideration a fleet of vans each of which embraces a drone and executes a delivery route in collaboration. The remainder of this paper is organized as follows. Section 2 briefly reviews the relevant literature. In Section 3 the proposed problem is presented followed by a heuristic algorithm to solve it. Finally, Section 4 provides the experimental results and key findings.

2. VAN – DRONE PROBLEMS, MATHEMATICAL MODEL & ALGORITHM

2.1 Literature Review in Van – Drone Problems

This section presents indicative research works for the van drone routing problem in tandem. Marinelli et al. (2018) studied the problem of optimum routing van and drone to serve clients. In this problem, drones can serve only one client every time. The goal is to reduce the service cost of clients. The authors considered that customer service is carried out using one van and one drone. The problem was modeled as Mixed Integer

Programming (MIP) and it was solved exactly with CPLEX 12. In Sacramento et al. (2019), the authors assume that the drone serves one customer at a time and then moves to the distribution center or to another customer where the van is already. The objective is to minimize the cost of all deliveries. The authors considered that drones have a limited flight time and took into account the preparation time of the drones before each landing. The problem was modeled as MIP and solved by an exhaustive method via a metaheuristic algorithm. A more complex study was carried out by Kitjacharoenchai et al. (2020) where the authors assumed that drones can serve more than one customer on the same route before returning to the distribution center or the van. Moreover, the authors considered the mean speed of two types of vehicles and the maximum flight time of a drone with a fully charged battery coupled with certain capacities for both vehicles. The objective of this problem was to minimize the total service time of all customers by using vans and drones in collaboration. The problem was modeled by a MIP and solved by a heuristic algorithm. In Mourelo Ferrandez et al. (2016), the authors studied the same problem assuming that the available drones of each van are more than one. The concept was to coordinate the operation of different types of vehicles for increasing customer service. The goal was to minimize the total time for parcel delivery and reduce the number of used batteries. The problem was solved through the development of a genetic algorithm. Our approach investigates the Van-Drone Routing Problem in Cooperation (VDRPC) for parcel delivery. The VDRPC aims at coordinating the two different types of vehicles in an optimal way to serve all customers. The problem is modeled as a Mixed Integer Linear Programming (MILP) problem and a heuristic algorithm to solve it is introduced. Different scenarios are developed for each area (urban and semi-urban) and the optimal time to complete service is computed based on the number of available drones, the operating time with a fully charged battery of a drone, and the average speed of the vehicles.

2.2 Mathematical Model & Algorithm

A fleet of homogenous vans is considered, each of them embracing a dedicated fleet (up to 2) of homogenous drones. Drones deliver parcels of small weight and volume to customers, while the remaining parcels are delivered by vans. The problem takes into consideration the maximum flight time of a drone with a fully charged battery, the maximum capacity that can be transported from drones and vans, and the required time for preparation of the drone before each launch (i.e. replacement of battery with new fully charged and parcel placing). Moreover, when planning the routes of vans and drones, we take into consideration different mean speeds of the van and drone as well as the required time of a) serving clients with the van, b) launching and the land of the drone in any one node, and c) serving clients with a drone.

2.2.1 Mathematical Model

In this section, we formally define the VDRPC. The objective function (1) minimizes the total time (cost) of serving all customers using vans and drones in cooperation. The total serving time depends only on the operating time of the vans. The problem is described by equation (1) to (37). In the following, we assume G =(N, A) to be the network, in which $N = \{0, 1, ..., t\}$ represents the arcs of the network. Let $C = \{1, 2, ..., c\}$ be the set of clients and let $\mathcal{C}' \subseteq \mathcal{C}$ be a subset of \mathcal{C} containing the clients that can be served by a drone. Let $N = \{0, 1, 2, ..., c + 1\}$ be the set of all nodes in the network. Nodes 0 and c + 1 represent the distribution center at the departure and arrival of the vehicles. Let, $N_d = \{0, 1, 2, ..., c\}$ be the set of nodes that a vehicle can depart from and $N_a = \{1, 2, ..., c + 1\}$ be the set of nodes that a vehicle can visit. Let T be the set of available vans. The variable t_{ij} defines the time duration (cost) of moving from node i to node j using a van, where $i \in N_d$ and $j \in N_d$. In case where there is only one client and it is served by a drone directly from the distribution center, the van's travel time is equal to zero, $t_{0,c+1} \equiv 0$. The variable t'_{ij} defines the travel time (cost) from node *i* to node *j* using a drone, where $i \in N_d$ and $j \in N_a$. Let τ_i^t the time when a van $t \in T$ approaches the node $j \in N_a$, $\tau_j^t \ge 0$. Let V be the set of available drones on each van. Let $\tau_j'^{v^t}$ be the time when a drone $v \in V$ of a van $t \in T$ approaches node $j \in N_a$, $\tau'_j^{v^t} \ge 0$. Let q_{ij}^t define the load of van $t \in T$ when it moves from node $i \in N_d$ to node $j \in N_a$. The variable q_{tvij} defines the load of the drone $v \in V$ of a van $t \in T$ when it moves from node $i \in N_d$ to node $j \in N_a$. The parameter s_L defines the required time for a drone to launch, while s_R defines the required time for a drone to land. Parameter e defines the flight time of a drone with a fully charged battery. Let P be the set that contains all possible tuples of the form <t, v, i, j, k > which defines all possible three node orderings composed by a drone $v \in V$ of a van $t \in T$. Specifically:

• Node $i \in N_d$ must not be the terminal node in the distribution center c + 1.

- The delivery point $j \in N_a \cap j \in C'$: $j \neq i$ must be a client that can be served by a drone and must not be the same as the launch point, i.e. $j \in C': j \neq i$.
- The landing point $k \in N_a$ can be either a client or a distribution center. However, the node $k \in N_a$ • must not be any of the nodes *i*, *j*.

The variable d_j defines the demand of the customer j, where $j \in C$. The parameter Cv defines the maximum capacity of each van. The parameter Cd defines the maximum capacity of each drone. The parameter prcddefines the required time (cost) of preparation of a drone before launching, while *std* defines the required time (cost) for serving the clients of the drone. Let x_{ij}^t the decision variable, with $x_{ij}^t = 1$ if the van $t \in T$ makes the move from node $i \in N_d$ to node $j \in N_a$: $i \neq j$, and $x_{ij}^t = 0$ otherwise. Let y_{tvijk}^t be also a decision variable, with $y_{tvijk}^t = 1$ if the drone $v \in V$ of the van $t \in T$ moves from node $i \in N_d$ to node $j \in C'$ and from there to the node $k \in N_a$: $\langle t, v, i, j, k \rangle \in P$ then $p_{ij}^t = 1$, and $p_{ij}^t = 0$ otherwise. Note that we set $p_{0j}^t \equiv p_{0j}^t = 0$ $1 \forall j \in C, \forall t \in T$ to imply that for all $j \in C$, vans depart from the distribution center. The decision variable, p_{ii}^t is used to ensure that the launching and landing nodes of the drones are in the path of the vans. Finally, let u_i^t be a sub-path elimination variable for van $t \in T$ and represent the order of the nodes. In other words, the value obtained by the variable u_i^t reveals the position of the client i along the way. Finally, let M be a big number. The objective function (1) minimizes the total time (cost) of serving all customers using vans and drones in cooperation. Equations (2) - (8), (25) - (27), (31) refer to van routing constraints regarding subroutes and route continuity when a van visits a node. Equations (9) - (13) refer to the feasible nodes where drones can be launched and landed. Equations (14), and (15) refer to the routes of the drones. Equations (16) -(19) refer to the capacity of vans and drones. Equations (20) -(24) and (28) -(30) refer to time constraints. Finally, equations (32) - (37) refer to binary variables and define the variables accessed.

| $\min Z = \sum_{t \in T} \tau_{c+1}^t$ $\sum_{t \in T} \sum_{t \in T} \tau_{c+1}^t$ | | (1) |
|--|---|------|
| $\sum_{i \in I} \sum_{l \in N_d} \sum_{i \in I} \sum_{j \in V} \sum_{i \in N_d} \sum_{i \in N_d} \sum_{k \in N_d} \sum_{i \in V} \sum_{j \in I} \sum_{i \in I} \sum_{j \in V} \sum_{i \in I} \sum_{j \in V} \sum_{i \in I} \sum_{j \in V} \sum_{i \in V} \sum_{i \in V} \sum_{i \in V} \sum_{j \in V} \sum_{i \in V} \sum_{j \in V} \sum_{i \in V} \sum_{j \in V} \sum_{i \in$ | $\forall j \in \mathcal{C}$ | (2) |
| $\sum_{t \in T} \sum_{j \in C} x_{0j}^{t} + \sum_{t \in T} \sum_{v \in V} \sum_{j \in C'} \sum_{k \in N_a} y_{tv0jk} \le \mathcal{L} $ | | (3) |
| $ \sum_{t \in T} \sum_{i \in C} x_{0i} - \sum_{t \in T} \sum_{j \in C} x_{j0} $ $ u_{t}^{t} - u_{t}^{t} + 1 \le (c+2) \cdot (1-x_{t}^{t}) $ | $\forall t \in T \ \forall i \in N \ \forall i \in N$ | (4) |
| $\sum_{i \in \mathcal{I}} \sum_{i \in \mathcal{N}} x_{ii}^{t} \leq 1$ | $i \neq i, \forall i \in N_a$ | (6) |
| $\sum_{t \in T} \sum_{i \in N_d} x_{ii}^t \leq 1$ | $i \neq j, \forall j \in N_a$ | (7) |
| $\sum_{i \in N_d} x_{ij}^t = \sum_{\substack{k \in N_d \\ k \neq i}}^{t} x_{jk}^t$ | $i \neq j, \forall j \in C, \forall t \in T$ | (8) |
| $\sum_{\substack{j \in C' \\ i \neq i}} \sum_{\substack{k \in N_a \\ j \neq i}} y_{tvijk} \le 1$ | $\forall i \in N_d, \forall t \in T, \forall v \in V$ | (9) |
| $\sum_{\substack{j \in C' \\ i \neq i}} \sum_{t \in T} \sum_{v \in V} \sum_{\substack{k \in N_a \\ \in P}} y_{tvijk} \le V \cdot T $ | $\forall i \in N_d$ | (10) |
| $\sum_{\substack{i \in N_d \\ i \neq k}} \sum_{\substack{j \in C' \\ i, k > \ell \\ p}} y_{tvijk} \le 1$ | $\forall k \in N_a, \forall t \in T, \forall v \in V$ | (11) |
| $\sum_{\substack{i \in N_d \\ i \neq k}} \sum_{t \in T} \sum_{v \in V} \sum_{j \in C'} y_{tvijk} \le V \cdot T $ | $\forall k \in N_a$ | (12 |
| $2 \cdot y_{tvijk} \leq \sum_{\substack{h \in N_d \\ h \neq i}} x_{hi}^t + \sum_{\substack{l \in N_d \\ l \neq k}} x_{lk}^t$ | $\forall i \in C, \ \forall j \in \{C': j \neq i\}, \forall t \in T, \\ \forall k \in \{N_{-}: < t, v, i, i, k > \in P\} \ \forall v \in V$ | (13 |
| $u_k^t - u_i^t \ge 1 - (c+2) \cdot (1 - \sum_{j \in C'} y_{tvijk})$ | $\forall t \in T, \forall i \in N, \forall j \in N$ | (14) |
| $\sum_{j \in C'} \sum_{k \in N_a} y_{t\nu 0 jk} \le \sum_{i \in N_a} x_{0i}^t$ | $\forall t \in T, \ \forall v \in V$ | (15) |
| $\sum_{\substack{i \in N_a \\ i \neq i}} q_{ji}^t \cdot x_{ji}^t - \left(\sum_{k \in N_a} q_{ik}^t \cdot x_{ik}^t \right) = d_i$ | $i \neq j, j \neq k, \forall i \in C, \forall t \in T$ | (16) |
| $\sum_{\substack{i \in N_d, \\ i \neq j}} \sum_{k \in N_d} q_{tvij} \cdot y_{tvijk} = d_j$ | $i \neq j, j \neq k, \forall j \in \mathbb{C}', \forall v \in V, \forall t \in T$ | (17) |
| $q_{ij}^t \in [0, C]$ | $i \neq j, \forall i, j \in N, \forall t \in T$ | (18 |
| $q_{vtijk} \in [0, Cd]$ | $i \neq j, \forall i, j, k \in N, \forall v \in V, \forall t \in T$ | (19) |
| $\tau_k^{\prime v^{t}} \leq \tau_k^t - M \cdot (1 - \sum_{\substack{i \in N_d \\ j \neq i}} \sum_{\substack{j \in C' \\ < t, v, i, j, k > \in P}} y_{tvijk})$ | $\forall k \in N_d, \forall t \in T \; \forall v \in V$ | (20) |
| $\tau_k^t \ge \tau_h^t + \tau_{hk} + prcd \cdot \left(\sum_{v \in V} \sum_{l \in C} \sum_{m \in N_a} y_{tvklm}\right) - M \cdot (1 - x_{hk}^t)$ | $\forall t \in T, \forall h \in N_d, \forall k \in \{N_a : k \neq h\}$ | (21 |
| $\tau_j^{v_pt} \ge \tau_i^{v_pt} + \tau_{ij}' + s_L + s_R + std - M \cdot (1 - \sum_{\substack{k \in N_a \\ (s \neq v_l) \ i \ k > s \neq P}} y_{tvijk})$ | $\forall t \in T, \forall v \in V, \forall j \in C' \forall i \in \{N_d : i \neq i\}$ | (22 |
| $\tau'_{k}^{vt} \geq \tau'_{j}^{vt} + \tau'_{jk} + s_{L} + s_{R} - M \cdot \left(1 - \sum_{\substack{(i \in N_{d}, v_{L}) \in \mathcal{V}_{d}}} y_{tvijk}\right)$ | $\forall t \in T, \forall v \in V, \forall j \in C', \forall k \in \{N : k \neq i\}$ | (23 |
| | $\forall t \in T, \forall v \in V, \forall k \in N_+, \forall j \in I$ | |
| $\tau'_{k}^{v^{t}} - \left(\tau'_{j}^{v^{t}} - \tau'_{ij} - s_{R} - s_{L}\right) \le e + M \cdot (1 - y_{tvijk})$ | $\{C': j \neq k\}, \forall i \in \{N_d: < t, v, i, j, k > \in P\}$ | (24) |
| $u_i^t - u_j^t \ge 1 - (c+2) \cdot p_{ij}^t$ | $\forall t \in T, \forall i \in N, \forall j \in N$ | (25) |
| $u_i^t - u_j^t \le -1 + (c+2) \cdot (1 - p_{ij}^t)$ | $\forall t \in T, \forall i \in N, \forall j \in N$ | (26) |
| $p_{ij}^t + p_{ji}^t = 1$ | $\forall t \in T, \forall i \in N, \forall j \in N$ | (27) |
| | | |
| $\tau'_{l}^{v^{t}} \geq \tau'_{k}^{v^{t}} - M \cdot \left(\begin{array}{c} 3 - \sum_{\substack{j \in \mathcal{C} \\ \in \mathcal{P} \\ j \neq l}} y_{tvijk} - \sum_{\substack{m \in \mathcal{C} \\ m \neq i \\ m \neq k}} \sum_{\substack{n \in \mathcal{N}_{d} \\ v, t, l, m, n > \in \mathcal{P} \\ m \neq i \\ n \neq i \\ \end{array}} y_{tvimn} - p_{il}^{t} \right)$ | $ \begin{aligned} \forall i \in N_d, \ k \in \{N_a : k \neq i\}, \ l \in \{C : l \neq i, l \neq k\} \end{aligned} $ | (28) |
| $\tau_0^t \ge 0 \qquad \qquad$ | $\forall t \in T$ | (29 |
| | | |

| ${\tau'_0}^t \ge 0$ | $\forall t \in T, \forall v \in V$ | (30) |
|-----------------------------|--|------|
| $p_{0j}^{t} = 1$ | $\forall t \in T$ | (31) |
| $x_{ij}^t \in \{0,1\}$ | $\forall i \in N, \forall j \in N, \forall t \in T$ | (32) |
| r = (0, 1) | $\forall i \in N, \forall j \in N, \forall k \in N,$ | (22) |
| $y_{tvijk} \in \{0,1\}$ | $\forall t \in T, v \in V$ | (55) |
| $1 \le u_i^t \le (c+1) + 1$ | $\forall t \in T, \forall i \in N$ | (34) |
| $	au_i^t \ge 0$ | $\forall i \in C, \forall t \in T$ | (35) |
| $\tau'_{i}^{vt} \geq 0$ | $\forall i \in C, \forall v \in V, \forall t \in T$ | (36) |
| $p_{ij}^t \in \{0,1\}$ | $\forall t \in T, \forall i \in N, \forall j \in N$ | (37) |

2.2.2 Solution algorithm for VDRPC

To solve the presented VDRPC problem a heuristic approach is developed. The algorithm begins by implementing the Clarke & Wright (C&W) algorithm for all clients. After that, the routes which results are examined one by one. The point of this step is adapting of drones in each route. This is done in three phases. In the first phase, customers are divided into two sets. One set concerns the customers who will be served by the van and the other set includes the customers who will be served by the drones. In this phase, the route of the van is created also. In the second phase, the drones' routes are created by considering the routes of vans. More specifically, in this phase the points where drones will be launched and landed regarding the van's route, are determined. Finally, in the third phase, the time of the vans and drones that arrive or depart from each node is defined.

<u>Phase one</u>

Step 0. Data entry.

Step 1. Solve the Vehicle Fleet Routing Problem (VRP) for every client to serve.

Step 2. Study each route from the VRP separately.

Step 3. Calculate the lowest possible LVL price.

Step 4. Splitting the clients into two sets. Van's clients and drone's clients, based on drone capacity.

Step 5. If the LVL value is satisfied, the process goes to Step 7, otherwise to Step 6.

Step 6. Move the client from the drone's set to van's set and return to Step 5.

Step 7. Move clients between van's set & drone's set if van's travel time (cost) is reduced.

Step 8. Variation of the van's route if time (cost) is reduced.

Step 9. If the generated van's route has been previously considered the process goes to Step 10, otherwise the LVL value is incremented by 1 and the process goes to Step 26.

Step 10. Calculate the time (cost) of the first phase. It contains the required time (cost) to complete the van's route.

Step 11. If the time (cost) in Step 10 is less than the best time (cost) so far the process goes to Step 12, otherwise the value of LVL is increased by 1 and the process goes to Step 26. <u>Phase two</u>

Step 12. Create all possible triplets (launching client - drone service client - landing client) for each client in the drone set.

Step 13. If all drone clients have feasible launching-landing points the process goes to Step 17, otherwise to 14.

Step 14. Investigate the best client movement from the drone to the van.

Step 15. If the generated van's route has been previously considered, the LVL value is incremented by 1 and the process goes to Step 26, otherwise the process goes to Step 16.

Step 16. Enter the client with the smallest change in time (cost) on the van's route. The process returns to Step 12.

Step 17. Calculation of the time (cost) of the second phase. This time (cost) consists of the time (cost) of the first phase plus the time (cost) of introducing a customer to the van's route. (That is if Step 16 was implemented).

Step 18. If the new time (cost) is less than or equal to the previous best the process goes to Step 19, otherwise the LVL value is increased by 1 and the process goes to Step 26.

Phase three

Step 19. Scheduling the operation of the vans and calculating the total service time (cost).

Step 20. Attempt to improve overall service time (cost) by moving a client from van to drone.

Step 21. If a change has been made the process goes to Step 12, otherwise to Step 22.

Step 22. Attempt to improve overall service time (cost) by eliminating "dead" van waiting times for drone return.

Step 23. If Step 22 is achievable the process goes to Step 19, otherwise to Step 24.

Step 24. Save the solution.

Step 25. If there is any remaining path to consider the process goes to Step 3, otherwise the algorithm terminates.

Step 26. If all possible values of LVL have been considered the process goes to Step 25, otherwise to Step 4. **Step 27.** Calculation of total and minimum service time (cost).

3. RESULTS

The data that has been used for the experiments can be found in Athanasiadis et al. (2023). Table 2 presents indicative results obtained from solving the VDRPC using the proposed algorithm in the case of Semi-Rural Solitary (SRS). The corresponding costs for the problem where parcel deliveries are made only with the vans are 108.5 min (minimum service time) and 331.9 min (Total Service Time). Figure 1 presents the total results (7 scenarios) obtained in an aggregated manner. For each scenario the following abbreviations are used: SR/U/SRS refers to the servicing area (SR: Semi-Rural, U: Urban, SRS: Semi-Rural Solitary). The number 100, 60, 40, and 20 refers to the number of clients to be serviced. As it can be seen, the best routing result is obtained when the vans move with a high average speed and there are 2 drones assigned to each van. Additionally, independently of the scenario, the cost of clients' service is significantly reduced when two drones are used. As expected, when the service is carried out in an urban area, the completion time is significantly lower than in the case of a semi-urban area.

| Results of VDRPC | | | | | | |
|-----------------------------------|------------------------------------|----------|------------------|--------|--------------|--|
| Routes of van | | | Routes of drones | | | |
| Van ID | Client sequence | Drone ID | Launching node | Client | Landing node | |
| | | 1 | 0 | 10 | 9 | |
| | | 2 | 0 | 11 | 9 | |
| 1 | 0-9-8-6-7-0 | 1 | 6 | 4 | 7 | |
| | | 1 | 7 | 19 | 0 | |
| | | 2 | 7 | 5 | 0 | |
| | | 1 | 0 | 13 | 18 | |
| | | 2 | 0 | 2 | 18 | |
| 2 | 0 10 14 12 0 | 1 | 18 | 17 | 14 | |
| 2 | 0-18-14-12-0 | 2 | 18 | 20 | 14 | |
| | | 1 | 12 | 3 | 0 | |
| | | 2 | 12 | 15 | 0 | |
| 3 | 0-16-0 | 1 | 0 | 1 | 16 | |
| Minimum servi | Minimum service time 81.09 minutes | | | | | |
| Total service time 176.92 minutes | | | | | | |



Figure 1: Experimental results

To conclude, this paper studied the van-drone routing problem with multiple delivery points, in which vans and drones are used for parcel delivery. A drone may travel with a van, take off at a stop to serve customers, and land on the van at another client's site or at the depot as long as the flying range and loading capacity limitations are satisfied. The best routing result is obtained when the vans move with a high average speed and there are 2 drones assigned to each van. A future research agenda may include the investigation of the location-allocation problem of charging points in order to tackle the main limitation of drones which is battery

capacity. Furthermore, the implementation of the proposed algorithm in real-life cases could also be beneficial not only from a research point of view but also in terms of practical validation of the results obtained in the theoretical model.

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Towards the application of MCDM approaches in Corporate Risk Disclosure

lakovina Kanellopoulou Department of Business Administration, School of Administrative, Economics and Social Sciences, University of West Attica 250 Thivon & P.Ralli Str., 12241 Athens, Greece Nikos Tsotsolas Department of Business Administration, School of Administrative, Economics and Social Sciences, University of West Attica 250 Thivon & P.Ralli Str., 12241 Athens, Greece

Abstract

Efficient corporate risk disclosure can be paramount for a company's access to capital markets and thus, strategic decision-making procedures that integrate reliable quantitative and qualitative data are essential to its capacity to adjust to fickle reporting standards, to take into consideration business volatility and to amalgamate subjectivity and multiple corporate and management objectives. Multi-criteria Decision Analysis can provide sophisticated techniques which empower the decision-makers to interpret real-life corporate complexities and to demonstrate equifinality in meticulous corporate risk disclosure. More particularly, the underlined advantages of the Fuzzy Set Qualitative Comparative Analysis (fsQCA) and the Stochastic UTA method can be capitalized on generating pragmatic alternative paths based on aggregation – disaggregation mechanisms, interfusing behavioral patterns, preferences, information asymmetry and non-linear relationships, hence accrediting the scientific calibration of empirical evidence. The quantification of the linguistic dimension of the available data in one hand and the challenge towards the decision maker to better understand his/her value-system on the other, are two entirely different approaches that can bring forward a better understanding of corporate behavior in respect of risk reporting. The objective of this paper is to discuss on how the different MCDA approaches could efficiently serve the specific needs towards a corporate risk disclosure modeling, focusing on issues such as performance, robustness and easiness to apply it.

KEYWORDS

Corporate Risk Disclosure, Multi-criteria Decision Analysis (MCDA), Fuzzy Set Qualitative Comparative Analysis, Stochastic UTA, Robustness Analysis

1. INTRODUCTION

The decision processes involved in corporate risk reporting may emulate the complexity of a Mozart's symphony, if we consider that the final information disclosed is an amalgamation of expertise, corporate awareness, previous experience, subjectivity, reporting trends, business and regulatory public interests, not to mention the prevailing fluidity regarding future risks and opportunities that seem to affect the corporate world on a global scale.

Ineffectiveness, negligence and oversight have triggered a strong eagerness for transparency through corporate risk disclosure (Caruana, 2011), whereas extended access to corporate information and advanced credibility on business data disclosed apparently boost corporate accountability and moderate information asymmetry remarkably, thus enhancing market effectiveness and capital funding (Miihkinen, 2013). The increasing demand for enhanced risk management and for high-quality divulgence of corporate risk strategies has led a plethora of scholars to attempt to outline the key factors that affect a company's disclosure behavior, in order to identify specific characteristics, which in turn dictate certain action plans and insightful resolutions.

However, the traditional methods employed to discover regression coefficients have provided controversial results, leaving academics with a sense of confusion and further bemusement as to which factors are more influential than others and how the dynamics within the decision-maker's value system change.

2. BACKGROUND

Indeed, transparency is an imperative for economy and sustainable business relations and although its significance has been examined through the prism of corporate risk disclosure as early as the '80s (AICPA,

1987), after several notorious corporate scandals and quite a few market crashes the lack of credible and comprehensive quantifiable risk-related data, along with the shortfall of coherent and articulated reporting structure have been most apparent. Regulatory authorities, distinguished professional bodies and institutional agencies have developed several initiatives regarding risk reporting and disclosure, which led to a handful of mandatory frameworks, as well as to diverse guidelines on reporting material risks, providing an abundant of tools for companies to communicate their risks and prospects of their businesses. However, professional bodies, Institutional Boards, Fund Managers and highly-respected consulting corporations have brought forward the perplexity of the situation and the bewilderment of the business world to cope with so many and innovative disclosure requirements and at the same time to attract the right kind of attention, constantly adapting its strategy towards the tirelessly emerging trends in investing, consuming and evolving life styles (FT, 2021; United Nations, 2017; IRRC Institute, 2016; CDP, IGCC, PRI, 2021; S&P Global, 2021).

Which brings us back to the matter of disclosure configuration and its central components that assist the decision-makers (i.e. Management and Bord of Directors) to efficiently and diligently communicate their strategy and performance regarding corporate risks. Literature (Abraham & Cox, 2007; Ntim, et al., 2013; Oliveira, et al., 2006; Elshandidy, et al., 2013; Dobler, et al., 2011; Semper & Beltrán, 2014) has brought into the spotlight quite a few governance characteristics such as Board size and independence, CEO duality and ownership structure, as well as some company-related attributes, such as Book-to-Market Ratio, profitability, leverage and the industry, in which a company operates. Nevertheless, there is ample skepticism among scholars regarding the gravity of each determinant in a blueprint that prescribes an optimum corporate risk disclosure strategy. In addition, traditional regression analyses have often yielded contradictory results, such as that of Rodríguez Domínguez and Noguera Gámez (2014), who have studied Madrid's listed companies and have found a negative relationship between corporate size and risk disclosure, whereas Linsley and Shrives (2006) studied the UK listed firms and have confirmed a positive correlation.

Additionally, Rodríguez Domínguez and Noguera Gámez (2014) have found no significant association between company-related characteristics, such as profitability, leverage and industry, and the quality of riskdata disclosed, whereas Ntim et al.'s (2013) concrete findings suggest otherwise. Furthermore, Board size is an aspect that seems to ruffle some feathers, because although Pearce and Zhara (1992) manifest that it positively influences the disclosure of information about compulsory risks, Andres et al. (2005) pinpoint that the higher the Board size the more dainty a decision to publicize risk-related data becomes and therefore, the more timid the Board will be to disclose, hindering the reporting performance and the uncovering of the overall corporate risk profile. In addition, the industry, in which a company operates, leaves a decisive imprint on disclosure behaviors (Madrigal, et al., 2015; Richardson & Welker, 2001), especially when it comes to highly regulated or of great public interest industries, such as oil and gas or financial institutions, despite the not so slim evidence (Beretta & Bozzolan, 2004; Abraham & Cox, 2007; Netti, 2018) against it.

Now we know from to Soyer and Hogarth (2012) that regression analysis restraints the decision-maker's ability to generate solid probabilistic forecasts, overcasting the uncertainty inherent in the dependent variable and thus, falling into the trap called "the illusion of predictability". We also know, as Braumoeller (2004) ascertains, that regression analysis upholds a constrictive capacity to acknowledge interaction terms, while Fiss (2007) specifies its inability to showcase equifinality, due to the inference of global linearity. Manipulation and misuse of statistical outcomes and their questioning significance tests (Schwab & Starbuck, 2009), often attributable to complex causation, lead in many cases to idiosyncratic explanations, sacrificing the generalizability of results beyond the sample population (Wagemann & Schneider, 2010). And although literature (Douglas, et al., 2020) recommends multicriteria decision-aid methodologies as a complementary tool to regression analysis, still the disregarding of uncertainty, of subjectivity and of information asymmetry, which is evident in traditional statistical methods, ignores entirely the reality of multiple causation and the fact that alternative optimal or as closest to optimal as possible solutions could have the desired effect, which in our case is effective corporate risk disclosure.

Keeney regards (1992) that inexplicit decision problems are those that leave the doors open to troubling predicaments, regarding how to proceed with further actions or to circumvent imminent setbacks and as Dewey proclaims (1938) "[...] a problem well put is half solved", thence the benefits accrued from a multicriteria approach seem to be a lot more straightforward, given the constantly rising fluidity of business environments and global socio-economic conditions that affect the decision-maker. Driven by the necessity for extended transparency, markets shift towards more realistic simulations of the business setting and thus demand solutions that assimilate non-linear relationships and allow robust aggregation-disaggregation

functionalities, empowering the decision-maker to generate, rank and eventually single out favorable alternative courses of action and therefore, to adopt a more flexible risk disclosure strategy.

3. METHODOLOGY

There is a plethora of MCDA methodologies that can be applied in an effort to best outline the problem of agile and efficient corporate risk disclosure, however this paper discusses the implementation of only two techniques, singled out due to their distinctive rational and their powerful platform to provide concrete and substantial alternative solutions, incorporating vague abstractions, such as uncertainty, subjectivity and information asymmetry.

One of those methodologies is the Fuzzy Set Qualitative Comparative Analysis (FsQC), which is a combination of the Qualitative Comparative Analysis (QCA) technique and the fuzzy set theory. The QCA method relies on common sense and maintains an empirical focus, which is a known characteristic of qualitative methods, to survey asymmetric data, enabling the researcher to review large-scale information and to locate straightforward and distinctive set-ups of conditions that elicit a specific outcome. As per Berg-Schlosser et al. (2009), by applying Boolean algebra and the respective minimization algorithms, we obtain regular and intelligible patterns of multiple-conjunctural causation and of "nonlinear, nonadditive, non-probabilistic conception", unriddling inscrutable data-sets in a perceptive and all-embracing process (Ragin, 1987). However, the Boolean algebra insinuates the binary nature of the QCA method, which can be handled through the "fuzzy-logic", introduced by Lotfi A. Zadeh (1965), due to its applicability on challenging situations with equivocal, subjective and obscure perceptions, as well as its ability to quantify the linguistic facet of the available data (Shan, et al., 2015). Fuzzy logic features a mathematical framework to portrait a problem with flexible or hazy criteria and tolerates a varying degree of membership, using the whole range of the interval between 0 (false) and 1 (true) to narrate the decision-makers supposition, where as in classical set theory, boundaries and statements can be either true or false. In essence, the FsQC technique combines distinguishing traits of both quantitative and qualitative methodologies in a more robust and holistic approach and thereby bridges the absence of qualitative estimates in a quantitative value-focused analysis.

On the other hand, the Stochastic UTA method, developed by Jacquet-Lagreze and Siskos (1982), is in accordance with the additive utility function, but also evolved to harbor the stochastic attributes of settings such as the corporate world, where human judgment is involved. The main principal of the original additive utility method is to assemble multiple criteria into a unique collective criterion, named a utility function, and thereupon evaluate through linear-programming the consistency of the rankings acquired, in comparison to the ones given. For this process, the decision-maker's value system is an important component and can be outlined on the basis of a set of reference actions, such as past decisions or even supposed actions envisioned to take place. Stochastic UTA however uses probability distributions instead of crisp criteria values, thus underlying the decision-maker's perplexing subjectivity and therefore illustrating realistically how his/her mind operates.

Inevitably, the continuing conundrum of how someone reaches a decision and how preferences, limited knowledge and external variables affect his/her perception, elicits robustness issues "*in the sense that small deviations from the model assumptions should impair the performance only slightly*" (Huber, 1973). The robustness of models derived from applied MCDA methodologies and their results is as pivotal as the modelling itself in order to secure a pragmatic and successful implementation. Doumpos et al. (2014) may exemplify simple linear models as more robust than non-linear models, due to the small number of parameters involved in the procedure, which denotes poor sensitivity to available data. Nevertheless, several scholars (Tsotsolas & Alexopoulos, 2019; Siskos & Tsotsolas, 2016) have navigated their research right through the complexity of modern decision-modelling by suggesting specific frameworks and indices to efficiently address any anticipated robustness issue.

Regarding the FsQC method, literature indicates a number of robustness concerns that need to be handled, such as the fact that there could be causal conditions unrelated to the focal outcome or that results can be extremely complex to interpret or extremely sensitive to configuration changes. Hence, further data calibration is necessary by choosing thresholds that reflect full and non-membership, as well as the point that marks maximum ambiguity, which is typically set at the median value. Thenceforth, all raw data scores are transformed into fuzzy-set membership outcomes, utilizing the abovementioned thresholds as pillars to

describe the various degrees of membership (Greckhamer et al., 2018). Next, the researcher must perform a coverage test (Ragin, 2008) to determine the extent to which most sample's cases accommodate a distinct configuration and eventually use the "Proportional Reduction in Inconsistency" (PRI) as an additional core indicator to measure the consistency of subset relations (Greckhamer T., 2016) and consequently to assess the similarity among different combinations of conditions that continue to generate accordantly the focal outcome, matching the functionality of significance tests in regression analysis. A necessity analysis is also highly suggested (Ragin, 2008) in order to specify the individual conditions that are essential for the end result to transpire. If some are ranked as unnecessary, then they apply apparently along with other conditions concurrently to derive the focal outcome. Finally, a "truth table" should be compiled with the aid of a software program to demonstrate which format is sufficient enough for the focal outcome (Douglas et al., 2020).

In respect of the Stochastic UTA method, robustness indicators are assessed through the prism of postoptimality analysis, including the Average Stability Index (ASI), which calculates the mean value of the normalized standard deviation of the estimated values and the range of all ascertained utilities, which is a measure graphically represented. Optimal or near-optimal solutions of the LP post-optimal polyhedron can also be generated through the employment either of various heuristics approaches (MAX, MAXMIN) or of analytical ones, such as the Manas-Nedoma Hamiltonian search algorithm, however the judgment of how satisfactory a solution may be can only be affirmed by the analyst and if found inadequate, further information and re-assessment is required (Christodoulakis et al., 2013).

4. CONCLUSIONS

While traditional methods, either quantitative or qualitative, have provided several guidelines, regarding the most influential factors that affect corporate risk disclosure patterns of behavior, nevertheless the continuous inconsistent and ambiguous results make the employment of multicriteria decision-aid methodologies more pressing than ever before. Transparency and realism are essential to the markets' efficiency and thus, pragmatic and highly sophisticated approaches that assess the constantly evolving business setting are considered now fundamental.

Traditional statistics seem to lack the ability to integrate uncertainty, personal judgment, information asymmetry and limited understanding, while multicriteria decision-aid methodologies appear flexible and encompassing enough to decode such concepts into large data-sets. FsQC and Stochastic UTA are two entirely different techniques that can offer a deeper apprehension of corporate behavior, by modelling the problem through an entirely different perspective, either endowing with alternative configurations of causality or by assisting the decision-maker to test his value-system against the consistency of his/her decisions. In respect to Corporate Risk Disclosure, FsQC and Stochastic UTA can forge meticulous behavioral patterns and interrelations, thus providing enhanced and scrupulous modelling, incorporating group decision frameworks, where subjective and objective sources of knowledge are intertwined.

Evidently, the constantly changing risk-disclosure trends and requirements presuppose more flexibility on conditions and interaction effects among characteristics, depending upon innovative scientific calibration with robust solutions and alternative satisfactory configurations. On top of that, dealing with outliers, asymmetric data, asymmetric relationships and the different degrees of interdependency or even sufficiency among conditions, expose details about individuals and sub-groups within the population mostly uncharted. Hence, it is safe to say that innovative MCDM approaches can and should satisfy the ambition of the business world for advanced and more realistic modeling, subsequently offering unparalleled transparency on the process of adopting a risk-disclosure strategy.

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Sustainable Development without exclusion: Agenda 2030 for Sustainable Development with an emphasis on Social Protection of the rural population in Greece

Eleni A. Karanasiou¹ ekaranasiou1@gmail.com Elena Venizelou Hospital, Attica, Greece.

> Aspasia Goula⁴ agoula@uniwa.gr University of West Attica, Greece.

Anastasios Sepetis² <u>tsepet@uniwa.gr</u> University of West Attica, Greece.

Georgios Pierrakos⁵ <u>gpierrakos@uniwa.qr</u> University of West Attica, Greece. Vasileios G. Kormazos³ billkormaz@gmail.com Olive grower, Rahes Fthiotidas, Greece.

Konstantinos Dalakouras⁶ <u>kdalakouras@uniwa.gr</u> University of West Attica, Greece.

Abstract

The present research, through the questionnaire developed to collect the information that contributes to the formation of the conclusion, is carried out with the aim of investigating the yield of crops and by extension the living conditions of the rural population, their connection with environmental changes and the objectives of the 2030 Agenda, as the rural population is a group adversely affected by climate change and environmental disasters, which often lead to migration with an impact on poverty and social exclusion. The effort to explore these questions, in this particular research, aims to contribute in a creative way to highlighting the problem and the imperative need to implement and realize the goals of sustainable development for the social protection of the vulnerable group of farmers in Greece. A total of 114 farmers participated in the survey, 67 (59.29%) men and 46 (40.71%) women where 68 (59.65%) are engaged in monocultures while 46 (40.12%) are polycultures. According to the results, climate change affects: 49.12% increase in disease incidence, 64.91% yield, 43.75% planting, 37.72% planting soil, 41.23% product quality, 77.79% loss agricultural income.

KEYWORDS

Sustainable Development Goals (SDGs), Sustainable Local Development, Social Protection in Greece, Social Exclusion, Poverty, Migration, Climate change.

1. INTRODUCTION

The 2030 Agenda includes 17 Sustainable Development Goals aimed at ensuring human dignity and diversity, better healthcare services, quality education, eliminating inequalities, economic growth, and environmental protection. The concept of sustainable development, in its complexity, presents a multi-faceted and multi-leveled form, which in almost all the literature, as searching for the needs of this research, strongly includes the dimension of the environment and its relationship with the issues of society, economy, and development, such as poverty, health, education, human rights, and environmental protection. The strategy of sustainable development enables internationally and in particular the European Union to ensure the development of all member states. In the event that sustainable development is threatened by the developments of recent years, such as the economic crisis, conflicts, climate change, natural disasters, migration and the pandemic, then social protection, as it is to be shaped in the welfare state, is disrupted it also carries with it even the basic principles of sustainable society. The permanent question is whether this development can be shaped and implemented in the same way in all member states and more specifically in Greece, due to the many peculiarities, social and economic, that create difficulties in the implementation and sustainability of the project increasing employment and strengthening social cohesion.

The rural population is a group adversely affected by climate change and environmental disasters, which often lead to migration. The term environmental migration is used to describe population movements due to gradual environmental degradation that adversely affects lives or living conditions. Migration can be internal (within country boundaries) or cross-border (Bates, 2002).Climate change is undoubtedly of anthropogenic origin due to the continuous increase in greenhouse gas emissions and their accumulation in the Earth's atmosphere. It is expressed through the continued increase in the average temperature of the earth with the consequent rise of the sea level, the more frequent occurrence of floods, typhoons, prolonged periods of drought, fires and extreme weather events. It is pointed out that the fires with their passage both in our

country and worldwide, destroy huge areas of forest and arable land, increasing the temperature of the planet. In addition, human interventions, for example the expropriation of the environment in the context of development projects such as the construction of dams, national parks, airports, etc., deprive land of agricultural activity and the production of agricultural products.

Agriculture is one of the main sources of income and employment in rural areas and is by far the sector most affected by climate fluctuations since in the long term but also in the short term in extreme weather events, climate change has significant effects on agricultural productivity, with the reduction of production and quality of products, the degradation of the countryside and food security and indirectly, migration flows.

2. LITERATURE REVIEW

In recent literature on internal migration due to climate change presents studies that consider as causes of internal migration climate factors such as rainfall and extended droughts that negatively affect the vulnerable rural population. Comparing the two culprits, they emphasize drought as the main negative factor. This internal movement seems to drive the migratory mass towards urban areas, increasing urbanization rates and worsening socio-economic living conditions (Marchiori et al 2012). However, some studies argue that natural disasters may lead to international mobility (Gray C. and Mueller V. 2012a ' Cattaneo C. & Peri G. 2016). A 2016 study analyzes migration patterns due to climate change from rural to urban areas in 6 South American states and the main findings show that continued warming (drought) enhances the migration decision compared to rainfall and gradual climate change (Thiede et al., 2016).

Another study reported that climate change with the occurrence of typhoons and rising temperatures that negatively affected rice crop yield promoted mass internal migration (Bohra - Mishraetal 2017). In addition, according to research data, climate change has affected the sowing time of cereals, flowering and its stages as well as the quality of the products (Olesen et al 2012 'Chitu and Paltineanu 2020 ' Mohammed T. et al 2022).Crop pathogens and pests worldwide reduce the yield and quality of agricultural products often with emerging or re-emerging pests and diseases (Gullino et al 2022 ' Savary et al 2019 ' Eastburn et al 2011' Hertel ' Eastburn et al. ,' Mc Dowell and Hess, 2012, 'Thornton et al 2008), (olive4climate.eu). Climatic conditions and environmental degradation have adverse effects on the agricultural sector worldwide on crops and especially countries that have agriculture as their source of income (Gray 2009 ' Gray, C. & Bilsborrow R. 2013 ' Dillon et al 2011 ' Cattaneo C . & Massetti E. 2015 ' Beine M. & Parsons C. 2015 ' Gray C. L. & Mueller V. 2012 b' Alem Y. et al 2016 ' Bohra-Mishraetal 2014 ' Bazzi. 2017).

2.1 The field research

This research is carried out with the aim of investigating the yield of crops and the living conditions of the rural population, their connection with environmental changes and the goals of sustainable development. In addition, the effort to collect this information aims to contribute in a creative way to highlighting the problem and to imperative interventions for the social protection of the group of farmers in Greece. Below are the details of the research:

- Participants and Methods: A total of 114 farmers participated in the survey, 68 (59.29%) men and 46 (40.71%) women from different regions of Greece as the approach was carried out through social media where the link to the questionnaire was posted in groups of farmers. The questionnaire of Abdullah Al Mamun et al (2021) was used and specifically the 4th section partially modified by the researcher. Analysis was performed with SPSS v26.0 software and the significance level were set at 0.05 in all cases.
- Inclusion criteria: Farmers from various regions of Greece engaged in monoculture or polyculture.
- Exclusion criteria: People who are not exclusively engaged in agriculture.
- Statistical analysis: The data was collected through the Google forms application where it is possible to export the data to a spreadsheet. The statistical analysis selected for the present study was performed with SPSS v26.0 software and the level of significance was set equal to 0.05 in all cases. X2 independence tests were performed on all examined questions.

2.1.1 Descriptive statistic and Questionnaire results on perceived impacts of climate change on crops/rural population

The following Tables 1 and 2 presents information on farmers demographics, crop type and record the questionnaire questions with their percentage of responses on perceived impacts of climate change on crops.

| | | N | % |
|-----------------|----------|----|--------|
| Ser | Male | 67 | 59,29% |
| Sex | Female | 46 | 40,71% |
| | 25-35 | 22 | 19,47% |
| | 36-45 | 30 | 26,55% |
| Age group | 46-55 | 31 | 27,43% |
| | 56-65 | 22 | 19,47% |
| | Above 66 | 8 | 7,08% |
| | Basic | 65 | 58,04% |
| Education level | Degree | 36 | 32,14% |
| | Master | 11 | 9,82% |

 Table 1: Descriptive data of interviewed farmers.

Table 2: Counts and percentages of responses to questions about perceived impacts of climate change on crops or rural population. A. Perceive rs of climate change in crop production.

| | | N | % |
|---|-------------|----|--------|
| Type of crop | Monoculture | 68 | 59,65% |
| | Polyculture | 46 | 40,35% |
| | Not at all | 2 | 1,75% |
| 1. How adverse are the effects of climate | Little | 13 | 11,40% |
| change on your crops? | Moderate | 31 | 27,19% |
| | Very | 68 | 59,65% |
| 2 How strongly do you think that slimate | Not at all | 4 | 3,51% |
| 2. How strongly do you think that climate | Little | 19 | 16,67% |
| dispases? | Moderate | 35 | 30,70% |
| | Very | 56 | 49,12% |
| | Not at all | 3 | 2,63% |
| 3. How climate change affects your crop | Little | 15 | 13,16% |
| yield reduction? | Moderate | 22 | 19,30% |
| | Very | 74 | 64,91% |
| 4. How strongly in recent years due to | Not at all | 16 | 14,29% |
| climate change the planting took place in | Little | 22 | 19,64% |
| the second year (compared to the normal | Moderate | 49 | 43,75% |
| planting time)? | Very | 25 | 22,32% |
| | Not at all | 22 | 19,30% |
| 5. How strongly do you think that the soil | Little | 26 | 22,81% |
| of arable land has become unsuitable for planting due to climate change? | Moderate | 43 | 37,72% |
| Free | Very | 23 | 20,18% |
| C How strongly slimate shance has | Not at all | 10 | 8,77% |
| offected the production of quality | Little | 18 | 15,79% |
| agricultural products? | Moderate | 39 | 34,21% |
| | Very | 47 | 41,23% |
| 7 How strongly ovtromo climate overte | Not at all | 2 | 1,75% |
| have resulted in the loss of agricultural income? | Little | 6 | 5,26% |
| | Moderate | 18 | 15,79% |
| | Very | 88 | 77,19% |

The independence of the question ''How strongly does the lack of water affect the production in your crops due to climate change' is checked depending on the type of crop. According to the test X^2 it is not rejected and therefore the answers of the farmers should not be differentiated by their type of crop $X^2_3=0.801$; p=0.849. In a similar way, the independence of the question ''How strongly did climate change affect the production of quality agricultural products'' is examined depending on the type of crop. According to the X^2 test it is again not rejected and therefore the responses of the farmers do not differ with their type of crop $X^2_3=2.762$; p=0.430. Finally, there follows an examination of the independence of the question ''How intense

the extreme climatic phenomena resulted in the loss of agricultural income' depending on the type of crop. According to the test X^2 it is not rejected and therefore the answers of the farmers should not be differentiated by their type of crop X^2_3 =4.382; p=0.223. The estimates are presented in detail in table 3 while they are rendered graphically by graphs 1, 2 and 3 below.

Table 3: Examination of the independence of the questions "How much has water scarcity affected your crop production due to climate change", "How strongly has climate change affected the production of quality agricultural products" and "How much have extreme climates phenomena resulted in the loss of agricultural income, depending on the type of crop".

| | | Type of crop | | | | |
|-------------------------|------------|--------------|-------------|----|--------|---------|
| | | Mono | Monoculture | | ulture | р |
| | | Ν | % | Ν | % | |
| How strongly has water | Not at all | 9 | 52,9% | 8 | 47,1% | |
| scarcity affected your | Little | 7 | 58,3% | 5 | 41,7% | 0 849 |
| crop production due to | Moderate | 17 | 56,7% | 13 | 43,3% | 0,045 |
| climate change? | Very | 35 | 63,6% | 20 | 36,4% | |
| How strongly climate | Not at all | 7 | 70,0% | 3 | 30,0% | |
| change has affected the | Little | 13 | 72,2% | 5 | 27,8% | 0 4 2 0 |
| production of quality | Moderate | 20 | 51,3% | 19 | 48,7% | 0,430 |
| agricultural products? | Very | 28 | 59,6% | 19 | 40,4% | |
| How strongly extreme | Not at all | 0 | 0,0% | 2 | 100,0% | |
| climate events have | Little | 3 | 50,0% | 3 | 50,0% | 0.223 |
| resulted in the loss of | Moderate | 13 | 72,2% | 5 | 27,8% | -, |
| agricultural income? | Very | 52 | 59,1% | 36 | 40,9% | |



Figure 1: Examination of the independence of the question "How strongly has the lack of water affected the production of your crops due to climate change" depending on the type of crop.



Figure 2: Examination of the independence of question "How strongly has climate change affected the production of quality agricultural products" depending on the type of crop.



Figure 3: Examination of the independence of the question ''How intense the extreme climatic events resulted in the loss of agricultural income''according to the type of crop.

3. CONCLUSION

According to the results of the research, it is found that the same conditions prevail worldwide. For the social protection of the vulnerable group of farmers and the risks posed by the reduction or loss of agricultural production due to climate change, the contribution of the state is required with coordinated efforts and with the participation of both farmers and local and regional communities. As found by the study, drought and global warming are having negative effects on crops and because of this intervention is required for rational management of water resources in irrigation approaching climate smart agriculture. The technical intervention for the sustainable management of agriculture with technologies such as temperature measuring instruments, the use of irrigation software giving precise instructions for the amount of water at the right time, the use of software in crop protection, water management practices and soil analysis are important interventions. To point out the need to diversify crops in agricultural holdings as well as the need for incentives by investing in alternative crops with adaptation to soil and climate conditions that will bring sustainability.

Furthermore, due to the effect of climate change on the flowering of crops with effects on production, modification of pruning should be proposed and demonstrated to protect and maintain flowering in case of severe weather events. It is also proposed to reform the state aid by increasing it in cases of crop loss as well as the facility with low interest or subsidized agricultural loans. Of particular value is the contribution of science to the development of crops resistant to climate change and the improvement of the resistance of existing ones. The guidelines for the correct use of the functions of the plant microbiome will particularly support agricultural production by strengthening and natural increase/resistance to drought, defense against pathogenic microorganisms, environmental restoration and the promotion of the bioeconomy, in particular, of less developed countries.

Consequently, according to the above, there is a need to organize agricultural conferences, information campaigns and targeted seminars for growers by the involved bodies, which in this case is the Ministry of Rural Development and Food as well as the local Regional Departments of Rural Development.

Coordinated efforts will bring positive results in preventing and dealing with the effects of climate change and by extension the social protection of the group of farmers, opening the horizon for rural sustainable development.

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Industrial chocolate production as an optimization problem

Christos Gogos* University of Ioannina Arta, Greece Christos Valouxis University of Patras Patras, Greece Panayiotis Alefragis University of Peloponnese Patras, Greece Alexios Birbas University of Patras Patras, Greece

Abstract

As George Box has aptly put it, all models are wrong, but some are useful. A useful model for the industrial process of manufacturing various chocolate products for a factory in Greece is presented in this work. An interesting aspect of the problem is that reservoirs are used for storing intermediate products. At the same time, several other resources like mixing-refining-conching machines, tempering networks, dosage machines, packaging machines, and others must be intelligently shared. The dosage and packaging might be synchronous or asynchronous based on the product type. Synchronous means that the dosage machine casts the pieces of the final product and feeds them directly to the packaging machine, so a production rate in pieces per work shift is given for the combination of the machines. On the other hand, asynchronous means that the intermediate product that the dosage machine produces can be temporarily stored and then sent to the appropriate packaging machine at a convenient time. A further complication is that each mixing-refining-conching machine should process mixtures that will eventually be transformed into final products in a specific order that guarantees minimum costs for cleaning the machine before preparing the following mixture. Even more complications exist, such as that some products (i.e., chocolate pralines) must be stored in refrigerators for specific periods before they are finally ready for the market. Besides providing a feasible schedule that accurately prescribes the production schedule for a horizon of a month, the objective is to minimize energy consumption by exploiting every possible opportunity, such as the simultaneous operation of machines that share air-conditioned spaces, prioritizing the usage of energy generated by the Photovoltaics of the factory and others. Our approach uses a constraint programming model since interval variables and the reservoir constraint are invaluable for modeling the problem. Preliminary results are quite promising.

KEYWORDS

Scheduling, Constraint Programming, Industrial Processes, Chocolate Products Production.

1. INTRODUCTION

Industry provides an ideal environment for optimization since several opportunities arise for making better decisions (Kallrath, 2022), especially during the so-called Industry 4.0 era that we are currently experiencing (*Parente et al., 2021*). Cost reduction and resource utilization are obvious targets, while flexibility, conformation with regulations, personnel safety and environmental protection are other important targets that should be met for the industry and the society at large. Major benefits might be possible by replacing existing installations with new ones, upgrading equipment, or even re-thinking the purpose of products and services and reengineer them to new ones. Nevertheless, the typical case of optimizing industry production involves the utilization of existing resources. The right scheduling decisions have the potential to bring significant benefits to stakeholders and drive the production towards specific goals such as that introduced by the climate crisis (Gao et al., 2020). In this line, this paper examines the optimization problem that arises at an industrial level chocolate production facility in Greece. It is essentially one of the use cases of the Horizon 2020 project Enerman¹, contributed by a business partner of the project. The Enerman project aims at developing solutions for the industry that achieve better energy usage and lower CO₂ emissions (Alefragis et al., 2022).

This paper is a preliminary work about the chocolate production at industry level problem that focus on capturing key aspects and important details of the problem, as it is manifested in our case study, and proposing the usage of Constraint Programming for constructing an optimized production schedule.

¹<u>https://enerman-h2020.eu/</u>

2. PROBLEM DESCRIPTION

Chocolate production at industrial level is a complicated process that must be performed diligently to have the desired results. Quality guarantees, production speed and traceability are only some of the challenges that must be met. A bird's eye view of the process that produces a single chocolate product is shown in Figure 1.



Figure 1: Steps for producing chocolate products.

Figure 2: Recipe for final product F001 (mixture: M1001, semifinal: SF2001).

A number of products must be produced by utilizing in the best possible way the available resources. Each final product is produced by following recipes that employ certain machines and personnel for specific durations and eventually transform raw materials to the final product.

The main machines that constitute the equipment are the Mixing Refining Conching (MRC) machines, the Dosaging machines, the Tempering machines and the Packaging machines. MRCs prepare batches of mixtures. These batches are known as "conches" and require several hours of monitored processing in order for the mixture to acquire the desired characteristics. The exact duration of preparing a single conche depends on the recipe. When a coche is ready it is uploaded to a tank based on the prepared mixture type. Then, when machines needed by the recipe are available, the tank offloads its content through a tempering network to a tempering machine. The tempering machine sends its output to a dosaging machine that forms the pieces of the final product and then a packaging machine wraps these pieces in plastic packages.

The factory operates 5 days a week, employing 3 shifts of 8 hours each. These shifts are 6:00-14:00 (day shift), 14:00-22:00 (mid shift) and 22:00-6:00 (night shift). Operations of machines during the night shift should be avoided if possible. In this setting, we consider that personnel needed while the machines are working is always available. So, scheduling shifts for personnel is out of the problem definition.

The graph on Figure 2 shows the recipe for final product F001. It starts with 16 hours of mixing refining and conching at MRC2. This gives mixture M1001 which is loaded to tank 9. Then, through a tempering network it is fed to a synced pair of a dosage machine and a package machine. At this stage the product is called semi-final. Then, another packaging step follows that gives the final product. Given the demand for final products, it is decided how many batches of each recipe must be made. Each recipe is analyzed to a sequence of tasks and each task is defined by its start time, finish time and resources needed. An example of a task is a mixing refining task uses an Refiner/Concher machine for the duration of preparing the mixture. Another example of a task is a dosage/package task that uses a dosage machine and package machine that operate in sync for producing products. Note that identifiers used for products, machines, etc. are anonymized.

The factory is equipped with PhotoVoltaics (PVs) that produce energy at varying quantities during certain periods of the day. It is expected that the production will be shifted to periods when PVs are expected to produce much energy. Moreover, some machines (dosage & package) are situated at the same air conditioned (A/C) rooms of the factory. It is energy efficient for these machines to operate simultaneously, if possible, so as to minimize the usage of A/C.

Related work to our problem can be found by searching bibliography about production problems for consumer goods at industry level. For example (Elekidis et al., 2019) presents a Mixed Integer Programming model for the packaging stage of consumer goods. Also, at (Çölova, 2006) a similar to our problem is analyzed and schedules for chocolate production lines are produced.

2.1 Frontend and backend phases

It is convenient to separate the production process in two phases, the frontend phase and the backend phase. In the frontend phase two tasks are identified, the task of preparing the mixture at the MRC, which typically lasts for several hours and the much shorter task of offloading the MRC to the appropriate tank. While the frontend phase fills tanks with mixtures, the backend phase consumes mixture from the tanks. So, in the backend phase mixtures are drawn from tanks at paces dictated by the machines that are employed then. These machines are typically tempering and dosage machines and are responsible for emptying the tanks. Furthermore, more tasks might follow that perform the packaging which can be done in one or two phases based on the final product.

2.1.1 Order of mixtures prepared at each Mixing Refining Conching machine

An important part of the production occurs at the MRC machines. These are big machines that are filled with raw materials, either by "air-transfer" through a pipe network or manually by workers. Refining is the grinding of particles in liquid chocolate that eliminates grit and gives smooth texture. Conching is the process of mixing and aerating hot liquid chocolate. Various off-flavored compounds and water, escape out of the chocolate throughout this procedure. The strong mixing motion ensures that every solid particle is completely coated with cocoa butter, giving the chocolate the desired flavor and texture.

Since various mixtures are prepared in each MRC, a specific order of mixtures must be followed for each one, so as the remaining mixture at the walls of the MRC to have the minimum possible effect on the characteristics of the mixture that will be prepared next. In some cases, an MRC must be washed out, between mixtures. This occurs using cottonoil and is a process that lasts for relative short durations. Table shows for our problem instance the capacities of MRCs in Tons. Next to these values in parentheses are the actual loads that an MRC uses in order to achieve the optimal point of operation as given by the manufacturer. The third column of the table shows the sequence that should be followed for preparing the mixtures in the MRC. The presence of letter W in the sequence denotes the washing procedure that was previously mentioned. If a mixture should not be prepared due to no demand of the final product that uses it, its presence in the sequence is simply ignored.

| MRC | Capacity (Tn) | Order of preparing mixtures |
|----------|---------------|---|
| MRC1 | 5 (4.2) | M2173, M2116, W, M2336 |
| MRC6 | 3 (2.2) | M1502, M2189, M2356, M2198, W, M2392, M2486 |

 Table 1: Capacities of MRCs in Tons

2.2 Product types

Products may assume different production patterns. Based on this observation the following five product types are identified:

- Type 1: Final product that is collected at a Dosage machine. The production rate of the Dosage machine is given in pieces per shift.
- Type 2: Final product that is produced by synchronized production of a Dosage machine and a Package machine. Synchronized production of Dosage and Packaging machines means that the output of the Dosage machine is consumed directly by the Packaging machine, so a single production throughput in pieces per shift is given.

- Type 3: Final product that is produced by asynchronous production of a Dosage machine and a Package machine. In this context, asynchronous means that the Dosage machine operates in isolation producing pieces of the final product, and at a later stage Packaging occurs. So, two production rates (in pieces per shift) are given, one for the Dosage machine and one for the Packaging Machine.
- Type 4: Final product that is produced by synchronized production of a Dosage machine and a Package machine, followed by another asynchronous Package machine.
- Type 5: Final product (pralines), uses specialized machine that fills buckets of various sizes, which must then be kept for a specific period (e.g., 24h) in a refrigerator room.

2.3 Orders

The factory operates by preparing orders for a period of 30 days. Each order line is identified by a pair of codes, the code of the mixture (mixture_id) that should be prepared and the code of the final product (final_id) that should be produced. The line is complemented by the number of pieces of the final product that is ordered. So an example of an order includes the 3 first columns of Table 2.

Table 2: Orders for the next 30 days

| mixture_id | final_id | pieces | gr/piece | quantity (Tn) |
|------------|----------|--------|----------|---------------|
| M2001 | F101 | 72000 | 100 | 7.2 |
| M3333 | F002 | 32000 | 125 | 4.0 |
| | | | | |
| M2929 | F343 | 440 | 20000 | 8.8 |

The weight of a piece of each final product is known and based on that the quantity of the mixture that should be prepared is calculated by multiplying the number of pieces with the weight per piece. Then, since each MRC can prepare only conches of a certain quantity (2.2T or 4.2T based on MRC), the decision is given to the human operator whether surplus pieces of a final product should be produced and later stocked, or whether it can be tolerated to produce a lesser number of pieces. So, orders of Table 2 might be altered and become as shown in Table 3.

| mixture_id | final_id | pieces | surplus pieces | conches |
|------------|----------|--------|----------------|-------------|
| M2001 | F101 | 84000 | +12000 | 2 (x 4.2Tn) |
| M3333 | F002 | 33600 | +1600 | 1 (x 4.2Tn) |
| | | | | |
| M2929 | F343 | 420 | -20 | 2 (x 4.2Tn) |

Table 3: Orders for the next 30 days (adjusted quantities)

3. MODEL OF THE PROBLEM

The optimization problem is defined as usual by its decision variables, constraints, and objective. The decision variables specify start and finish times for all tasks. The constraints enforce that the demand is satisfied, no machine is used by more than one task at the same time, tanks don't overflow or underflow, and the mixtures are prepared on the required sequence at each MRC. The objective has three parts. The first one aims at fully utilizing the energy produced locally by photovoltaics. The second one aims at avoiding operation during night shifts. The third part of the objective aims at scheduling with maximum overlap tasks for machines that are located at the same A/C room.

Many approaches exist for addressing scheduling problems like this one, Mixed Integer Linear Programming, Constraint Programming (CP), Heuristics, Metaheuristics, Machine Learning based approaches, and others. Our selection was CP. CP has several advantages like the support of a wide range of constraints that can ease the formulation of problems and the existence of modern CP solvers that are very capable like Google's ORTools CP-SAT (Perron & Furnon, 2023) and IBM's ILOG CP-Optimizer (IBM: ILOG CP, 2023). Two major advantages of CP that apply to this problem and other scheduling problems are the interval variables and the reservoir constraint.

3.1 Interval variables

An interval variable is a special type of variable used in CP to represent a range of possible values rather than a single specific value. Some advantages of interval variables are that they add flexibility in modeling scheduling problems, they enable efficient constraint propagation, they enhance solution space exploration, they enable handling of over-constrained situations, and they support optionality (i.e., an interval decision variable might not exist in the solution in favor of other optional interval decision variables). The following interval decision variables are identified in our problem:

- Interval variables for refining conching tasks (including time needed to load raw materials).
- Interval variables for tasks representing emptying an MRC and loading a tank.
- Interval variables for tasks that offload mixture from a tank (e.g., a dosage/package task).
- Interval variables for tasks that follow offload mixture tasks (e.g., a package task).

3.2 Reservoir constraints

As we have seen in Section 2.3, orders that should be fulfilled during the scheduling horizon, become round numbers of conches prepared at various MRCs. Each conche, once prepared is offloaded to a tank and then consumed from it through tempering, dosage and package steps, based on the product type. A challenge in modeling this problem is to capture the role of the tank as a buffer space that gives the opportunity of temporary holding mixture quantities and postpone the start of later steps until the best possible time. A constraint programming model of the problem can capture this type of situation with the reservoir constraint that is briefly explained below.

The reservoir constraint is a specialized constraint supported by modern CP solvers like IBM's ILOG CP Solver and Google's ORTools CP-SAT. It essentially keeps a reservoir level within bounds. It is defined by a list of times, a list of demands, a minimum level, and a maximum level. The level of the reservoir starts at 0, and each pair of items at index i of the list of times and the list of demands, denotes that at time[i] the reservoir level either increases or decreases based on the value of demand[i]. The constraint ensures that changes at the reservoir level always result to values no less than the minimum level and no greater than the maximum level or else the constraint is violated. Note that the time list can contain decision variables, but the demand list contains integer constants.

In our problem setting the reservoir constraint bridges the frontend phase and the backend phase of the chocolate production process as shown in Figure 3. When the MRC task finishes, this means that the mixture is ready, and it can be used to fill the associated tank. This is handled by the "load mixture task" that lasts for relatively short time (e.g., 1 hour). Therefore, we consider that the full amount of the prepared mixture is offloaded to the tank at the end time of the load mixture task. At the other end, the backend task that follows empties the tank though a process that might last for several hours. In order to model more accurately this process, we assume that the backend process that consumes the mixture from the tank is divided into subtasks of specific granularity (e.g., for granularity of 1 hour, a backend task that has duration 7:45 hours will have 7 subtasks of 60 minutes each and a subtask with a duration of 45 minutes). These subtasks are considered to draw mixture from the tank at their start times. No overlap should occur among subtasks, and all of them should lie between the start and the end time of the backend task that draw mixture from the tank.



Figure 3: The frontend and backend phases of filling and emptying a tank

4. INITIAL EXPERIMENTS

A simple example of applying the reservoir constraint in Google's ORTools is shown in Figure 4. It refers to a reservoir with a capacity of three units and four tasks that either fill or empty the reservoir.



Figure 4: Google's ORTools reservoir constraint example

Figure 5: Level of tank

The solver finds a way to correctly schedule all tasks and outputs values [1, 4, 3, 6] which correspond to Figure 5. An initial example of using interval variables and applying the reservoir constraint in our problem is shown in Figure 6. Tasks with the same color represent the same product, and the frontend tasks must be finished for the corresponding backend tasks to start.



Figure 6: Partial schedule

Since night shifts should be avoided, intervals are defined for all night shifts across the scheduling horizon and a part of the objective is to minimize the overlap of night shifts with tasks. The overlap can be measured by using the formula shown in Figure 7. The same formula can be used to measure the overlap of tasks with the intervals where Photovoltaics are expected to provide energy to the system. In this case the amount of overlap must be maximized. The same holds for tasks that represent operations on machines that are located at the same A/C room.



overlap = max(0, min(end1,end2) - max(start1, start2))

Figure 7: Formula that measures the extend of overlap between two intervals.

5. CONCLUSIONS

Industrial processes must be optimized, or else competitors will gain advantage and ultimately win the market war. Chocolate production at industry level is an interesting scheduling problem with several opportunities for optimization. In this paper we presented the problem of scheduling the industrial production of chocolate products as manifested at a factory in Greece. The target is to optimize the usage of energy, given that the factory is equipped with PhotoVoltaics and that it hosts various machines at rooms that retain specific temperatures using Air Conditioning. In this preliminary work we concluded that Constraint Programming seems to be a good fit for the problem since it enables easy modeling of the tanks' behavior and the measure of the extend that tasks overlap.

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The application of Supply Chain Operations Reference (SCOR) model with Multi-Criteria Decision-Making (MCDM) methods in the Agri-food sector: A systematic literature review

Georgios Sidiropoulos Department of Financial and Management Engineering, School of Engineering, University of the Aegean, Chios – 82100, Greece Nikos Tsotsolas Department of Business Administration, School of Administrative, Economics and Social Sciences, University of West Attica 250 Thivon & P.Ralli Str., 12241 Athens, Greece Vasileios Zeimpekis Department of Financial and Management Engineering, School of Engineering, University of the Aegean, Chios – 82100, Greece

Abstract

Agri-food supply chain management (ASCM) has faced numerous challenges in recent years, especially in the fields of performance measurement and decision making. In addition, the use of multi-criteria decision-making (MCDM) methods with standard frameworks for supply chain modeling and optimization has attracted much attention over the last decade, with the SCOR model being one of the most important frameworks. SCOR model provides a standard description of supply chain processes, performance metrics, best practice and enabling technologies. In this context, this paper provides a systematic literature review focusing on the application of SCOR model with MCDM methods for Supply Chain Performance Measurement (SCPM). This research uses specific criteria and elements to review selected papers. Web of Science and Scopus were used in the compilation of studies published between 1996 and 2022. This research work is the first attempt to make a critical literature review of available literature on SCOR model and MCDM methods for improved benchmarking and competitiveness in the agri-food sector. The study addressed the research questions and identified the research gap. Moreover, the future research directions were consolidated into a research agenda that has a two-fold purpose: it can be used by researchers to enrich literature and provides practitioners the opportunity to evaluate existing Supply Chain Management (SCM) issues and concentrate on establishing a solution through the development of a conceptual framework on SCPM. To attain this objective, a conceptual model will be proposed in future research as a new framework, based of risk assessment, business and quality performance that will improve customer satisfaction through a set of objective metrics. Finally, this tool will be further examined in future research to assist researchers, managers, practitioners and companies to improve and assess the Supply Chain Performance (SCP), as well as improving SCM to increase sector's competitiveness.

KEYWORDS

Systematic literature review (SLR), Supply Chain Operations Reference (SCOR) model, Multi-Criteria Decision-Making (MCDM) methods, Supply Chain Performance Measurement (SCPM), Agri-food supply chain management (ASCM)

1. INTRODUCTION

Supply chain management (SCM) can be defined as the management of complex relationships throughout the supply chain. The biggest goal and challenge of supply chain management is the synchronization of supply chain value creation and customer satisfaction. From the beginning of an order entry through after sales service, all market interactions and product transactions, supply chain must be always evaluated to detect performance gaps and processes that must improve or change. Supply chain performance measurement (SCPM) is increasingly becoming the most important issue in Supply chain management (SCM) because of the competitiveness between companies (Bai et al, 2012), such as selecting specific objectives to improve for performance measurement (Beske-Janssen et al., 2015). Furthermore, it is very important to be noted that there is no available model that can manage three critical elements that are of direct interest and crucial for companies: quality and business performance and risk assessment. Many recent literature review studies have discussed supply chain management and performance measurement from various perspectives. However, there is no existing research that can combine MCDM methods with SCOR model and generate comprehensive and acceptable performance evaluation models. To address the gap, this study presents a systematic literature review based on the PRISMA approach. Web of Science and Scopus were used in the compilation of studies published between 1996 and 2022.

2. SUPPLY CHAIN OPERATIONS REFERENCE (SCOR) MODEL

In 1996, the Supply Chain Council (SCC), a global non-profit organization has developed and maintains a supply chain diagnostic tool, the Supply Chain Operations Reference (SCOR) to analyze, evaluate, describe and understand supply chains that are very simple or complex, using a common set of definitions (SCC, 2012). In 2014, APICS Supply Chain Council (APICS SCC) was formed through the merger between APICS, a leading professional association for the supply chain and operations management, and the Supply Chain Council. SCOR model is characterized as a total systematic approach to manage flow of Information and material through the supply chain (internal and external). Poluha (2016) noted that the SCOR model define "a common language for communication between the various internal areas with the external supply chain partners". The SCOR Model is a strategic tool that can efficiently measure complex supply chain processes to improve performance (Caricato et al., 2014; Li et al., 2011; Huang et al., 2005). To sum up, this supply chain model is a cross-industry (Harrison and Van Hoek, 2011), highly structured and systematic (Slack et al., 2013) framework for supply chain management and excellence, consisting specific attributes, business processes, people, actions, best practices and SCOR metrics named Key Performance Indicators (KPIs) to evaluate, control, understand and improve every company's Supply Chain Performance to support the SCM strategy (Huan et al., 2004; Tramarico et al., 2017). Furthermore, companies can use this model to build or reorganize supply chain processes (Heizer and Render, 2017; Reiner & Hofmann, 2006) and for the configuration of Supply Chain Management (SCM). Figure 1 shows the SCOR model as a process framework from the combination of the four techniques that referred in SCC (2017):



Figure 1: SCOR model as a single integrated approach (Source: www.apics.org)

Also, as a reference tool, SCOR analyzes the complex characteristics of supply chain (Giannakis, 2011). This model includes strategic processes on Level 1 that represent the missing link between suppliers, company and customers (Rotaru et al., 2014). Figure 2 shows that SCOR model is organized around six primary management processes (Plan, Source, Make, Deliver, Return and Enable):



Figure 2: Supply Chain Operations Reference (SCOR) Model (Source: <u>www.apics.org</u>)

Zhou et al. (2011) showed a direct relationship between these processes. Each of the above processes is examined at three levels. Level 1 has a strategic scope regarding with company's supply chain configuration through those six processes. Level 2 has a different strategic purpose from Level 1 because these processes

contribute to determine the supply chain strategy. Level 3 processes present detailed information for each one of the six level 2 processes. Russell and Taylor (2014) referred that one of the unique characteristics of SCOR model is the application of a set of "metrics" or KPIs for the supply chain performance measurement and are organized into "customer-facing" or "internal-facing" categories. Customer-focused KPIs measure supply chain reliability, responsiveness, and agility with respect to suppliers and customers. Internal-focused KPIs measure supply chain cost and asset management efficiency. These metrics can also be used for multiple supply chain processes (Persson, 2011) and are used to develop a "SCORcard". This procedure gives a competitive advantage to its owner because it can evaluate both a company's supply chain performance for different processes and its competitor's metrics. After this step, the company estimates the level of metrics that needs to be at the same level with the competition, to gain a distinct and competitive advantage over the other companies or sometimes to be superior.

3. METHODOLOGY

A Systematic Literature review is an approach that can identify research gaps in order to suggest areas for further investigation and future research. The systematic literature review was conducted with the application of PRISMA method in the area of supply chain management and performance measurement with MCDM methods, using SCOR model. The preferred reporting items for the PRISMA method were used for the selection of all the available existing studies, to review the steps in the process (identification, screening and eligibility). Also, data abstraction and analysis through PRISMA method was conducted using two of the largest resource databases, Web of Science (WoS) and Scopus. Several keywords related to SCOR model, MCDM methods and agri-food sector were selected. Table 1 presents the search strings utilized in both databases.

Figure 3 depicts the PRISMA flow diagram utilized in this study. The shortlisted 25 papers were analyzed and descriptive analysis was used to summarize the selected papers.



Figure 3: The PRISMA flow diagram of the study (Source: <u>http://www.prisma-statement.org</u>).

Table 1: Search strings used in the SLR

| Journal Database | Search string |
|------------------|--|
| | (Title-Abstract-Keywords) ("SCOR model OR & AND Supply Chain |
| | Operations Reference model"), ("SCPM OR & AND Supply Chain |
| WoS and Scopus | Performance Measurement"), ("MCDM OR & AND Multi-Criteria |
| | Decision Making methods"), ("Agri-Food OR & AND Agro-Food |
| | sector"), ("Agrifood SC OR & AND Agrofood SC") |

4. **RESULTS**

An overview of papers about SCOR model and the combination of Level 1 KPIs with MCDM methods is provided in this section. Except for specific years which observed with a negative slope of the selected 25 papers that are analyzed and published between 1996 and 2022, Figure 4 shows an upward trend in the publication of these papers, with more than half having been published in the last 10 years.



Figure 4: Publication years of papers

The distribution of the selected papers demonstrates that a wide range of journals addresses the topic of supply chain performance approaches with MCDM methods (Figure 5). The most cited papers from the 25 papers cover a wide range of topics, including various MCDM approaches and methods that are used for supply chain performance evaluation, especially on supplier selection and evaluation.



Figure 5: Distribution of published papers by journals





Figure 6: Distribution of Published papers by categories

5. CONCLUSIONS

In this paper, a systematic literature review reported the extent to which the SCOR model has been applied to the agrifood sector for supply chain management and performance measurement with MCDM methods. Based on the above results, few from the selected papers are related to the agri-food sector and the application of the referred MCDM methods were only for supplier evaluation and selection. Most papers used SCOR level 1 processes and metrics and the results reported that there is no aggregation model or prior research work on adaptation of the SCOR model that is commonly accepted. This research work is a first attempt to make a critical review of the available studies on SCOR model and MCDM methods for improved benchmarking and competitiveness in the agri-food sector.

6. LIMITATIONS AND FUTURE RESEARCH

It is important to be noted that there were less papers than expected for agri-food sector and MCDM methods, and also SCOR model was used less than expected, which indicates that there is still important to perform an extensive literature review. In future research it is suggested to focus on these areas giving special attention to the three elements that were referred and how to incorporate them in the SCOR model. A conceptual model will be proposed as a new framework, based of risk assessment, business and quality performance that will improve customer satisfaction through a set of objective metrics. Finally, this tool will be further examined in future research to assist researchers, managers, practitioners and companies to improve and assess the Supply Chain Performance (SCP), as well as improving SCM to increase sector's competitiveness.

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Tackling the Balance of Performance (BoP) Debate in Motorsports: Development and Simulated Application of Algorithm for BoP Scheme Evaluation and Adjustment

Angelos T. Kottas University of Macedonia, Department of International and European Studies 156, Egnatia Str., 54636, Thessaloniki, Greece Irs20022@uom.edu.gr Michail N. Bozoudis NATO Communications and Information Agency (NCIA) Boulevard Leopold III 1110 Brussels, Belgium michail.bozoudis@ncia.nato.int Michael A. Madas University of Macedonia, Department of Applied Informatics, Information Systems and e-Business Laboratory (ISeB) 156, Egnatia Str., 54636, Thessaloniki, Greece <u>mmadas@uom.edu.gr</u>

Abstract

Motorsports championships across the globe involving Grand Touring (GT) racecars implement the Balance of Performance (BoP) concept, in order to equalize the winning potential of the participants. The organizing bodies of these championships impose a set of technical rules pertinent to racecar eligibility and performance parity. Most BoP schemes fundamentally stipulate for engine horsepower and racecar curb weight initial determination and subsequent adjustment, while additional provisions mandate for aerodynamics, suspension, fuel tank volume, etc. Nevertheless, the methodology deployed by organizing bodies for evaluating performance and adjusting technical features in order to achieve competitive equality, remains a subject of great debate due to the reduced visibility provided to competitors and racecar manufacturers. In fact, motorsports organizing bodies avoid disclosing details associated with imposing, evaluating, and adjusting BoP schemes for a specific championship series. Our proposed research deals with the evaluation and subsequent adjustment of motorsports' BoP schemes, by developing an integrated algorithm incorporating statistical tests and Data Envelopment Analysis (DEA). The validity of the devised algorithm is tested by performing a simulated application using a widely-known racecar simulator, with the results designating the algorithm's potential to accurately and fairly evaluate/adjust BoP schemes.

KEYWORDS

balance of performance, motorsports, pairwise performance evaluation, data envelopment analysis

1. INTRODUCTION

Unlike traditional sports, competitiveness in motorsports is mainly based on vehicle technical capability. Irrespective of the vehicle type involved (e.g., single-seaters, sportscars, motorbikes), winning potential in motorsports is directly associated with technological prowess achieved by vehicle manufacturers. Within the specific framework, organizing bodies of various motorsports championships impose regulations aiming to restrict technological features of race vehicles within specific limits. In addition, organizing bodies are making amendments to the set of regulations on a year-by-year basis, thus hindering certain participants to dominate and ensuring that grid size is quite extensive.

The most widespread concept implemented by motorsports organizing bodies and especially the ones associated with the so-called grand-touring or GT racecars, for the purpose of attaining competitive parity, is "Balance of Performance" or BoP. Apart from its technological dimension, BoP has evolved into a major issue of political debate among organizing bodies, racing teams, and racecar manufacturers. However, BoP comprises an important tool for organizing bodies to maintain a healthy grid size, cap team budgets, attract racecar manufacturers, and increase popularity of the championship series (Cotton, 2016; Raymond, 2019).

With respect to the disclosure policy of organizing bodies regarding BoP schemes, only power and weight figures are reported. Yet, important aspects associated with statistical/mathematical methods for defining performance disparities and the subsequent justification for imposing handicaps or advantages to certain racecars are not publicly released, thus raising the issue of reduced transparency (Raymond, 2021).

Although racecar performance parity within the BoP framework has become one of the most controversial subjects in motorsports, no piece of scholar research has dealt with it. In this context, our paper attempts to develop a novel algorithm founded on proven scientific methods, for the purpose of:

- Objectively evaluating BoP schemes imposed by motorsports organizing bodies, via implementation of robust statistical tests, which designate significant performance differences.
- Objectively quantifying the handicap/advantage that needs to be imposed on any racecar respectively demonstrating significantly superior/inferior performance.
- Stimulating transparency enhancement, taking into account that organizing bodies do not disclose details pertinent to the implemented methodology associated with BoP schemes' evaluation and adjustment.

The rest of the paper is structured as follows: Section 2 makes a brief description of the BoP concept and presents the relevant literature. In Section 3, framework and main aspects of proposed algorithm for BoP evaluation and adjustment are presented. Section 4 contains the concept and the results of the proposed algorithm's simulated application using a racecar simulator. Finally, Section 5 provides concluding remarks and proposals for future research

2. BOP DEFINITION & PREVIOUS RELEVANT LITERATURE

Due to non-existing scholar research pertinent to BoP, *Racecar Engineering* magazine comprises the main source for relevant literature. Secondary literature sources include websites associated with motorsports organizing bodies and motorsports analysts. Before proceeding with a brief description of relevant literature, we shall set forth a BoP definition, which is phrased as follows:

The scheme devised by an organizing body, for the purpose of eliminating any tangible competitive advantage/disadvantage among competing racecars, thus ensuring that wins and top place finishes are attained by a large portion of contenders.

The first article of *Racecar Engineering* magazine dealing with BoP is the one of Divila (2014), which concisely describes the effort of FIA-ACO (Fédération Internationale de l'Automobile – Automobile Club de l'Ouest) to equalize racecar performance in the famous Le Mans 24-hour race. In the specific article, the term "Equivalence of Technology" (or EoT) is concurrently used with the term BoP. The article of Cotton (2016) analyzes the BoP framework adopted by three different organizing bodies, i.e. FIA-ACO, SRO (Stéphane Ratel Organization), and IMSA (International Motorsports Association). Subsequently, the article of Cotton (2017) focuses on BoP scheme applied by FIA-ACO in WEC (World Endurance Championship), which according to the author is based on specially-developed algorithm, with its details not being specified.

In the article of Raymond (2019), the necessity of BoP in motorsports is justified, with the sustainability of a racing class mentioned as the most important reason for implementing it. The subsequent article of Raymond (2020a) outlines the homologation process of FIA-ACO, SRO, and IMSA in their respective GT championships, while simultaneously introducing the term "reference car" in order to describe the racecar comprising the performance benchmark for all other participating racecars. The topic of performance management is analyzed by Raymond (2020b), i.e. how participating teams can distort the performance outlook of any racecar by manipulating certain parameters. The article of Raymond (2021) refers to the exogenous factors affecting racecar performance, additionally stressing the usefulness of simulation for preliminary assessment of racecar performance. The novel concept of "raceability" is introduced by Raymond (2022), which is defined as the ability of the different cars belonging to a specific class to race each other, along with the ability of a racecar to deal with racecars belonging to other classes. In addition, Raymond (2022) stresses the need to balance racecar performance within a stint (set of laps between successive stops for tire change/refueling), thus rejecting the focus on individual lap times.

3. PROPOSED ALGORITHM FOR BOP SCHEME EVALUATION & ADJUSTMENT

Before constructing the algorithm, its objectives are determined beforehand. The first objective is to assess whether the demonstrated performance of any racecar significantly differs from the performance of all other participating racecars. Subsequently, the second objective is to impose a rational handicap/advantage on any such racecar, in order to eliminate the ascertained significant performance difference.

After studying the BoP schemes adopted by FIA-ACO, SRO, and IMSA, the discrete steps of the proposed

algorithm are as follows:

• <u>Racecar Testing</u>: Every car model participating in the upcoming championship season is tested by incorporating technical features stipulated by the homologation process, within a set of specific prerequisites, thus ensuring minimum variability of exogenous factors (or *ceteris paribus*).

• <u>Statistically Significant Performance Differences Detection</u>: The results obtained from the previous step, are evaluated on a pairwise comparison basis, using appropriate statistical tests. Hence, the power of the deployed statistical test to accurately designate significant performance differences comprises the basis for fairness evaluation of any BoP scheme. After delving into literature dealing with statistical tests used for pairwise comparisons (Hsiung & Olejnik, 1994; Ramsey and Ramsey, 2009; Ramsey et al., 2010; Sauder and DeMars, 2019), the Games-Howell statistical test has been determined as the most proper for defining performance differences. Besides adequately controlling Type I error in cases where equal/unequal sample size and variance exists, Games-Howell any-pair power is superior to other statistical tests used for pairwise comparisons.

Power/Weight Adjustments: The racecars which demonstrate statistically significant performance differences undergo a process in which it is initially defined which racecar is prioritized for having its performance revised and subsequently the magnitude of power and/or weight handicap/advantage is quantified, in order to eliminate the respective performance excess/deficit. Engine power and racecar curb weight are selected as adjustable technical features, given that narrow changes are not entailing major modifications. The prioritization process is executed by counting the instances of statistically superior/inferior performance, while the quantification of power/weight changes is executed utilizing DEA (Data Envelopment Analysis) in an inverse way, as introduced by Wei et al. (2000). Given the fact that racecars comprise technical systems which concurrently pursue to minimize inputs and maximize outputs, a non-oriented VRS (variable returns to scale) DEA model is deemed as most suitable. The non-oriented DEA model initially suggested by Tone (2001) and further refined by Tone (2010) and Tone (2011) has been selected for the particular instance. Nominal engine maximum power, nominal engine maximum torque and racecar curb weight comprise the inputs, while total required time, i.e. total time recorded in order to complete the testing sessions comprises the output. Given that we have undesirable input (curb weight) and undesirable output (total required time), we implement transformations proposed by Halkos and Petrou (2019). Hence, we implement nominal engine maximum power per tonne and nominal engine maximum torque per tonne as inputs, while total required time has been subtracted from a positive number of significantly greater numerical value. After obtaining the efficiency scores, quantifying power/weight handicap/advantage imposed on any racecar with performance adjustment requirement, is done by setting the total required time equal to the one achieved by the "reference racecar" and subsequently calculating efficiency scores for different combinations of adjusted power/weight. The power/weight combination resulting in efficiency score with the minimum delta (i.e. original efficiency minus recalculated efficiency) is chosen as the one implemented in order to eliminate statistically significant performance differences. For the purpose of avoiding imposing power/weight handicap/advantage of increased value, we devise the concept of the "upper tier reference racecar" and "lower tier reference racecar". The "upper tier reference racecar" is the racecar which has recorded the lowest total required time among racecars not demonstrating significant performance differences, while "lower tier reference racecar" is the racecar which has recorded the highest total required time among racecars not demonstrating significant performance differences. Hence, when we have a racecar outperforming certain racecars, we set its total required time equal to the one achieved by "upper tier reference racecar". On the other hand, when we have a racecar outperformed by certain racecars, we set its total required time equal to the one achieved by "lower tier reference racecar". The specific practice aids in avoiding any performance pendulum effect, as stressed by Cotton (2017).

• <u>Racecar Re-Testing & Statistically Significant Performance Differences' Elimination Verification</u>: The racecar which has its engine power and/or weight adjusted undergoes additional testing, deploying the testing framework of the first step. Subsequently, pairwise comparisons are executed using Games-Howell statistical test, in order to verify that previous statistically significant performance differences cease to exist (2nd step). If the statistically performance difference still exists, racecar undergoes the same testing session with the power/weight combination providing equal or nearly equal efficiency score delta. If statistically significant performance differences are eliminated from the specific racecar and remains in other racecars, we reiterate 3rd step and 4th step of the algorithm accordingly. The algorithm cyclical execution stops when there is no racecar demonstrating statistically significant superior or inferior performance difference.

4. SIMULATED ALGORITHM APPLICATION

Given that any real-world racecar testing is associated with high costs and taking into account the statement of Raymond (2021) which stipulates for conducting vehicle dynamics simulation as an alternative tool in order to balance racecar performance, we have opted for evaluating the devised algorithm utilizing a globally recognized racecar simulator. The specific simulator implements its own BoP scheme, thus being ideal for testing the algorithm's effectiveness. We have selected 14 racecars belonging to GT3 class, which have actually taken place in racing series or specific endurance races across the world. The racecars are named by using the concept of phonetic aviation alphabet (Alpha, Bravo, Charlie, Delta, Echo, Foxtrot, Golf, Hotel, India, Juliet, Kilo, Lima, Mike, and November) for the purpose of avoiding any hint of brand preference/affiliation.

With respect to the 1st step (initial racecar testing), *ceteris paribus* testing framework included the following elements:

- One of the authors undertook the task of being the sole test driver, given the extensive previous experience of over 240,000 km and proven skills designated by belonging to the top 7 percent in terms of online race performance.
- Same track conditions, tire compound, fuel tank capacity, downforce, and traction control setting.
- Each car undergoing 3 stints in each selected racetrack, with each stint starting from pit paddock exit.
- Racecar damage and racetrack limits' violation was set to the most realistic mode, thus aborting any stint with major damage or racetrack limits' violation (notified by simulator software).

The racetracks selected for the simulated algorithm application were the Nürburgring racetrack (24-hour race configuration of 25.378 km) and the Le Mans 24 Hours racetrack (13.629 km), which by the standards of SRO can be respectively characterized as mid speed/higher downforce and high-speed/lower downforce. The initiative behind selecting those fundamentally different racetracks is to additionally evaluate whether the unified BoP scheme of racecar simulator (i.e. same power and weight figures for all tracks included) or segmented BoP scheme of SRO (i.e. different power and weight figures depending on racetrack configuration category) is more proper.

The testing session for each racecar in each racetrack comprises of 3 stints (set of laps between successive refuellings/tire changes), which nearly accounts to 500 km of covered distance. The racecar simulator BoP scheme features and the descriptive statistics for initial racecar testing in both racetracks are presented in the following tables. For the Nürburgring racetrack, each stint comprises of 6 laps, while for the Le Mans racetrack each stint comprises of 12 laps.

| Racecar | Engine Maximum Nominal Brake Horsepower (BHP) | Engine Maximum Nominal Torque (kgfm) | Curb Weight (kg) |
|----------|--|---|------------------|
| Alpha | 535 | 52.3 | 1,317 |
| Bravo | 564 | 67.1 | 1,325 |
| Charlie | 555 | 72.6 | 1,326 |
| Delta | 555 | 56.6 | 1,332 |
| Echo | 528 | 54.6 | 1,285 |
| Foxtrot | 581 | 67.6 | 1,350 |
| Golf | 568 | 77.6 | 1,300 |
| Hotel | 549 | 71.7 | 1,302 |
| India | 564 | 63.7 | 1,243 |
| Juliet | 576 | 70.6 | 1,300 |
| Kilo | 557 | 69.9 | 1,287 |
| Lima | 598 | 63.4 | 1,326 |
| Mike | 556 | 65.7 | 1,326 |
| November | 556 | 66.9 | 1,280 |

Table 1: Racecar Simulator BoP Scheme Features
| Racecar | Mean | Median | Std. Deviation | Variance | Range | Minimum | Maximum | Total |
|----------|-----------|-----------|-------------------|----------|-------|---------|---------|-----------|
| Alpha | 499.18033 | 498.82500 | 2.240059 | 5.018 | 8.914 | 495.510 | 504.424 | 8,985.246 |
| Bravo | 497.98511 | 497.40850 | 1.631760 | 2.663 | 6.373 | 495.387 | 501.760 | 8,963.732 |
| Charlie | 498.40372 | 498.29950 | 2.201690 | 4.847 | 6.950 | 495.264 | 502.214 | 8,971.267 |
| Delta | 500.31283 | 500.93400 | 1.692703 | 2.865 | 5.052 | 497.361 | 502.413 | 9,005.631 |
| Echo | 500.33772 | 500.03050 | 1.933868 | 3.740 | 6.682 | 497.203 | 503.885 | 9,006.079 |
| Foxtrot | 499.69311 | 500.31750 | 1.772357 | 3.141 | 5.689 | 496.655 | 502.344 | 8,994.476 |
| Golf | 499.92711 | 499.55150 | 2.165134 | 4.688 | 6.732 | 496.978 | 503.710 | 8,998.688 |
| Hotel | 499.54728 | 500.14650 | 2.042697 | 4.173 | 6.464 | 496.390 | 502.854 | 8,991.851 |
| India | 500.56528 | 500.83950 | 2.116495 | 4.480 | 6.465 | 497.408 | 503.873 | 9,010.175 |
| Juliet | 498.68511 | 498.49150 | 1.642752 | 2.699 | 5.710 | 496.078 | 501.788 | 8,976.332 |
| Kilo | 498.38739 | 498.85750 | 1.930801 | 3.728 | 6.561 | 495.337 | 501.898 | 8,970.973 |
| Lima | 499.13689 | 498.88500 | 1.842444 | 3.395 | 5.464 | 496.096 | 501.560 | 8,984.464 |
| Mike | 497.66967 | 497.81450 | 1.726466 | 2.981 | 6.171 | 494.393 | 500.564 | 8,958.054 |
| November | 496.88956 | 497.01500 | 1.982837 | 3.932 | 5.803 | 494.083 | 499.886 | 8,944.012 |

Table 2: Nürburgring 24 Hours Racetrack Testing Lap Times Descriptive Statistics (units in seconds)

Table 3: Le Mans 24 Hours Racetrack Testing Lap Times Descriptive Statistics (units in seconds)

| Racecar | Mean | Median | Std. Deviation | Variance | Range | Minimum | Maximum | Total |
|----------|-----------|-----------|-------------------|----------|-------|---------|---------|-----------|
| Alpha | 241.19000 | 240.89900 | 1.339263 | 1.794 | 6.617 | 239.316 | 245.933 | 8,682.840 |
| Bravo | 240.60375 | 240.43650 | 1.124727 | 1.265 | 4.960 | 238.769 | 243.729 | 8,661.735 |
| Charlie | 240.59208 | 240.36350 | 1.126439 | 1.269 | 4.782 | 239.189 | 243.971 | 8,661.315 |
| Delta | 241.09350 | 240.93150 | 1.109515 | 1.231 | 4.936 | 239.557 | 244.493 | 8,679.366 |
| Echo | 241.98464 | 241.78150 | 0.934471 | 0.873 | 3.850 | 240.843 | 244.693 | 8,711.447 |
| Foxtrot | 241.08000 | 240.64600 | 1.336400 | 1.786 | 6.066 | 239.640 | 245.706 | 8,678.880 |
| Golf | 241.05494 | 240.72100 | 1.117807 | 1.249 | 4.249 | 239.754 | 244.003 | 8,677.978 |
| Hotel | 241.01664 | 240.80750 | 1.096013 | 1.201 | 4.875 | 239.698 | 244.573 | 8,676.599 |
| India | 240.36472 | 240.08050 | 1.079477 | 1.165 | 4.394 | 238.769 | 243.163 | 8,653.130 |
| Juliet | 240.37667 | 240.25900 | 0.823244 | 0.678 | 4.124 | 238.954 | 243.078 | 8,653.560 |
| Kilo | 240.34358 | 240.01450 | 1.093840 | 1.196 | 5.493 | 238.862 | 244.355 | 8,652.369 |
| Lima | 240.23186 | 240.07450 | 1.180765 | 1.394 | 5.551 | 238.362 | 243.913 | 8,648.347 |
| Mike | 240.47622 | 240.46150 | 1.093612 | 1.196 | 5.351 | 238.955 | 244.306 | 8,657.144 |
| November | 241.05406 | 240.84450 | 0.968436 | 0.938 | 4.196 | 239.863 | 244.059 | 8,677.946 |

4.1 NÜRBURGRING RACETRACK

The most noticeable results of Games-Howell statistical tests are the 6 instances of November racecar outperforming other racecars, while the Delta, Echo, and India racecars is each outperformed by 3 racecars (November, Mike, and Bravo). Hence, we proceed with adjusting November racecar performance. The DEA efficiency scores are deemed satisfactory in terms of discriminatory power, given that 3 out of 14 racecars' efficiency score is equal to 1 (Avkiran, 2006). The performance target shall be the one achieved by the "upper tier reference racecar", i.e. the Kilo racecar. Subsequently, we shall set the output of total required time for November racecar equal to 8.970.973 seconds and given the DEA efficiency score of 1, we shall apply percentile decrements in power and percentile increments in weight (according to simulation software) and select the combination which is less severe in terms of handicap, while simultaneously providing the same (or nearly same) efficiency score. After executing respective calculations, the selected handicap combination is 2 percent decrease in power (544 BHP along with 65.4 kgfm of torque) and 3 percent increase in weight (1,317 kg). The re-testing sessions result in total required time of 8,981.947 seconds (deviation of 0.1223% from the target performance).

The reiteration of Games-Howell statistical tests results in Mike and Bravo racecars each recording instances of outperforming Delta, Echo, and India racecars (3 in total for each). Given that Mike racecar has the smallest total required time, it is the one selected for having its performance equalized to the one recorded by the "upper tier reference racecar", which is Kilo racecar. We recalculate DEA efficiency scores, once again being satisfactory with respect to discriminatory power (2 efficient racecars out of 14). We set the total required time of Mike racecar equal to 8,970.973 and recalculate efficiency scores for combinations of percentile

power decrements and percentile weight increments. The less severe handicap combination for the revised performance target is 1 percent weight increase (1,339 kg). The subsequent re-testing session results in a total required time of 8.970.392 seconds, which responds to a miniscule deviation of -0.00647% to the target.

Reiterative execution of Games-Howell statistical tests designates requirement for Bravo racecar performance reduction, given that outperforms 3 racecars, i.e. Delta, Echo, and India. DEA efficiency score recalculation results in Bravo racecar efficiency equal to 1, while discriminatory power remains satisfactory (3 efficient racecars out of 14). The "upper tier reference racecar" is the Mike racecar, hence Bravo total required time shall be set equal to 8.970.392 seconds. Subsequent recalculation of Bravo racecar DEA efficiency, setting combinations of percentile power decrements and percentile weight increments, designates 1 percent power decrease and 2 percent weight increase as the less severe handicap. Re-testing session results in a total required time of 8,971.862 seconds, namely a mere 0.01639% deviation from the performance target. Reiteration of Games-Howell statistical tests results in no instance of statistically significant performance difference. Hence, the revised BoP scheme is fair from a statistical viewpoint.

4.2 LE MANS RACETRACK

The initial execution of Games-Howell statistical tests for all racecar pairs, results in Echo racecar demonstrating 11 instances of being outperformed, i.e. outperformed by all other racecars except for Foxtrot and Alpha racecars. The particular observation designates the need to augment the performance of Echo racecar to the performance level of the "lower tier reference racecar", which according to Table 3 is the Alpha racecar. Next, we calculate DEA efficiency scores, with Alpha, Lima, Kilo, and Mike racecars being efficient, thus designating sufficient discriminatory power (Avkiran, 2006). Hence, we set the total required time value of Echo racecar equal to 8,682.840 seconds and recalculate efficiency scores for percentile power increments and percentile weight decrements. Given the initial efficiency score of 0.9586 of Echo racecar, the less interfering advantage is 1 percent weight decrease.

Re-testing session of Echo racecar with unchanged power (528 BHP with 54.6 kgfm corresponding torque) and revised weight (1,273 kg), results in 8.666.874 seconds of total required time, i.e. 0.1838% deviation from target value. Games-Howell statistical test reiteration confirms elimination of all prior statistically significant performance differences, thus obtaining a revised BoP scheme which is fair from a statistical viewpoint.

5. CONCLUDING REMARKS

Given that no existing scientific research has stressed the subject of BoP in motorsports, current paper is definitely a novel attempt for the particular topic. Disclosure policy of motorsports organizing bodies restricting the release of technical details pertinent to BoP schemes, comprises a formidable challenge in terms of deploying the proper scientific tools for evaluating and adjusting the performance of a whole grid of racecars.

The proposed algorithm is definitely based on sound scientific methods, while its effectiveness has been adequately verified by the results of the simulated application, with the main conclusions drawn being the following:

- The segmentation of tracks with respect to attained speed/downforce as implemented by SRO, definitely
 incorporates less bias than the unified BoP scheme of the racecar simulator and organizing bodies of
 certain motorsports championships.
- Racecar performance potential assessment should be executed on a *ceteris paribus* basis, i.e. assigning testing to certain driver of very limited cadre of drivers with extensive previous experience, along with adhering to uniformity in terms of track conditions, fuel capacity, tire compound, downforce, testing distance etc.
- The concept of "upper tier reference racecar" and "lower tier reference racecar" is certainly more suitable to the single "Model Representative Car" adopted by IMSA organizing body, given that adjustments are of fairly reduced range, thus avoiding pendulum effect in racecar performance.
- Despite the transformations applied in order to deal with undesirable input (curb weight) and output (total required time), the developed DEA model based on the research of Tone (2001, 2010, 2011) has proven capable of providing revised power and weight figures of sufficient accuracy, for the purpose of

adjusting racecar performance to certain revised levels.

Regarding future research, any effort dealing with BoP schemes in motorsports should mainly focus on improved methods for detection of performance differences and subsequently seek for DEA models directly dealing with undesirable inputs and output, concurrently maintaining a satisfactory level of discriminatory power. In any case, the subject of BoP in motorsports is interdisciplinary, thus requiring researchers from different scientific fields to collaborate, in order to devise improved methods that could be adopted by motorsports organizing bodies.

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Barometer of teachers' satisfaction in terms of the organization and operation of the educational system

Sofia Meretaki University of West Attica <u>meretaki@yahoo.com</u>

Abstract

Realizing the educational policy's strategic goals depends on the quality of the educational work provided, which is linked to teachers' satisfaction. Teachers' satisfaction in terms of the way the educational system is organized and operates greatly affects their performance. It is for the first time that such a research has been conducted in Greece in order to measure teachers' satisfaction regarding the organization and operation of the educational system based on the methodology of MUSA (Multicriteria Satisfaction Analysis). The aim of this study is to assess teachers' satisfaction level so as to highlight the critical satisfaction dimensions that need improvement and determine and prioritize the improvement actions in light of the strategic planning of educational policy. The results it provides can contribute to the fulfillment of the strategic objectives of education through the effective management and the strategic reorganization of educational policy.

KEYWORDS

satisfaction barometer, teachers' satisfaction, internal customer, organization and operation of the educational system, multicriteria satisfaction analysis (MUSA), satisfaction measurement

1. INTRODUCTION

The successful implementation of the national educational strategy depends on the quality of the educational services provided by teachers. Teachers' satisfaction with the organization and operation of the educational system is inextricably linked to their performance and the delivery of high quality of educational work. As the social cohesion and economic development of the country depends on the success of the educational strategic goals, it is important to constantly improve teachers' satisfaction level. However, in order to improve the degree of teaching personnel satisfaction, it is necessary in the first instance to determine it through measurements and then analyze the factors that compose their satisfaction. This need is more urgent today than ever, considering the rapidly changing challenges that the crucial and sensitive Education sector has been facing in the context of the economic crisis that our country experienced in 2009, but also the unprecedented global health crisis due to the covid19 pandemic. This is an original study, given that the literature review shows that no similar research has been conducted in Greece in order to measure teachers' satisfaction with the organization and operation of the educational system implementing the MUSA (Multicriteria Satisfaction Analysis) method.

Customer satisfaction is defined in the literature either as an outcome of the experience of consuming or using a product or service or as an evaluation process according to client's expectations. In terms of an outcome, according to Howard & Sheth (1969), "...satisfaction is a cognitive state of the customer, regarding his adequate or insufficient reward for the sacrifices and efforts he has made...". From a process perspective, according to Hunt (1977), "...satisfaction is an evaluation process based on whether the particular experience was as good as the customer thought it would be...". The most popular definition of customer satisfaction is based on the confirmation of customer expectations. Satisfaction is a measure of how well the overall product or service offered meets customer's expectations [Oliver (1996); Hill (1996); Gerson (1993); Vavra (1997)]. Modern researchers approach satisfaction measurement by defining as customers those people who determine the quality of the products or services provided by a company, as they can express their dissatisfaction if their expectations and needs are not met [(Czarnecki (1999); Gerson (1993); Dutka (1995)]. Alternatively, Edosomwan (1993) advocates that "...a customer is the person or group of persons who receives the produced work output...". In light of this proposal, the human resources of an organization constitute the internal customers. These customers are the actual users of the products and services produced by the company's internal processes.

Teachers are internal customers as far as the organization and operation of the educational system is concerned. The aim of the study is to assess teachers' global and partial satisfaction so as to determine the critical satisfaction dimensions that need improvement and highlight the priorities of improvement initiatives. The goal of the research presented in this paper is to reveal:

- 1. How satisfied are teachers, overall?
- 2. How satisfied are teachers in terms of the five satisfaction criteria: human resources management, working conditions, personal development and empowerment, relationships and leadership skills?
- 3. How satisfied are teachers on the sub-criteria of the basic satisfaction criteria?
- 4. What are satisfaction strengths and weaknesses and what should the priorities be for improving each of the critical dimensions?
- 5. What is the amount of effort required to improve satisfaction characteristics and what is the outcome of improvement initiatives?

The paper consists of four sections. Section 2 presents briefly the MUSA methodology, emphasizing on the most important results it provides and the assessed satisfaction criteria. Section 3 is devoted to the results drawn by the data analysis and in particular the global satisfaction and the partial satisfaction dimensions. Finally, concluding remarks and future research extensions are included in Section 4.

2. METHODOLOGY

2.1. The MUSA method

According to Grigoroudis & Siskos (2009) the MUSA (Multicriteria Satisfaction Analysis) method is a dynamic tool for measuring the satisfaction of a group of people (customers, employees) according to the system of preferences and values of these individuals in total, which is considered as a single one. Based on multicriteria decision analysis, the purpose of MUSA is to collect individual evaluations from a set of respondents, composing a quantitative mathematical value function. The philosophy of the MUSA methodology is based on the assumption that the overall satisfaction of each individual customer is determined by a set of variables that constitute the characteristics of the product or service. Thus, the customer's overall satisfaction is formed based on the set of these individual characteristics that represent the criteria X=(X1, X2,...Xn) and are called satisfaction dimensions. Each respondent is asked to evaluate the provided products or services by expressing both global and partial satisfaction on each dimension.

2.2. The MUSA results

The results provided by the MUSA method are summarized below [Grigoroudis & Siskos (2009)]:

- Satisfaction functions: they reflect the assigned value of all customers to a certain qualitative level of satisfaction and determine the extent to which customer expectations are met.
- Criteria weights: they reveal the relative significance of each of the evaluated criteria.
- Average satisfaction indices: they reflect on average the level of satisfaction of the respondents in total and partially for each satisfaction dimension.
- Average demanding indices: they show the real improvement possibilities for specific criteria and the extent of the effort required to achieve the desired outcome.
- Average improvement indices: they represent the improvement margins of each criterion and depend on the importance of satisfaction criteria and their contribution to dissatisfaction.
- Action charts: they show satisfaction strengths and weaknesses and improvement actions priorities.
- *Improvement charts:* they indicate the margins of improvement and the amount of effort required for the expected outcome.

The competitive advantage of the MUSA methodology is that it takes fully into account the qualitative dimension of customer preferences collected through the expression of their views, extracting highly detailed quantitative information. Its results are immediately usable, as they determine global satisfaction and partial satisfaction dimensions, they highlight strengths and weaknesses and they identify which improvement actions ought to be prioritized for each of the critical satisfaction dimensions [(Kyriazopoulos et al. (2007)].

2.3. Satisfaction Criteria

The characteristics that make up the overall satisfaction are presented in the figure below. An original questionnaire was created based on the following satisfaction criteria hierarchy. The first part contains demographic data. The second part assesses the degree of partial satisfaction of each sub-criteria and total satisfaction of each of the five criteria. Finally, we assess the global satisfaction.



Figure 1: Satisfaction criteria hierarchy

3. RESULTS

3.1. Survey and sample

The survey took place in January 2022. An anonymous questionnaire was chosen in order to enhance the validity of the survey. The research was based on a random sample of Primary and Secondary Education teachers in Attica. One hundred twenty-eight (128) questionnaires were received. The analysis of research data is based on the methodology of MUSA and was carried out using MUSA special software.

86% of the sample were female teachers. 79% belong to the 40-59 age group. 74% are married and 42% of all respondents have children. 56% hold a master's degree. 76% have more than 13 years of teaching experience, of which 33 percentage points have more than 21 years of experience. Permanent teachers represent 84% of the sample. Participants were equally distributed in Primary and Secondary Education.

3.2. Global satisfaction analysis

This section presents the results provided by the MUSA method and highlights the strong and weak points of the organization and operation of the educational system. The results are not at all encouraging as the overall

satisfaction index reaches only 14%. The satisfaction function has a convex shape, i.e. the concavities point upwards, indicating that teachers are demanding. Therefore, they are not satisfied unless they are offered the optimal level of organization and operation of the educational system.



| Criterion | Weight (%) | Average satisfaction index (%) | Average demanding index (%) |
|------------------------------------|------------|-----------------------------------|--------------------------------|
| Human Resources Management | 34,39 | 7,50 | 74,41 |
| Labor Conditions | 11,58 | 33,58 | 22,84 |
| Personal Development & Empowerment | 25,44 | 12,89 | 66,20 |
| Relations | 17,45 | 24,46 | 48,42 |
| Leadership skills | 11,15 | 24,12 | 27,03 |
| Global Satisfaction | - | 14,01 | 53,13 |

Human resources management system and possibilities for personal development and empowerment seem to have a significant contribution to global teachers' satisfaction, given that they are the two most important criteria with a weight of 34% and 25%, respectively. They show a remarkably large room for improvement, as the average satisfaction index reaches only 8% and 13%, respectively, being the lowest average level of satisfaction in relation to the rest of the dimensions, while they show an even lower level of satisfaction compared to the extremely low overall satisfaction index (14%). Teachers are quite demanding, since the average demanding index for human resources management is 74% and for personal development and empowerment is 66%, which implies a particularly high effort to increase their satisfaction.





Figure 5: Basic criteria improvement chart

Action and improvement charts confirm these findings. Human resources management and personal development and empowerment belong to the action area, i.e. the lower right quadrant with weaknesses, which is the first priority of improvement actions (Figure 4). They are the most critical characteristics that need improvement to increase teacher satisfaction, since they are important criteria for which teachers are not satisfied. Improvement efforts should be focused on these two dimensions, as they show high impact and demanding, in the upper right quadrant (Figure 5).

3.3. Satisfaction dimensions analysis

The results presented in the following table reveal additional information as far as analytical satisfaction dimensions are concerned.

Table 2: Results of analytical dimensions of satisfaction

| Criterion | Sub-criterion | Weight (%) | Average satisfaction index (%) | Average demanding index (%) |
|---------------------------|---|---------------|--------------------------------------|-----------------------------------|
| | Personnel recruitment | 10,57 | 25,23 | 24,28 |
| Human | Staffing in responsibility position | 18,26 | 14,47 | 56,19 |
| Resources | Wages | 13,13 | 15,30 | 39,07 |
| Management | Training | 13,13 | 18,63 | 39,07 |
| | Evaluation | 44,91 | 3,52 | 81,30 |
| | Working environment | 12,08 | 35,12 | 17,21 |
| Labor | Frame of work | 11,37 | 41,98 | 12,02 |
| Conditions | Tools | 18,31 | 17,21 | 45,39 |
| | e-learning | 58,24 | 3,85 | 81,69 |
| | Professional development | 11,44 | 19,71 | 38,21 |
| Deveewel | Personal development | 9,99 | 29,97 | 33,28 |
| Personal Development 8 | Guidance | 38,45 | 4,65 | 80,58 |
| Development & | Support | 23,83 | 7,42 | 70,91 |
| Empowerment | Autonomy | 8,67 | 42,48 | 23,10 |
| | Participation in decision making | 7,62 | 43,45 | 11,61 |
| | Collaboration | 14,70 | 71,04 | -32,00 |
| Delettere | Recognition | 11,96 | 47,24 | 14,74 |
| Relations | Feedback | 58,53 | 10,13 | 82,23 |
| | Education Directorate Service | 14,80 | 32,25 | 32,45 |
| | Empathy | 7,57 | 52,08 | 0,50 |
| Leadership | Active listening | 7,04 | 50,75 | 5,36 |
| | Conflict resolution | 7,07 | 50,03 | 5,67 |
| Skills | Crisis management | 7,09 | 50,22 | 6,03 |
| | Ministry is aware of teacher profession needs | 54,64 | 2,54 | 28,62 |
| | Ministry takes into account teachers' opinion | 16,58 | 3,95 | 58,99 |

1. Evaluation is human resources management system weakness, since it represents the dimension to which teachers attribute the greatest importance and appear highly demanding, and yet it scores the lowest average satisfaction index. In fact, it has a lower level of satisfaction than both the other sub-criteria and the overall satisfaction index.

- 2. As far as labor conditions are concerned, teachers are not at all satisfied with the way e-learning was organized by the Ministry of Education during the pandemic, while it is a very important dimension for global satisfaction and teachers are very demanding, so it will take a lot of effort to achieve the expected improvement. It presents a significantly lower level of satisfaction than both overall satisfaction and the sub-criteria, i.e. tools provided, environment and work context.
- 3. Guidance and support are the most critical dimensions regarding their satisfaction with the possibilities of personal development and empowerment, as they are the criteria with the highest level of significance and the lowest degree of satisfaction. In the meanwhile, teachers appear demanding, therefore a great effort is required to increase their satisfaction.
- 4. In terms of relations, the feedback they receive on their work is particularly important to teachers and they present a high level of demanding, so a lot of effort is needed to achieve high impact. However, this sub-criterion has the lowest degree of satisfaction, even lower than the total satisfaction index.
- 5. Teachers are not satisfied with the extent to which the Ministry of Education is aware of their profession needs, which is the most critical dimension of their satisfaction concerning leadership skills. At the same time, they are not satisfied with the degree to which their opinion is taken into account and they are highly demanding, however they do not attribute as much weight to this characteristic as to the sub-criterion concerning the degree to which the Ministry of Education is aware of their job needs.

4. CONCLUSIONS

The results of the presented survey reveal that the teaching members of staff enjoy little satisfaction. The MUSA method is an innovative administrative tool for rational decision-making. Highlighting strengths and weakness of the organization and operation of the educational system and prioritizing the importance of improvement actions for the critical dimensions of satisfaction, it contributes to the strategic planning of educational policy that will increase teachers' satisfaction, optimizing their performance and ensuring the continuous improvement of high quality in education. In this direction, critical satisfaction dimensions on which improvement initiatives should be focused include:

- the existing evaluation system
- the way of organizing and implementing e-learning during crisis
- the development of a framework of effective guidance and constant support for teachers
- the creation of a system of interaction by providing communication possibilities between the parties involved to ensure feedback to teachers
- the development of an administrative framework that will allow the Ministry of Education to be aware of the teaching profession needs and take into account teachers' opinion.

Limitations of the study consist in the limited time allowed to complete the questionnaires and the local scope of the sample. An idea for a future survey could be to measure satisfaction of a larger sample on a national basis in order to draw conclusions for segmented groups of participants. In view of the rapidly changing conditions, an equally important extension concerns the adoption of a permanent teacher satisfaction barometer. A portal could be set up, where 2,000 teachers could submit their views on a regular basis. Satisfaction barometer allows systematic monitoring over time of upcoming changes in teachers' demands, enabling to assess the impact of potential improvement actions. In this way, it contributes to the continuous improvement of the organization and operation of the educational system in the context of the ever-changing environment, ensuring thus teachers' satisfaction.

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The risk of poverty and social exclusion for single-parent families and big families during the crisis

Dimitra Melidi MSc 'Health and Social Care Management University of West Attica

Anastasios Sepetis MSc 'Health and Social Care Management University of West Attica Dimitra Latsou MSc 'Health and Social Care Management University of West Attica Chrysostomos Natsis MSc 'Health and Social Care Management University of West Attica

George Pierrakos MSc 'Health and Social Care Management University of West Attica

Abstract

Background: At the global level, the issues related to poverty and social exclusion are an integral part of the current affairs and their treatment emerges as an issue of the highest priority.

Aim: The aim of this paper was to examine the indicators related to the risk of poverty of single-parent and big families in Greece during the socioeconomic crisis of 2010-2018.

Method: The present analysis focuses on the study of the index of risk of poverty or social exclusion in single-parent and large-child families through an overview of the available statistical data. The main source of data for the evolution of the risk of poverty in Greece during the crisis is the Hellenic Statistical Authority (ELSTAT) from 2009 to 2021. Accordingly, the data concerning the European Union 27 comes from the Eurostat Database and concerns the years 2013 - 2021.

Results: According to the ELSTAT data (2021), 32.1% of single-parent households in 2009 were at risk of poverty. This rate increased at 43.2% in 2011 and at 66% in 2012. However, the risk of poverty for a person with dependent children remained high in 2021 (30.1%). Moreover, large families (with two adults and three or more dependent children) were at risk of poverty during economic crisis. In 2009, the at-risk-of-poverty rate was estimated at 28.6% and increased at 36.8% in 2012, which remained in high level even in 2021 (28.5%). The corresponding percentages for families with two children are around 25% during economic crisis.

Conclusion: During the economic crisis, single-parent families were more at danger of poverty and social exclusion, and households with three or more dependents were much more at risk. Our findings illustrate unequivocally the significance of well-functioning safety nets in reducing poverty and especially for single-parent and big families.

KEYWORDS:

risk of poverty, social exclusion, big families, single-parent families

1. INTRODUCTION

The global economic crisis that hit the country during the period 2010-2018 resulted in causing economic difficulties to the population with a direct impact on the living conditions of the population and the country's well-being. The fiscal austerity measures implemented since 2010 in Greece led to a dramatic worsening of poverty indicators in the country [1].

In particular, 28.1% of the Greek population was estimated to be at risk of poverty or social exclusion in 2008, increasing significantly during the crisis. In 2012 it amounts to 34.6% of the population with a higher percentage in 2014 which amounted to 36% of the population (i.e. 3,884,700 people). In the following years there is a steady decrease in the index of about 1% per year. However, a decade after the start of the crisis, this risk still exists as in 2022 it was estimated at 26.3% [2]. In contrast, the poverty rate in the European Union (EU) was around 17% in the years 2011-2018 [4]. Compared to European data, Greece during the crisis, but even today, is among the countries with the highest rates of risk of poverty and social exclusion in the EU.

Historically, single-parent and large-child families faced an increased risk of poverty compared to other family structures in Greece. The crisis has had a profound impact on these vulnerable types of households, exacerbating their pre-existing challenges. According to data from EU-SILC, 13% of households in the European Union consist of large families, while single-parent families represent 15%. Accordingly, Greece is

among the European countries with the lowest percentages of multi-child or single-parent households (1.6% and 8% respectively).

The aim of this paper was to examine the indicators related to the risk of poverty and social exclusion of single-parent and big families in Greece during the socioeconomic crisis of 2010-2018.

2. METHODOLOGY

The present analysis focuses on the study of the index of risk of poverty and social exclusion in single-parent and large-child families through an overview of the available statistical data. The main source of data and official indicators for the evolution of the risk of poverty in Greece during the crisis is the Hellenic Statistical Authority (ELSTAT) [2,3]. The years considered are from 2009 to 2021 (latest data available). Accordingly, the data concerning the European Union 27 come from the Eurostat database [5] and the years examined are from 2013 (latest data available) to 2021.

3. RESULTS

According to the ELSTAT data (2021) [2], 32.1% of single-parent households in 2009 were at risk of poverty. In comparison, the corresponding risk for households with 2 parents and 2 dependent children amounted to 22.4%. Subsequently, during the first four years of the crisis, the index had an upward trend with significant fluctuations. It is characteristic that in a two-year period the percentage of single-parent families at risk of poverty increased significantly (2011: 43.2%) with a peak in 2012 where 66% of single-parent families were at risk of poverty. In 2021 the risk of poverty for a person with dependent children was estimated at 30.1% (**Figure 1**).

In addition, it is observed that large families (with two adults and three or more dependent children) present high rates of poverty risk. Already from the beginning of the crisis (2009) 28.6% of large families were at risk of poverty. This risk clearly increased from 20.8% in 2011 to 36.8% in 2012. During the crisis the poverty index fluctuates with relative fluctuations of around 30%. The corresponding percentages for families with two children are around 25%. Recent data from ELSTAT (2021) show that the poverty rate for people living in large families was estimated at 28.5% in 2021, while for families with two children it is much lower (18.1%) (**Figure 1**) [2].





Similar are the data from Eurostat Database [5] regarding the poverty index by type of household. In particular, it is observed that single-parent families and large families are in the groups at high risk of poverty or social exclusion compared to families with 2 adults and 2 children (**Figure 2**). The poverty index for single-parent families was approximately 33% in the years 2013-2021, for large families 26%, while for families with 2 adults and 2 children it was much lower (14%).



Figure 2: The at-risk-of-poverty rate by household type, in EE27, Source: Eurostat Database 2023 [5]

To confirm the above, the consumption costs of the sub-examination of family types are presented. Compared to the other types of families with dependent members, single-parent families seem to have the lowest consumption rate over time, even before the crisis (**Figure 3**). Specifically, in 2008, single-parent families have expenditures of 1,932 euros, which constitute 91.2% of the average expenditure of all households (\pounds 2,117.67). During the crisis single-parent families reduced spending to \pounds 1826.19 in 2010, while the average monthly expenditure was \pounds 1956.42. Two years later (2012) the expenditure decreased to \pounds 1,268.64, resulting in 77.5% of the average expenditure amounting to \pounds 1,637.10. The burdened position and the difficulties that single-parent families had to face can be seen. During the course of the crisis over the next four years, it appears that consumer spending (compared to the average monthly expenditure) increased by 99.1% (\pounds 1,446.77) in 2014 and 90.2% (\pounds 1,256.13) in 2018.

In addition, it is observed that the size and the dependent members that make up the household increase, the needs they have to serve also increase, and therefore the consumption expenditures (Figure 3). In particular, families with many children spent \in 3,056.18 in 2008, which is 144.3% of the average monthly expenditure in Greece (\notin 2,117.67). In the following years 2009-2012, a steady decrease in expenditure was observed, which decreased to \notin 2,585.5 (132.2% of the average household expenditure) in 2010 and \notin 2,348.28 (143.4%) in 2012. during the economic crisis, the downward trend of consumer spending by families with many children, which are higher than the average household, continued. Specifically, the expenses of families with many children constitute 138.0% (\notin 2,015.88) in 2014 and 149.7% (\notin 2,083.46) of average households (\notin 1,460.52 and \notin 1,392.03 respectively).



Figure 3: Average monthly consumer expenditure by household type, Source: Hellenic Statistical Authority, 2021 [5]

4. **DISCUSSION**

The paper examined the at risk of poverty rates of single-parent and big families in Greece during the economic crisis of 2010-2018. Our results showed that both single-parent and big families were at high risk of poverty, compared to families with 2 adults and 2 children, as well as the corresponding rates of EE.

Single-parent families are at greater risk of experiencing persistent poverty compared to households of different composition [6]. Going deeper, 80% of single-parent households in Greece are represented by women. In this type of households, social transfers have relatively little effect on reducing the risk of poverty [7]. Single-parent households are at increased risk of poverty during the economic crisis, as wages have suffered significant cuts. On the other hand, the combination of income in families with two adults may compensate for income losses [8]. Similarly, in the categories of households with dependent children, it is observed that large families (with two adults and three or more dependent children) also present high rates of risk of poverty.

Regarding the protection of the family, at the European level the data show differences. Expenditures for family and child protection in the form of family benefits amounted to 330 billion euros in 2014 in the EU, therefore representing 8.6% of total social benefits, which consist of benefits for the elderly (45.9%) and health, sickness and disability benefits (36.5%) [9]. Greece belongs to the countries with the smallest family and child benefits, representing only 4.4% of total social benefits in 2014, followed by Portugal (4.6%) and the Netherlands (3.1%). At the same time child and family benefits account for 15.6% of social benefits in Luxembourg, 13.1% in Ireland and 11.9% in Hungary.

On average in the EU the costs for family benefits approach the amount of \pounds 651 per inhabitant. Greece belongs to the countries where the expenditure in this particular category is significantly below the European average with expenditure less than 200 euros per inhabitant (Greece, 2014: \pounds 184) as well as Romania (\pounds 91), Bulgaria (\pounds 182), Portugal (\pounds 195 euros) and others. In contrast, the countries with the highest percentage of spending on family protection per inhabitant are Luxembourg (\pounds 3,090), Denmark (\pounds 1,668), Sweden (\pounds 1,368), Finland (\pounds 1,212), Germany (\pounds 1,132) and others [9].

5. CONCLUSIONS

The socioeconomic crisis in Greece has had severe repercussions on the living conditions and ability of households to meet their basic needs. The data indicates a significant increase in material deprivation, a heightened risk of poverty, and a decline in the quality of life for various types of households, particularly single-parent and larger families. The economic crisis not only strained Greece's economy but also significantly disrupted the living conditions and well-being of single-parent and large families. The crisis had a disproportionately adverse impact on single-parent households and those with three or more dependents in Greece. This led to a significant deterioration in the socio-economic status of extended families and single-parent households, increasing their vulnerability to poverty and social exclusion.

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Solving the Maximum Coverage Location Problem in the Class of Irregular Polygons

Sergiy Yakovlev Lodz University of Technology al. Politechniki 8, 90-924 Lodz, Poland Adam Wojciechowski Lodz University of Technology al. Politechniki 8, 90-924 Lodz, Poland Dmytro Podzeha National Aerospace University Chkalova st. 17, 61070 Kharkiv, Ukraine Iryna Yakovleva National University of Urban Economy in Kharkiv, Marshala Bazhanova st. 17, 61002, Kharkiv, Ukraine

Abstract

The Maximum Coverage Location Problem (MCLP) is studied when both the demand zone and the service areas have different sizes and irregular polygonal shapes. Each service area is associated with a centroid, relative to which the polygon vertex coordinates are determined. The task is to find such a location of the polygons that provides maximum service coverage. The novelty of this work lies in the fact that arbitrary irregular geometric items are considered. The MCLP mathematical model is formulated as a non-linear optimization problem, where the variables are the polygon placement parameters, and the objective function defines the area of the zone covered by demand. Since it is very difficult to analytically determine the objective function. To solve the problem, an approach is implemented that combines the local and global optimization stages. For local optimization, the BFGS method was used, in which the gradients were calculated by first-order differences. The multi-start method is implemented for global optimization. To speed up the search for local solutions, an auxiliary task is formulated based on the construction of an elastic model of the packing problem. The proposed approach has been tested in solving MCLP for various polygonal shapes of coverage demand and service areas.

KEYWORDS

Maximum coverage location problem, demand zone, service area, irregular polygon, mathematical model, optimization.

1. INTRODUCTION

The maximum coverage location problem (MCLP) is of great theoretical and practical interest, as it is related to a wide range of applications. Theoretically, such a problem is studied in operations research theory and computational geometry. The maximum coverage of areas is associated with video surveillance systems, warning systems, environmental monitoring, image processing, service maintenance, etc. This raises the problem of analyzing the location of objects providing services based on spatial proximity. Spatial location reflects service coverage and can be regular or irregular, contiguous or fragmented in area. One of the most common approaches to item location modelling is based on solving MCLP.

The problem of item location analysis based on modelling coverage problems is considered in detail in [1]-[4]. The article [5] provides an extended overview highlighting the application, solution, development and generalization of this important analytical approach to location. With the development of mathematical modelling tools and computational technologies, the formulation of the MCLP has been significantly generalized and extended, considering applications to various domains such as the location of police stations, the allocation of emergency response centers, the placement of drone facilities to provide various services, the positioning of antennas, the placement of charging stations for electric vehicles, and many others. It is necessary to construct appropriate mathematical models of the listed tasks, taking into account the geometric properties of the demand zone and service areas.

In the initial publications devoted to the solution of MCLP [6], [7], the demand was presented as point data without measurement, which was a significant limitation when building a mathematical model.

Typically, demand is distributed continuously over a unit area of a certain geometric shape, and such a distribution must be taken into account when specifying the site [8]-[11]. Recent studies have therefore used continuous regional representations of demand. This requires a deep understanding of the spatial description of demand and service areas, such as their size, shape and relative position, and incorporating this information into location modelling. The widespread use of geographic information systems and digital

spatial information increases the importance of exploring alternative shape representations of both demand and service areas when modeling their location. The originality of this paper lies in the study of MCLP in continuous representation using irregular polygonal demand and service areas.

2. PROBLEM STATEMENT

The maximum coverage problem in the general setting is formulated as follows. There are the demand zone and the family of service areas. Each service area is associated with a point, called a centroid, relative to which its shape and sizes are specified. The problem is to determine such a position of centroids and the location of the corresponding service areas in order to provide maximum service coverage of the demand zone. Restrictions can be placed on the position of the centroids that define their allowable location. The mathematical model of MCLP depends on the ways of specifying demand and service areas, the formation of the objective function and restrictions.

The following notation will be used for further presentation: $J_n = \{1,...,n\}$, $J_n^0 = \{0,1,...,n\}$ - the numbering sets; S_0 - the demand zone; S_i , $i \in J_n$ - the service areas; c_i , $i \in J_n$ - the centroids.

Within the framework of this article, we will assume that the demand zone S_0 and a service area S_i , $i \in J_0$

have a polygonal shape. Let Oxy be a Cartesian coordinate system in the Euclidean plane E^2 . To define the shape and size of a polygon S_i , one can specify the coordinates of its vertices. This allows the equation $f_i(P) = 0$ of polygon boundary to be formed using the equations of lines passing through its adjacent vertices.

Then polygon S_i is a set of points $P = (x, y) \in E^2$ that satisfy the inequality $f_i(P) \ge 0$.

Let $O_i x'y'$ be our own Cartesian coordinate system of polygon S_i with the origin O_i at point c_i . A location of S_i in Oxy is determined by its placement parameters $p^i = (x_i, y_i, \theta_i)$, where (x_i, y_i) are the coordinates of the centroid c_i ; θ_i is the angle of rotation $O_i x'y'$ relative to Oxy.

3. MATH MODELING

Consider a parametric family of polygons S_i(pⁱ) defined by the so-called general equation of position

$$F_{i}(P,c_{i},\theta_{i}) = f_{i}(A_{i}(P-c_{i})) = 0, A_{i} = \begin{pmatrix} \cos\theta_{i} \sin\theta_{i} \\ -\sin\theta_{i} \cos\theta_{i} \end{pmatrix}.$$

A polygon $S_i(p^i)$ with placement parameters p^i will be called parameterized.

Using the logical operators union and intersection, we define a parameterized complex polygon

$$S(p^{1},...,p^{n}) = S_{0}(p^{0}) \bigcap \bigcup_{i=1}^{n} S_{i}(p^{i}).$$
 (1)

We fix the position of polygon S_0 by setting $p^0 = (0, 0, 0)$. Thus, parameterized complex polygon $S(\mathbf{p}) = S(p^1, ..., p^n)$ for any $\mathbf{p} = (p^1, ..., p^n)$ is the set of points $P = (x, y) \in S_0(p^0) \subset E^2$ that satisfy at least one of the inequalities $f_i(P, p^i) \ge 0$, $i \in J_n$.

Let us introduce the characteristic function

$$\lambda(\mathsf{P},\mathbf{p}) = \begin{cases} 1, \text{ if } \mathsf{P} \in \mathsf{S}(\mathbf{p}); \\ 0, \text{ if } \mathsf{P} \notin \mathsf{S}(\mathbf{p}). \end{cases}$$

Then the function

$$\mu(\mathbf{p}) = \iint \lambda(\mathbf{P}, \mathbf{p}) d\mathbf{P}$$
(2)

defines the dependence of the area of parameterized complex polygon $S(\mathbf{p})$ on the placement parameters $\mathbf{p} = (p^1, ..., p^n)$. This means that $\mu(\hat{\mathbf{p}})$ determines the area of a complex polygon $S(\hat{\mathbf{p}})$ for any fixed placement parameters $\hat{\mathbf{p}} = (\hat{p}^1, ..., \hat{p}^n)$.

Summarizing the above, the maximum coverage location problem can be formulated as follows:

$$\mu(\mathbf{p}) \rightarrow \max$$
 (3)

subject to $\mathbf{p} \in D$, where D is feasible domain of placement parameters $\mathbf{p} = (p^1, ..., p^n)$.

The solution of such problem is much more complex due to its large dimension and multi-extremality. This explains the need to develop special optimization methods that take into account the features of objective function (3).

4. SOLVING THE OPTIMIZATION PROBLEM

We propose an approach based on the combined use of local and global optimization techniques. At the stage of local optimization, the specific properties of the function $\mu(\mathbf{p})$ are used, based on geometric considerations. Consider the features of the local optimization stage. Formalization of the objective function causes great difficulties for irregular polygons S_i , $i \in J_n^0$. Unfortunately, it is impossible to obtain an analytical

expression for function $\mu(\mathbf{p})$ in the form of a dependence on the variables $\mathbf{p} = (p^1, ..., p^n)$. Indeed, for this it is necessary to carry out integration, moreover, over a domain that depends on the parameters. Therefore, the approach to calculating the function using modern computational geometry libraries is promising.

There are a large number of libraries that allow you to form a complex geometric shapes, in particular, SymPy,

Shapely, CGAL, SpaceFuncs. To calculate function $\mu(\mathbf{p})$ for fixed placement parameters $\hat{\mathbf{p}} = (\hat{p}^1, ..., \hat{p}^n)$ of irregular polygon, we used the Python Shapely library [12]. The Shapely package allows to perform operations on polygons using the basic logical operators. As a result, you can build a complex polygon from a set of original polygons. In this case, the area of a complex polygon is calculated automatically in the process of its formation.

The choice of an effective method for optimizing a function essentially depends on the time it takes to calculate the values of the objective function $\mu(\mathbf{p})$. Unfortunately, this time increases non-linearly with the number of polygons involved in the formation of a complex polygon. Therefore, at the stage of local optimization of the function $\mu(\mathbf{p})$, it is proposed to approximate its values by solving an auxiliary problem. It

is clear that $\mu(\mathbf{p})$ will be the greater, the smaller the total area of pairwise overlapping of polygons $S_i(p^i)$ and $S_i(p^i) \quad \forall i, j \in \mathbf{J}_n, j > i$, as well as the area of overlapping $S_i(p^i)$ and the complement to $S_0(0) \quad \forall i \in \mathbf{J}_n$.

The total area of pairwise overlapping can be determined by the formula

$$\sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mu_{ij}(p^{i}, p^{j}) + \sum_{i=1}^{n} \mu(S_{i}) - \sum_{i=1}^{n} \mu_{i0}(p^{0}, p^{i}),$$

where $\mu_{ij}(p^i, p^j) \quad \forall i, j \in J_n^0$, j > i are the functions that determine the dependence of overlapping area of parameterized polygons $S_i(p^i)$ and $S_i(p^i)$ on their placement parameters p^i and p^j .

Taking into account that the areas of polygons $S_i, i \in J_n$ do not depend on their placement parameters, we can formulate the following auxiliary minimization problem

$$\tilde{\mu}(\mathbf{p}) = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mu_{ij}(p^{i}, p^{j}) - \sum_{i=1}^{n} \mu_{i0}(p^{0}, p^{i}) \to \min.$$
(4)

To calculate functions $\mu_{ii}(p^i, p^j)$, one can use used the Python Shapely library.

Model (4) is the generalization of the Elastic (quasi-physical quasi-human) model proposed in [13]-[15] for the optimal packing problem of circular items. The advantage of our model lies in the possibility of using it for geometric items of arbitrary shape. In our case, functions $\mu_{ij}(p^i, p^j)$ correspond to the elastic potential energy of extrusion.

Various methods can be chosen for local optimization of both functions $\mu(\mathbf{p})$ and $\tilde{\mu}(\mathbf{p})$. We used the Broyden-Fletcher-Goldfarb-Shanno (BFGS) method [16]. Note that although the function is differentiable, it is not possible to find analytical expressions for its gradients. Therefore we use a first order differences.

At the stage of global optimization, we use a multi-pass method for regulating the local extrema of the function $\tilde{\mu}(\mathbf{p})$. Upon completion of this stage, we determine the polygon placement parameters $\tilde{\mathbf{p}} = (\tilde{p}^1, ..., \tilde{p}^n)$ that correspond to the best solution. Then we choose $\tilde{\mathbf{p}} = (\tilde{p}^1, ..., \tilde{p}^n)$ as the starting point for local optimization of the function $\mu(\mathbf{p})$.

5. NUMERICAL TESTING

Let us illustrate the solution of problem (3) with the following initial data. The square-shaped demand zone S_0 and a family of n = 40 service zones S_i , $i \in J_n$ in the shape of polygons are given. The area of a square S_0 is 66677.6, and the total area of 40 polygons is 66678.3.

We carried out numerical experiments on a computer with the following configuration: Intel Core i7-5557U processor, CPU Speed 3.1 GHz, 2 cores, 4 threads; RAM 16 GB DDR3 1866 MHz; SSD 512 GB; Operating system Mac OS X11.0 Big Sur.

For global optimization of the function $\tilde{\mu}(\mathbf{p})$, a multistart method was used, during which various initial locations of polygons were generated and local optimization was carried out. To set the initial location of polygons $S_i(\hat{p}^i)$, $i \in J_n$ the placement parameters $\hat{p}^i = (\hat{x}_i, \hat{y}_i, \hat{\theta}_i)$ were randomly generated uniformly in such a way that $(\hat{x}_i, \hat{y}_i) \in S_0(\mathbf{0})$, $\hat{\theta}_i \in (0, 2\pi)$, $i \in J_n$.

Local optimization was performed by BFGS method using the Scipy.optimize Python library. As an example, in Figure 1 shows the location of the polygons corresponding to the local optimum of the function $\tilde{\mu}(\mathbf{p})$ for one of the starting point $\hat{p}^{i} = (\hat{x}_{i}, \hat{y}_{i}, \hat{\theta}_{i})$. With this location, the area covered by services is equal to 63173.14.

The best result when generating 100 starting points is shown in Figure 2. In this case, the area covered by services is equal to 63483.07. Further improvement of this solution, choosing it as a starting point for local optimization of the function $\mu(\mathbf{p})$, yielded 63483.48. We do not provide the corresponding figure, since visually it does not differ from the previous one.





Figure 1: Locally optimal location using BFGS method

Figure 2: The best location using the multistart method

The total runtime for solving the test problem was 1700 sec. This substantiates the expediency of using an auxiliary problem at the stage of global optimization. An analysis of the results confirms the validity of using the auxiliary problem at the stage of local optimization, since the local optima of the functions $\mu(\mathbf{p})$ and $\tilde{\mu}(\mathbf{p})$ are very close. Moreover, the use of the multistart method is also justified due to the high efficiency of local optimization methods.

6. CONCLUSIONS

As a result of the research, The Maximum Coverage Location Problem was studied when both the demand zone and the service areas have different sizes and irregular polygonal shapes. The MCLP mathematical model is formulated as a non-linear optimization problem, where the variables are the polygons placement parameters, and the objective function defines the area of the zone covered by demand. To solve the problem, an approach is implemented that combines the local and global optimization stages. For local optimization, the BFGS method was used, in which the gradients were calculated by first-order differences. The multi-start method is implemented for global optimization. To speed up the search for local solutions, an auxiliary task is formulated based on the construction of new elastic (quasi-physical quasi-human) model. The effectiveness of the proposed approach is confirmed by the example of test MCLP for polygonal shapes of demand zone and service areas.

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Surveillance in Logistics Facilities and Ports via UAVs Using YOLOv3 Algorithm

Georgios Tepteris, Konstantinos Mamasis, Ioannis Minis ¹ Department of Financial & Management Engineering, School of Engineering, University of the Aegean, 41 Kountouriotou Street, 82100, Chios, Greece, <u>fmed20005@aegean.gr</u>; <u>k.mamassis@aegean.gr</u>; <u>i.minis@aegean.gr</u>

Abstract

We investigate advanced methods for improving security and preventing intrusions in logistics hubs and ports. For this purpose, we employ unmanned aerial vehicles (UAVs) and object detection artificial intelligence (AI) methods. In recent years, UAVs have become an increasingly popular tool for surveillance due to their ability to provide real time video feed from difficult or inaccessible areas. Leveraging these UAV strengths, we use the YOLOv3 algorithm for real time object detection in surveillance images captured by UAVs. We train the YOLOv3 algorithm using various combinations of three UAV-generated datasets; VisDrone, DAC-SDC and the Stanford Drone Dataset. We then test the model versions obtained from each training dataset on independent images created under practical conditions. The results demonstrate the importance of robust training by using a dataset that has similar characteristics with the environment in which the system will operate.

KEYWORDS

UAVs, image detection, logistics 4.0, automated surveillance

1. INTRODUCTION

Logistics hubs are areas that require robust security. Unmanned aerial vehicles (UAVs) have become increasingly popular tools for surveillance in such environments, owing to their ability to provide real-time video feeds from inaccessible or challenging areas. In this study, we investigate an advanced method for intrusion detection using an AI method based on the YOLOV3 model tuned to detect objects from images captured by UAVs. We train the model using various combinations of three public UAV datasets: VisDrone, DAC-SDC, and the Stanford Drone Dataset and for each combination, we create a corresponding model version. We test all resulting model versions using a new dataset created through video feeds captured during UAV flights. Our results point towards guidelines of effective training for improved performance. The proposed experimental set up also contributes to the field of automated security in logistics hubs and ports using UAVs.

2. BACKGROUND AND RELATED WORK

Logistics facilities present challenges to security surveillance due to their large physical spaces (IFSEC GLOBAL, 2021). Closed Circuit TV (CCTV), a common method employed for security surveillance of such facilities, requires continuous human supervision and interpretation, which is labor intensive and, thus, costly (Toshiyuki & Johan, 2004). Additionally, CCTV footage is oftentimes of low resolution and has limited field of view, requiring multiple cameras and resulting in blind spots (IFSEC GLOBAL, 2021). The above problems can be overcome by implementing a UAV-based end-to-end system for automated real-time detection of malicious activity, process it in real-time and output appropriate alerts based on the activity detected. These alerts can be generated using Computer Vision (CV) algorithms trained to detect suspicious activity (Mishraa, et al., 2020; Xie, et al., 2021). This approach requires a fast and efficient algorithm for identifying suspicious activity. Sing, et al. (2018) proposed a two-stage approach for this task. The first stage is a Feature Pyramid Network (FPN) for accurate detection of humans from aerial video, and the second stage is a ScatterNet Hybrid Deep Learning model for pose estimation and classification of violent behavior. Computer Vision (CV) algorithms require considerable hardware resources which are challenging for UAVs due to their limited space and weight capacity. To address this, lightweight and powerful devices have been developed for onboard or off-board use (Liu & Szirányi, 2021; Hossain & Lee, 2019).

3. METHODOLOGY

3.1 YOLOv3 Algorithm Overview

YOLOv3 (You Only Look Once version 3) is a highly efficient and accurate object detection algorithm that is suitable for real-time applications. It was introduced in 2018 by (Redmon & Farhadi, 2018) and is an improvement over previous versions (YOLOv2 and YOLO). It has better accuracy and can detect a wider range of objects compared to its previous versions. The YOLOv3 algorithm works by dividing the input image into a grid of cells and predicting bounding boxes, objectness scores, and class probabilities for each cell. Each bounding box is associated with an objectness score that indicates the likelihood of an object being present in that bounding box. YOLOv3 uses a deep neural network with fifty-three convolutional layers and skip connections, allowing the network to detect objects at different scales and resolutions. The network outputs feature maps of different sizes, which are then used to predict objects at different scales. Finally, YOLOv3 uses anchor boxes to obtain the final bounding box predictions.

3.2 Method for training and model validation

This work focuses on detecting intrusions (persons and cars) in logistics facilities using UAVs. The YOLOv3 training method is critical for the system's performance and the method we propose is the following:

- 1) Identify appropriate and annotated datasets.
- 2) Train the YOLOv3 network
 - a) Define various training datasets. Each training data set consists of one or a combination of the identified annotated sets.
 - b) Train multiple model versions: one per training data set
 - c) Assess the effectiveness of training in terms of mean average precision (mAP). mAP is a widely used indicator to assess performance in object detection. It calculates the mean average precision across various precision-recall trade-off levels; higher mAP values indicate better recognition quality (Beitzel, Jensen, & Frieder, 2009)
- 3) Validate the performance of the various trained model versions
 - a) Generate a new (independent) set of images, precisely fitting the application in hand (detection of suspicious behavior in two different places with different altitudes and lighting conditions).
 - b) Annotate the new (independent) dataset (manually).
 - c) Test the performance of all YOLOv3 model versions using the annotated dataset.
 - d) Compare the performance of the model versions in a) the training test sets, vs. b) the independent dataset and use the results to develop training guidelines.

4. DATASETS AND EXPERIMENT DESIGN

4.1 Public datasets for training

Several image datasets have been thoroughly studied, annotated, and pre-processed by the research community for work related to the UAV image detection task, such as that of this project. The ones used in this study for model training are presented in Table 1, which provides the number of images comprising the training, validation, and testing subsets, as well as the related object classes.

- The VisDrone-DET (Zhu, et al., 2021) dataset features various objects; the images were extracted from heights ranging from 8 to 30 meters, with varying lighting conditions spanning day and night. For this work we retained the images that contained the person and car classes (8,629 images).
- From the DAC-SDC dataset (Xu, et al., 2021), we retained only the images corresponding to the Person and Car categories. The images were also captured by a range of altitudes (15-20 m) and lighting conditions (sunny and night).
- Finally, for the Stanford Drone Dataset (Robicquet, et al., 2016) the captured imagery was obtained at an altitude of 80 meters, with prevailing sunny lighting conditions. From this data set all images were used (7,531 images).

| Dataset | Training subset | Validation subset | Testing subset | Object classes |
|----------------|--------------------|----------------------|----------------|--|
| VisDrone | 6,471 | 548 | 1,610 | Persons, cars, pedestrians, vans, buses, truc motorcycles, bicycles, awning-tricycles, tricycles |
| DAC-SDC | 39,534 | 6,517 | 6,928 | Boat, building, car, person, drone, horseride, paraglid riding, truck, wakeboard, whale |
| Stanford Drone | 6,022 | 754 | 755 | Pedestrian, biker, skater, cart, car, bus |
| Total | 52,027 | 7,819 | 9,293 | |

| Table 1 | L: Distribution | of retained | annotated | images | per | dataset |
|---------|-----------------|-------------|-----------|--------|-----|---------|
| Tuble 1 | L. Distribution | orretunica | unnotated | muges | per | uutuset |

4.2 Experimental design

Training was processed on a computer with an AMD Ryzen 9 3900X processor, 32 GB RAM and NVIDIA GeForce RTX 3090 graphics card. The weights of the YOLOv3 model were initialized based on the Darknet-53 model (originally trained with ImageNet). Five hyperparameters were tuned: the maximum number of batches, the maximum number of classes, the number of filters, the width and height of the input images and number of steps. The selection of hyperparameter values should consider a balance between available computational resources, task-specific requirements, and the model's performance on validation data. The process of parameter tuning was conducted by referencing the modifications proposed by (Bochkovskiy, 2018). For the training of the two specified classes (human and car), the following parameter adjustments were implemented:

- Maximum number of batches (iterations): Reduced from the initial value of 500,200 to 4,000.
- Maximum number of classes: Reduced from the original 80 to 2.
- Number of filters: Modified in the three convolutional layers preceding the output for small, medium, and large object features, adjusting from the original 255 to 21.
- Width and Height: Adjusted from the initial dimensions of 416x416 to 608x608.
- Number of steps: The first and second values were modified to represent 80% and 90%, respectively, of the maximum number of batches.

Seven YOLOv3 model versions were trained corresponding to the datasets/combinations shown in Table 2 with an approximate training time of 5 hours for each training process. Two metrics were used to assess the performance of each resulting model versions: a) the mAP score related to the test subset of the training dataset, and b) the average of the mAP values obtained when each model version was tested on all seven test subsets of the seven training datasets (see Table 2). Testing of each model on all seven test subsets was done in order to assess the robustness of each model version in different environments (represented by the seven datasets).

| Datasets | mAP (own test subset) | mAP (average value resulting from all seven test subsets) |
|-------------------------------|-----------------------|---|
| DAC-SDC | 85.3% | 29.0% |
| VisDrone | 47.9% | 42.0% |
| Stanford Drone | 71.3% | 25.3% |
| DAC-SDC & Stanford Drone | 73.5% | 48.5% |
| VisDrone & DAC-SDC | 43.7% | 48.7% |
| VisDrone & Stanford | 53.9% | 53.6% |
| VisDrone & DAC-SDC & Stanford | 61.8% | 60.08% |

Table 2: Object recognition performance of the YOLOv3 model with combined public datasets

The test findings emphasize that dataset diversity, image acquisition height, and overfitting influence the object recognition model's performance. Specifically:

- The DAC-SDC has a very small image diversity, which results in overfitting during training. This explains the high mAP value when the model version is tested on its own test set and the low average mAP value when tested on all test sets.
- The Visdrone dataset's diversity contributes to the robustness of the related model version.
- The Stanford dataset contains high altitude (80m) images. When the related model version is tested on its own dataset, the model's performance is high but when tested on other lower-altitude datasets the model performance is poor.
- The model versions trained with the combinations of VisDrone and Stanford datasets are the most robust, due to the diversity of the images involved.

These conclusions underscore that training on a combination of datasets effectively addressed some of the specific challenges listed above, resulting in better outcomes in diverse object detection conditions than using individual datasets. It also emphasizes the significance of comprehending challenges specific to the dataset and their effect on model performance.

The performance of the seven model versions was further evaluated using a new dataset captures using an Autel Evo II Pro quadcopter equipped with a 20-megapixel camera capable of recording high resolution images of 5472×3648 pixels. The UAV was flown at an altitude of 15, 30 and 50 meters above ground level during both daylight and low light (dusk) at two distinct locations: a) A small port/shipyard with a variety of objects like cars, persons, and boats; b) A non-urban field empty of objects other than persons and cars. A total of 722 images were obtained, leading to 1,218 object annotations, 764 persons and 454 cars. Figures 2 and 3 show illustrative images with the corresponding bounding boxes surrounding each object of interest.

Figure 1 shows the mAP values versus flight height and lighting conditions for the seven models.

- Performance Variability: The VisDrone Stanford model version is the best performer in the 30m and 50m elevations. In the 15m elevation, the performance was slightly lower than the VisDrone model in all lighting conditions. This is hardly a surprising result, since, as concluded above, the model versions trained on dataset combinations that include the Visdrone and Stanford datasets are the most robust ones.
- Optimal Elevation Implications: The VisDrone Stanford model version performed best on images captured from a height of 15m. This was not true for all model versions. A characteristic example is the Stanford model version, which exhibited its worse performance in the 15m images (the Stanford dataset images were taken from an 80m height). This illustrates the value of training a model with images that fit the application for which the model will be used.
- Robust performance across lighting conditions: The VisDrone Stanford version performed equally well under both lighting conditions. This is valid for all model versions, since all contained images were taken under both conditions.

The model version showcasing optimal performance on the public datasets (Table 2) did not mirror the same success in the experimental test (Fig. 1). This observation, coupled with the insights detailed above, underscores three essential considerations: a) The training dataset's alignment with the model's intended real-world conditions is significant; b) equally significant is the model robustness, which results from training under a wide spectrum of conditions; c) the model achieving optimal performance during training does not necessarily ensure the same level of success in real-world scenarios.



Figure 1: Results on different heights and lighting conditions based on the trained weights.



Figure 2: Identification of objects in images taken from the small shipyard and an altitude of 30m.



Figure 3: Identification of objects in images taken from the open field area and an altitude of 50m

5. CONCLUSIONS

We have demonstrated the security value of a UAV based system with real time object recognition capabilities in expansive logistics areas. To achieve this, we trained the YOLOv3 model by adjusting its hyperparameters and using combinations of the publicly available datasets VisDrone-DET, DAC-SDC, and Stanford Drone Datasets. The study's findings emphasize how dataset diversity, acquisition height, and overfitting impact the object's recognition model performance. Combining datasets effectively tackles overfitting challenges and leads to improved results. Specifically, the diverse Visdrone dataset and lower image acquisition heights notably enhance performance and robustness, particularly when combined with datasets such as the Stanford dataset. Finally, this study highlights the crucial importance of selecting the appropriate dataset that fit the intended application.

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Performance of a Concrete Crack Detection Tool using Convolutional Neural Networks (CNN)

Nikolopoulos D. Undergraduate Researcher, University of West Attica, Department of Civil Engineering <u>d.nikolopoulos00@gmail.com</u> Moussas V. Associate Professor, University of West Attica, Department of Civil Engineering vmouss@uniwa.qr Vryzidis I. Assistant Professor, University of West Attica, Department of Civil Engineering i.vryzidis@uniwa.gr

Abstract

Identification, and classification of cracks in concrete are critical to verify the integrity and structural health of a construction under inspection. In this work we focus on advanced techniques for the automatic detection of cracks in concrete. Recently, there has been a great research interest in the development of new detection tools based on machine learning. The convolutional neural networks (CNN) is one of the tools that demonstrate very good performance in pattern recognition. In this work, CNN will be applied for the recognition and analysis of images containing cracks in concrete. Our results are based on widely available datasets with a large number of images that are used to evaluate the performance of the proposed system in identifying cracks. The classification success rates showed that the CNN-based approach for crack detection in concrete structures can provide satisfactory results and accelerate the maintenance and inspection of concrete structures. The results also suggest that a CNN-based identification/classification system for photos/images of cracks can significantly improve its performance when it is trained with by of adequate number & quality images.

KEYWORDS

Concrete cracks, Pattern recognition, Crack detection, CNN, Structural health, Machine learning

1. INTRODUCTION

Concrete is one of the most used construction materials in the world, due to its durability, strength and low cost to manufacture. Over time various factors such as environmental conditions, loads and material degradation, among others, can cause the formation of cracks in concrete structures. Detecting and evaluating these cracks on time is crucial for maintenance and repair if needed, to prevent further damage and ensure structural stability. Traditionally, concrete crack detection has relied on manual inspection by trained professionals. This process is not only time-consuming but also vulnerable to human errors, as it relies heavily on the judgment and expertise of the inspector. Furthermore, manual inspection may not be achievable for large-scale infrastructure and it is not possible to regularly monitor buildings that require constant attention due to their level of perpetual use. The rapid advancements in computer science and machine learning techniques have provided opportunities to develop automated systems for crack detection. Among these techniques, Convolutional Neural Networks (CNNs) have demonstrated exceptional capabilities in image recognition tasks. CNNs excel at learning complex patterns and features from large datasets, making them an ideal candidate for crack detection in concrete structures (Guo 2022) (Wenting 2021) (Falaschetti 2022) (Wilson 2018).

The aim of this paper is to evaluate the performance of a CNN based concrete crack detection tool. The proposed CNN tool uses deep learning and is trained with a comprehensive dataset of concrete images containing both cracked and uncracked samples. The trained CNN model will be evaluated for its accuracy, precision and effectiveness of providing help in detecting, identifying and classifying cracks. The rest of this paper is organized as follows: Section 2 provides an overview of related work on crack detection methods in concrete structures. Section 3 describes the methodology, including dataset collection. Section 4 analyses preprocessing, the CNN model and the training process. Section 5 presents the experimental results and performance evaluation of the developed crack detection tool. Finally, Section 6 concludes the paper by discussing the results, the limitations and the problems which occurred and potential future research in the field of crack detection using CNN. By using a Convolutional Neural Network, this paper aims to contribute to the improvement of a crack detection tool, providing a reliable and efficient solution for the maintenance and inspection of concrete structures.

2. CNN MODELS

2.1. From ANN to CNN models

A typical Artificial Neural Network (ANN) (Figure 1) is a neural network inspired by the human brain's structure & functioning, and consists of neurons organized in layers. ANN was one of the early attempts of an image-based detection tool developed to help recognize patterns (Özgenel 2018). Although, those methods yield acceptable results, their processing techniques have been found to be far from efficient. To address the limitations of typical (shallow) ANNs, the more complex (deep) technique of Convolutional Neural Networks (Figure 2) began to be used and have revolutionized the image-based analysis. CNN, is a type of ANN specializing in image processing which outperforms traditional ANNs due to the ability to capture spatial features and patterns in images



This is done by adding a usually large number of convolution layers, as a preprocessing stage, before the final classification stage. ANN & CNN may have similar input & output layers, but the hidden layers are completely different in size and complexity. In a CNN the convolution layers introduced dissolves the images in minor simpler elements, repeatedly layer after layer, and they create a list of features for the classification stage (Shengyan 2019). The number of convolution layers used, is a parameter that greatly affects the performance of a CNN and it must be tuned for each specific application. A CNN tool may vary from a single to dozens of convolution layers, in addition there are many parameters and mete-parameters of a CNN to be tuned for each application while any preprocessing of the image datasets also affects its performance. In this work we'll to define some of the parameters required for successful crack detection in concrete.

2.2 CNN modeling workflow

Currently there is an increasing interest by researchers in developing CNN tools that demonstrates the CNN potential within the field of concrete crack detection. The proposed tools have achieve the researchers' objectives with notably positive outcomes (Aravinda 2020) (Young-Jin).

An also important preprocessing stage is shown in Figures 3 & 4. The pre-processing tool accepts visuals of any size and the program dissects them into smaller components. Subsequently, it analyzes each subsection, identifying areas which contain cracks in the surface of concrete. The smaller components are then labeled as crack or no-crack images.





Figure 3: Typical image dissection & processing by a CNN



These sets can subsequently be used to train the CNN model. When training is complete, the new images can be dissected in the same manner and be processed by the CNN to classify them as crack or no-crack (Golding 2022).

3. METHODOLOGY AND DATASETS

In order to build a suitable CNN tool for concrete crack detection/identification, we first needed to test how well a Convolutional Neural Network identifies a captured image. Our initial step involved applying a ready & general-purpose classification algorithm, namely googlenet, that, through the computer camera captures a snapshot and tries to recognize the contents within the captured image.

The results of the already trained and general-purpose algorithm (googlenet), while showing the method's potential, are not reliable or trustworthy (Figures 5 & 6). This general CNN model frequently encounters errors or low confidence when attempting to estimate the objects depicted, attributed to factors such as: the limitations of the camera, the environmental conditions under which the image was captured (light, contrast, etc.) and above all of course the size/type of the training dataset.



Figure 5: Example of a general CNN algorithm (googlenet) recognizing a ballpoint pen with a success rate of 45%

Figure 6: Example of the same algorithm's unsuccessful recognition of the pencil, classifying it to be a projectile with a low confidence of 22%, a 'positive' crack (as nematode with 16%) & a 'negative' crack in concrete surface (as paper with 27% confidence).

To overcome the deficiencies of typical and general CNN tools, we proceeded to develop a more specialized tool, the Concrete Crack Detection Tool, by trying gradually better trained deep CNN version and with careful selection and preprocessing of the datasets.

As a first step in this process, our focus shifted towards acquiring enough datasets containing images that portrayed cracks in concrete. Thus, we had to find suitable images that depict both 'positive' cracks in the surface of concrete, as well as, 'negative' plain surfaces of concrete without cracks. Several repositories were investigated for appropriate datasets such as Kaggle and others (Kaggle 2023). Following the acquisition of a substantial volume of diverse datasets from the online datasets, we became equipped and prepared with enough data to proceed to the next phases and the training of the CNN model

4. PRE-PROCESSING OF THE DATASETS

In order to train the model effectively, a preprocessing of the data was required. The next step involved leveraging the collected datasets depicting cracks in concrete. The images are divided in two categories: one half containing cracks (Figure 7) and the other half without cracks (Figure 8). This supervised division helps the correctness of the training process, by providing accurate examples of both cases. In order for the program to yield accurate results and to ensure that program failures are easily noticeable, we assigned an equal number of images from each category.



Figure 7: Example of images with cracks in concrete

Figure 8: Example of images without cracks in concrete

After the first attempts, it became clear the importance to select the right images for the cracks to be easily visible, e.g., with sufficient light and preferably with high definition. Therefore, at this stage of the study, we chose images without any shadows that could interfere with the crack detection and analysis we were aiming to accomplish.

During the various tests of the CNN design & training, a measurement of the efficiency or accuracy was needed. The Confusion Matrix was used and its quantities (TP, TN, FP, FN) were reported for each case, i.e., in order to verify that the training of the CNN improves, the percentage of (False Positive + False Negative) should decrease and the percentage of (True Positive + True Negative) should increase (Figure 9). Therefore, after every revised or added selection or preprocessing step, the CNN model was trained & tested again to verify any improvement in its accuracy.



Figure 9: Typical performance metrics, derived from the confusion matrix, to compare the accuracy of crack detection.

In addition to the initial dataset quality selection, during the pre-processing of the chosen training images, and, in order to achieve the maximum possible efficiency, more tasks were involved such as: resizing the images (Figure 10), normalizing the pixel values (Figure 11) and augmenting the dataset through techniques like rotation, flipping and adding noise. These pre-processing steps are crucial to enhance and optimize the quality and diversity of the dataset, therefore enabling the model to learn in the most efficient and detailed way.



Figure 10: Example of image resizing, rotation, flipping and adding noise

Figure 11: Example of normalization

The above and more techniques can be applied during the data preparation, or also called 'data augmentation', stage. This can be done off-line before starting the training of the CNN, or on the fly (JIT) during the training. The aim of this stage is to feed the CNN with more data that are slight distortions of the original images, in order to make our CNN model more robust to various views of the same image.

Data augmentation extra sets are produced by a specific or random Rotation, Width or Height Shift, Zoom, Flip, Crop, as well as, random changes in RGB colors, contrast, brightness, etc.

In order to detect the data preprocessing and augmentation required for our case, a series of test was performed using the various types of transformation available and measuring the corresponding performance of a CNN to each method. A number of CNN designs was subsequently tested, starting with a simple one with one convolution layer (figure 12) and proceeding gradually to deeper ones with more layers.



Figure 12: The initial, single convolution layer, CNN, implemented in a MatLab tool

5. INITIAL RESULTS

The results of the tested CNN models showed that it is important to pay attention on the selection & preprocessing of the datasets. The Dataset selection, preprocessing and augmentation improved the accuracy rate of the basic CNN up to 80%, but, further improvement is only achieved only by enlarging the depth of the CNN model. By adding just one or two additional layers, the accuracy reached 95%.

Table 1: Sample of various improvements in CNN accuracy due to preprocessing and model enhancement

| Processing Steps | Accuracy rates (%) |
|---|--------------------|
| Raw/Unprocessed Data | <=50% |
| Selection of more suitable datasets | 50-60% |
| Data Normalization | 55-65% |
| Data Augmentation (pre) | 50-65% |
| Data Augmentation (train-jit) | 55-80% |
| Increased No. of Convolutions & Validations | 65-90% |
| Additional Convolution layers | 75-95% |

As observed during these tests, CNN the tool exhibits the potential to yield reliable outcomes for our problem. Specifically, it was noted that under conditions of optimal lighting (Figure 13), high resolution and with a moderate amount of noise image, the likelihood of successful recognition of the depicted content in an image is considerably high.



Figure 13: Example of crack images with sufficient and insufficient light

However, when confronted with inadequate illumination (Figure 14), diminished image resolution and without noise, the resultant identification becomes unreliable. This is substantiated by the program's modest success rate, thereby revealing the program's sensitivity to these factors. Although, the tool is currently in its early development phases, the outcomes achieved thus far have proven to be satisfactory and show substantial potential for further improvement.

6. CONCLUSION

This work is a part of an ongoing research, where, the simple CNN model presented and tested will be expanded for multiple and new images taken on site from large areas/buildings. The expected outcome of this work is to give the possibility to process batches of hundredths of images in a short time. As a result, a civil engineer could greatly improve the speed of building inspections, especially when he is able to use a drone/UAV for automatic and fast image collection from the area or the building under investigation and subsequent automatic detection through the developed tool.

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Exploring the Trainers' Digital Competencies of Public Vocational Training in Greece during COVID-19 period

Dimitrios Kiriakos Department of Business Administration University of West Attica. kiriakos@uniwa.gr Anastasia Themeli Department of Primary Education University of Athens natashathem@primedu.uoa.com

Christos Kytagias Department of Business Administration University of West Attica <u>ckyt@uniwa.gr</u>

Yannis Psaromiligkos Department of Business Administration University of West Attica yannis.psaromiligkos@uniwa.gr

Kalliopi Rigopouli

Department of Business Administration, University of West Attica

krigopouli@uniwa.gr

Abstract

The European Union prioritizes, especially after the impact of COVID-19 pandemic on employment and social policy, towards the development of green and digital skills on Vocational Education and Training. In this framework, the teaching profession, which evolves and changes rapidly, require broader and more sophisticated set of competences than before. These competences focus on 6 main areas according to the European Digital Competencies for Education (DigCompEdu) framework, that is professional engagement, digital resources, teaching and learning, assessment, learners' empowerment and learners' digital competence facilitation. The current study constitutes a systematic effort to enhance research on vocational training and presents a repetition of a previous study (Kiriakos et al., 2021) that took place during the pandemic organized by PANEDDIEK (Panhellenic Union of Directors of Public Vocational Training Institutes) in collaboration with the University of West Attica. The Public Vocational Training Institutes (DIEK) offer initial vocational training to persons over the age of 18 in over 72 different occupational specializations that are divided into 8 Orientation Groups. This research aims at capturing the level of the digital competence and digital skills of the trainers of Public Vocational Training Institutes (DIEKs). For this purpose, we designed a questionnaire that has layered questions which allow us to extract simple competence descriptors. From these descriptors we derive indexes for the 6 areas of the European Digital Competencies for Education (DigCompEdu) framework that we cross reference with every vocational orientation group in order to provide an insight into the trainers' digital competence in each group. The research in question involved 68 DIEK, 76 different professional specialties and 655 trainers from dispersed geographical areas of Greece. The value of the research lies in the fact that it is a pioneer effort to track trends in training provided by DIEK during the pandemic period. Other important features are the range of the specialties that are covered, the geographical spread of the sample all over Greece and the fact that it is an ongoing project. Collection of questionnaire answers will be collected on a regular basis, to include even more data that will help us identify patterns in digital proficiency. A preliminary analysis of the results revealed, as expected, that specialties closely tied to technology exhibit higher digital competency indices than those associated to professions that require a more hands-on approach.

KEYWORDS:

Vocational Training, Public Vocational Training, Public Vocational Training Institutes, Distance Training, Diek Trainers, Covid-19 And Distance Training, Digital Competences

1. INTRODUCTION

The digital competence of educators, especially in the context of vocational education and training, remains relatively unexplored (Antonietti et al., 2022). The purpose of this study is to investigate the level of digital competence of educators in the context of vocational education & training. In education in general and in vocational training in particular, there is a complex dynamic between the factors that influence the use of technology. Although support from the educational institution is crucial to the integration of technology in educational context, it is not a sufficient and necessary condition for the use of technology in the classroom. A very important factor is the teacher's belief about his ability to use technology effectively in his educational practice. Therefore, the availability and access to digital tools as well as the quality of digital infrastructure, although necessary prerequisites, are not sufficient for the integration of technology in the classroom. (Bingimlas, 2009). In vocational training institutions, digital technologies play an important role in bridging the gap between what is taught in the classroom and what students apply in their workplace during their internships (Schwendimann et al., 2015).Very often there is a gap between theoretical and often abstract

knowledge and procedural tacit knowledge from workplace practice (Schaap et al., 2012).Digital technologies can be used to bridge the gap between theoretical knowledge and practice by facilitating communication, overcoming spatial and temporal barriers, and bringing professional experiences to school. With the use of simulations and appropriate training materials they can offer rich and diverse educational experiences that integrate professional practice. Digital technologies can also create spaces for collaboration, either synchronous or asynchronous, allowing joint problem solving and different experiences to be shared and reflected. Therefore, in the context of vocational education and training, linking theoretical knowledge with competences development is crucial. Teachers should combine the learning activities in which pupils participate with the competences they need to develop in the workplace in order to link theory with practice (Kyndt et al., 2022).Vocational Training educators should therefore have digital competence as outlined by the European Commission Digital Competence Framework for Educators (Joint Research Centre (European Commission) et al., 2017).

1.1 Vocational education in Greece

In the Greek Education System, Vocational Education & Training (V.E.T.) provides education and training in various professional specialties and is included in various levels of EQF/NQF (European Qualifications Framework / National Qualifications Framework):

- Level 3: Vocational Training Schools (E.S.K. from the Ministry of Education) and Vocational Schools (EPA.S. from the Ministry of Labour), educational institutions that can be attended by high school graduates (level 2 graduates), are two-year studies with theoretical and practical training or "Workplace Learning Program" that provide basic vocational training in various specialties.
- Level 4: Vocational Lyceum (EPA.L.), which offers vocational educational training in various specialties and have a teaching period of 3 years
- Level 5: Public Vocational Training Institutes (D.I.E.K.), Private Vocational Training Institutes (I.I.E.K.) and Year of Apprentice (Dual system) of Vocational Lyceum EPA.L graduates. D.I.E.Ks and I.I.E.Ks offer specialized vocational training and prepare students for the labor market. Their duration is 4 semesters of theoretical and laboratory courses and 6 months of practical training in companies, a total of 2.5 years. They are attended by high school graduates and many University graduates or University dropouts, as well as adults. The Year of Apprentice for of Vocational Lyceum graduates lasts 11 months of internships, 4 days a week in companies and one day in the Vocational Lyceum (EPA.L.)

Overall, the VET system in Greece ensures that students acquire specialized knowledge and skills that allow them to enter the world of work in various sectors and professions. Public vocational education in Greece is provided by a network of 125 vocational institutes across the country that provide post-secondary vocational education and training in more than 72 active specialties, which form the backbone (European Commission Communication from the Commission to the European Parliament, 2015). The specialties are categorized into 14 sectors based on the scientific field such as IT, business and economy, tourism, health and welfare, hospitality enterprises, etc. In addition, they are grouped in turn into 8 Vocational Orientation Groups and cover a wide range of occupations, namely: Technological Applications, Business and Economy, Agricultural and Nutrition, Applied Arts and Artistic Studies, Communication and Media Professions, Tourism and hospitality, Health and Welfare and last but not least the Miscellaneous specializations (*Vocational Orientation Groups for Public Vocational Training Institutes (DIEKs)* N.4186/2013, 2013).

1.2 The Digital Competencies Framework for Educators

The European Union recognizes that digital competence and the development of digital skills are particularly important for active participation in society and the economy. Digital competence can be broadly defined as the confident, creative and critical use of digital technologies to achieve objectives related to learning, work, employability, leisure, inclusion and/or participation in society (European Commission. Joint Research Centre. Institute for Prospective Technological Studies., 2012). Digital Competence is a key factor related to the acquisition of other basic knowledge and competencies such as knowledge of science, acquisition of the ability to "learn how to learn", to form "cultural consciousness", etc.

Towards this direction, it is very important to integrate digital technologies in the educational process and to achieve this one of the key components is teachers' digital readiness and digital competence. European research focusing on teachers' digital competencies developed the European Digital Competence Framework for Educators (DigCompEdu) (Joint Research Centre (European Commission) et al., 2017). The framework

describes a set of 22 digital competencies for the teaching profession categorized into six areas, as presented in Image 1. The framework is addressed at teachers at all levels of education, including vocational training.



Image 1: Digital Competencies for Educators self-assessment framework (Joint Research Centre European Commission, 2017)

In area 1 of the framework a progress model is proposed that promotes educators' continuous professional development (CPD) by provoking reflection on their personal strengths and weaknesses, describing different levels of digital skills development. In Areas 2-5 the framework focuses on the digital pedagogical competence of teachers, the promotion of effective and innovative teaching and learning strategies in the educational process. Area 6 of the framework focuses on facilitating learners' development of digital skills as well as transversal skills such as problem-solving, teamwork and communication. The ubiquity of digital technologies and the constant development of new technological wonders in our daily lives requires us to continue updating the digital competencies framework. Recently, the EU presented an updated Digital Competencies Framework containing more than 250 new examples of knowledge, skills and attitudes, including new and emerging technologies such as artificial intelligence systems, that help citizens make confident, critical and secure use of digital technologies (Joint Research Centre (European Commission) et al., 2022).

1.3 Research Questions

In this research we present the results of an ongoing effort to investigate the digital competencies of Public Vocational Education Institutions educators, which is conducted by PANEDDIEK in collaboration with the University of West Attica. The main objective of the survey was to capture and explore the digital competencies of educators in public IEKs during the second semester of 2021. This is a supplement-update of a previous, similar survey concerning the semester October 2020-February 2021. The specific objectives of the research are to investigate the training provided to Public VETs through distance learning and to monitor the level of digital competencies of VET educators per Vocational Orientation Group, based on the Digital Competencies Framework for Teachers of EU (DigCompEdu). Our research questions are the following:

- What is the level of Digital Competence of Vocational Education & Training teachers in relation to the EU Digital Competence Framework for Educators (DigCompEdu)?
- Are the digital competencies of educators differentiated in each of the 8 Vocational Orientation groups regarding the six areas of the European Framework (DigCompEdu)?
- If we examine each Vocational Orientation group separately, do we see differences in the digital competencies of its trainers in relation to the six areas of the European Framework (DigCompEdu)?

The results of the survey will be used to draw useful conclusions about the effectiveness of the training offered through distance education during the time period from February to June 2021. We would like to remind that the first survey concerned the critical period from October 2020 to February 2021 the ban on face-to-face classes during the period of COVID19.

The paper is organized as follows. In the second part a literature review on vocational training and digital skills assessment is conducted. The third part, presents the research methodology and the fourth part discloses the research findings. At the fifth part we reflect on the results of our research, we draw conclusions, and consider future investigation bearings.

2. LITERATURE REVIEW

At the heart of the European Commission's political agenda lie both the green and digital transitions to create a more equitable, resilient, and sustainable European economy. At this point, the EU has consistently strived

to assist Member States in their VET reform efforts. A variety of EU programs provide tools and support for VET stakeholders, with the purpose of supporting Member States in improving the quality and transparency of their VET systems and making the EU's vision for VET a reality across Europe. At this point, it is essential for VET institutions and systems to promote upskilling and reskilling (European Commission. Directorate General for Employment, Social Affairs and Inclusion., 2022).

The need for digital transition, and especially effective integration of technology in education and training, is reflected in the development of several frameworks that attempt to clarify what digital competences include. In general, (Ilomäki et al., 2016) proposed four components of digital competence; "technical skills and practices in using digital technologies[...], abilities to use and apply digital technologies in a meaningful way [...], abilities to understand the phenomena of digital technologies [and], motivation to participate and engage in the digital culture" (Ilomäki et al., 2016). Although, in educational terms, educator's digital competence is an additional layer that educators have to include as part of their professional development (Cattaneo et al., 2022). A representative conceptual framework, in this direction, is the Technological Pedagogical Content Knowledge (TPACK) framework that assumes that the mastery of digital competence lies in the synthesis of educators' digital, pedagogical, and content knowledge (Mishra & Koehler, 2006). The DigCompEdu framework is a more practice-oriented framework connected to educational policies. It offers a clear guideline for educators to integrate technology in learning and teaching as well as in their professional setting. It is an educator-specific competency framework that identifies and describes important competencies, and proficiency levels that serve as a generic reference to promote the establishment of these educator-specific digital competencies. Compared to TPACK, it covers a wider aspect of educators' digital competencies as a combination of knowledge, skills, and attitudes. However, it is more focused on the pedagogical dimension in the Areas 2-5. According to (Caena & Redecker, 2019), DigCompEdu's emphasis on the pedagogical dimension enables it to provide detailed information while remaining adaptable across all subjects in a continually shifting technological environment. Thus, it explicitly describes how digital technologies can be effectively integrated into teaching and learning, how they can be used to enhance teaching and learning. Despite numerous developed frameworks, various corresponding measurement instruments have also been created, including self-assessment ones (Caena & Redecker, 2019; Ghomi & Redecker, 2019). For example, SELFIE (Self-reflection on Effective Learning by Fostering the use of Innovative Educational technologies) is a freely accessible tool that contributes to the digitalization of schools, including the VET ones. It can be adopted to enhance the comprehension and integration of digital technology in teaching and learning practices. This tool collects anonymous feedback on how technology is used in schools from students, instructors, and school leaders via questionnaires to provide a report outlining the school's technological assets and limitations (Vocational Education & Training, n.d.). Other tools based on the implementation of the DigCompEdu are DigCompEdu Self-Reflection tools (Caena & Redecker, 2019; Ghomi & Redecker, 2019) as well as the new SELFIE for TEACHERS. Although, the current instruments should be customized to the specificities of digital competencies in the VET context (Lucas et al., 2021).

In a study on assessing digital competence in vocational education, (Cattaneo et al., 2022)examined a sample of 1692 Swiss VET trainers, by utilizing an assessment instrument relied on the DigCompEdu competence areas, as well as by accounting for VET-related specificities. The authors, also, tried to investigate if there are differences in digital competence based on the VET trainers' profiles and to explore whether personal and context-related factors play a similar role in VET like in other educational settings. Furthermore, in previous research on 29 VET schools in Greece during the pandemic period, (Kiriakos et al., 2021) designed two instruments based on DigCompEdu framework to cross-check trainers' and trainees' perceptions of their digital competencies level.

3. METHODOLOGY

3.1 Procedure and sample

The data was collected through an online survey voluntarily completed by vocational training educators during the period from February to June 2021, which was conducted by PANEDIEK in collaboration with the University of West Attica. In this survey participated 68 IEKs, 76 different professional specialties and 655 trainers from scattered geographical areas of Greece. The Table 1 below illustrates the distribution of survey respondents' responses by Vocational Orientation Group.

| Vocational Orientation Group | Teachers' responses |
|------------------------------|---|
| Agricultural and Nutrition | 34 |
| Applied Arts | 62 |
| Business and Economics | 98 |
| Health | 158 |
| Media | 3 |
| Technological Applications | 71 |
| Tourism | 91 |
| Various Specializations | 139 |
| | Vocational Orientation Group Agricultural and Nutrition Applied Arts Business and Economics Health Media Technological Applications Tourism Various Specializations |

Table 1: Vocational Orientation Group and responses

Of the 655 responses to the questionnaires, 3 of those concerned the Media Vocational Orientation group. Those were excluded from further analysis of the results as they were not a representative sample of this Vocational Orientation group. After cleaning the data and removing outliers, our final sample involved 562 responses from educators.

3.2 METRICS

Utilizing the DigCompEdu self-assessment framework, we designed a questionnaire focusing on the 6 digital competencies areas of the framework. In each area of the digital competencies framework we have 3 to 5 competencies. The questions are designed in such a way as to capture the perceived competency level that each educators believes he possesses. For each competency in the framework, we have 3 questions in our effort to capture the perceived competency level. Each question can be answered using a 5-point Likert scale: "No", "Yes, with great difficulty", "Yes, with little difficulty", "Yes, with ease", "Yes, with great ease". If the teacher answers "No" it means that they do not have the competency, so they are at level 0 for that competency. If the educators answer "Yes, with great difficulty" or "Yes, with little difficulty", at the 1st question it means that has mastered the competency at an initial, superficial level and not in depth and is at level 1 regarding the competency. The 2nd question of the competency appears only if the educator answer "Yes, with ease" or "Yes, with great ease" to the 1st question. Similarly, question 3 appears only if the educator answer "Yes, with ease" or "Yes, with great ease" to the 2nd question. At the 2nd question, If the educator answer "No" or "Yes, with great difficulty" or "Yes, with little difficulty" it means that has reached at level 2 for the specific competency. At the 3rd question If the educator answer "No" or "Yes, with great difficulty" or "Yes, with little difficulty" it means that he/she is at level 3 for this competency. Finally, if in the 3rd question the educator answer "Yes, with ease" or "Yes, with great difficulty" it means that has acquired the level 4 regarding the competency. In this way, a 5-point scale of level 0 to 4 is formed, as illustrated in Image 2, which characterizes the level that the teacher considers to possess one of the competencies mentioned in the DigCompEdu digital competencies self-assessment framework.



Image 2: Competency Level Scale

3.3 DATA ANALYSIS

For the cleaning and proper formatting of the results we used power query and pivot tables in Excel, while for the statistical processing of the results we used the popular statistical processing application SPSS. Initially, using SPSS, a reliability analysis was performed to assess whether the measurement scale for the level of perception-acquisition of a skill for each of the 6 areas of DigCompEdu shows reliability in terms of internal data coherence (Karlis, 2005). The value of α (Cronbach's Alpha) For each dimension they ranged from 0.67 to 0.863 (0.67, 0.746, 0.743, 0.863, 0.825, 0.783) indicating the internal consistency of the data by dimension.

To further analyze our data, we used power query and pivot tables in Excel. For each competency we analyzed using Microsoft's Power Query language, we got a value from 0 to 4 that corresponds to the scale for the perceived acquisition level of the digital competency from the layered questions we mentioned earlier. For each six areas of the framework, which included 3 to 5 Digital competencies, in order to form a metric, we considered the average value. So, for example for the 1st Area of the framework that refer to Professional Engagement, we have 4 competencies: Organizational Communication, Professional Collaboration, Reflective Practice and Continuous Digital Professional Development, and a value for the perceived acquired level of for the competency that ranges from 0 to 4. Considering the average value in these competencies we obtain an indicator from 0 to 4 for the level of digital competence in the 1st area of the framework, i.e. the digital competencies related to the professional engagement of educators. Based on these measurements, we developed indicators for each of the 6 areas of the EU Digital Skills Framework, which we used to compare the level of digital competence per vocational orientation group and per area of the framework.

4. RESULTS

The research in question involved 68 DIEK, 76 different professional specialties and 655 trainers from dispersed geographical areas of Greece.



Image 3: average score per DigCompEdu Area

Making a comparison of the 7 vocational orientation groups per area of the Digital Competencies Framework for Educators we noticed the following. Regarding the 1st area, which refers to Professional Development, the best score in terms of average value is displayed by the vocational orientation group of Applied Arts, followed by the vocational orientation groups of Various Specializations and Technological Applications. In general, all vocational orientation groups have a high average score above 3 in the 1st area of the digital competencies' framework. Regarding the 2nd area, which refers to Digital Resources, the best average is presented by the vocational orientation group of Technological Applications, followed by the groups Applied Arts and Business & Economics. In the 3rd area that refers to Teaching & Learning, the best score is achieved by the Applied Arts group, followed by the Technology Applications and Business & Economics groups, while the rest of the vocational orientation groups show an average below 3. In the 4th area mentioned in the framework, the best result has the Technological Applications group, followed by the Business & Economics and Tourism groups. In general, however, we observe that regarding the Assessment area that we have much lower scores, ranging from 1.9 to 2.5 approximately, compared to the other areas of the framework. For the 5th area that refers to Empowering Learners, the best result is displayed by the Applied Arts group, followed by the Technological Applications and Tourism groups. Finally, in the 6th area, Facilitating Learner's Digital Competence, the best result is shown by The Applied Arts group, followed by the Technological Applications and Business & Economics. In all areas of the framework, we observe the vocational orientation groups Agriculture & Nutrition, Health and, Various Specializations (with some exceptions), show the lowest values in average score, suggesting a particular difficulty of the educators of these groups to integrate digital technologies into their educational process.


Image 4: Average score per average score per Vocational Orientation Group

Looking at each vocational orientation group separately in the digital competencies areas described within the European Union's framework, we observe the following. The Agriculture & Nutrition group shows its best performance in the areas that refer to Digital Resources and Professional Engagement, while it scores particularly low in the Assessment area. The Applied Arts group performs very well in almost all areas, with an average above 3, with the exception of the Assessment area, in which it shows an average below 2. The Business & Economics group shows the best performance in Digital Resources and Professional Engagement, and small variations in scores for the rest of the areas, with the exception of the Assessment area where it has its lowest score. The Health vocational orientation group scores best in the Professional Engagement and Digital Resources areas and the worst in the Assessment area. The Technology Applications group shows its best performance in the areas of Digital Resources and Professional Engagement, and relatively good scores in the rest of the regions, with the exception of the Assessment area where it also scores its lowest. The Tourism group shows its best performance in the areas of Professional Engagement and Digital Resources and the lowest values in the area of Assessment and then in the area of Facilitating Learners' Digital Competence. Finally, the Various Specializations group shows its best performance in the areas of Professional Engagement and Digital Resources and the lowest value in the Assessment area. As a general observation, we noticed that the Assessment area shows the lowest scores in all vocational orientation groups compared to the other areas of the digital competencies framework.

5. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

The current research involved 68 DIEK, 76 different professional specialties and 655 trainers from dispersed geographical areas of Greece. The value of the research lies in the fact that it is a pioneer effort to track trends in training provided by Public Vocational Training Institutes during the pandemic period and constitutes a systematic effort to enhance research on vocational training as it presents a repetition of a previous study (Kiriakos et al., 2021). Another important feature is the range of the specialties that are covered, the geographical spread of the sample all over Greece and the fact that it is an ongoing project.

The research findings confirmed that the vocational training sector faced several challenges due to COVID-19. The research provided us with evidence that not every Vocational Orientation Group faced the same challenges and dealt with the difficulties during the pandemic. The Vocational Orientation Groups of Applied Arts Group and Technological Applications presented overall higher grades (average values) in all the areas of the Digital Competences for Educators Framework. All the Vocational Orientation Groups scored their lowest in the areas of Assessment and Facilitating Learners' Digital Competence compared to the rest of the Digital Competences areas of the framework. Amongst them, the Technological Applications group performed better in the Assessment area of framework. The Professional Engagement and Digital Resources are the 2 highest scoring across all Vocational Orientation groups. Although, even if digital technologies are available to VET educators, there are still Vocational Orientation groups in which e-learning cannot be directly implemented and exceptional difficulties are presented. One such case is that of post-secondary health institutes, whose specialties largely require physical presence in hospitals, clinics or doctors' offices. The indications from the research further emphasizes that trainers and educators have a greater need to develop their digital skills and competences in order to Integrate technology in the appropriate pedagogical contexts.

6. LIMITATIONS

The largest percentage of questionnaire responses came from the geographical area of Attica (44.36%), followed by Central Macedonia (16.16%) and Epirus (13.57%). Better geographical distribution of the sample

would be desirable to form a more complete view of the digital competence in Vocational Training. Also, in our sample data we had very few, just 3 responses, referring to the Media Vocational Orientation Group, so we did not have a representing sample of this group. Another restriction is that the research is purely quantitative and can only provide us with indications for the level of digital competence of Educators in vocational education & training. It would be preferred to cross our findings with the finding of a Qualitative Research for a broader and more in-depth picture.

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Turn Benefit of Doubt to trustworthiness of MCDA¹

Takis Varelas Danaos Research Centre <u>tv.drc@danaos.gr</u>

> Sofia Archontaki Danaos Research Centre <u>drc@danaos.com</u>

John Dimotikalis Hellenic Mediterranean University jdim@hmu.gr Dimitris Kaklis Danaos Research centre <u>Dk.drc@danaos.gr</u>

Artemis Flori Danaos Research Centre <u>af.drc@danaos.gr</u>

Abstract

In this work we focused not only to suggest optimal among alternate linearly formulated decisions not even to unify the better but at the same time to gain the minimum benefit of doubt, in other words the maximum trust or the confidence of decision maker(s). This is achieved with a non-linear programmed and integrated interactive e-model to resolve the ranking problem with aggregation of known ordering techniques weighted / non-weighted sum, multi-criteria analysis, topsis index and dea superior index or matrix of indexes. Therefore, the novelty is that the solution satisfies different ranking methods. Furthermore, it can also adjust further the suggested weights based on relative supreme relationships according to decision maker's preferences. The power of interactivity enables the running of what-if scenarios, to simulate strategies or to proof related theorems. It utilizes several models linear and non-linear and was used in several operational cases. Variables values may be expressed as crisp or fuzzy numbers and initial weights from one or a group of experts may be assigned. Different data normalization (min-max, linear, vector, z-score) may be are utilized. This work resolves the mentioned contradictions by extracting the endogenous composite indicators that furthermore may be adjusted and personalized according to experts' supreme preferences. Initially normalization, ranking methods are presented and a new variation of dea composite indicator is defined. Subsequently, the non-linear method to unify topsis and dea ranking is described and some theorems are proved. Finally, the developed "BoD e-model" is presented deploying the decision making for vessel's emission monitoring as it was implemented within the content of EMERGE EU project.

KEYWORDS

TOPSIS, DEA, MADM, LP, DP, normalization

1. INTRODUCTION

Decision-making is one of the much-discussed problem of operational research. The problem is formalized as linear or nonlinear multivariable objective while constraints, values, and relations are defined and finally optimization techniques are applied to unify the better decision. Frequently the solutions of existing optimization techniques to rank the *dmus (decision making units)* differ concluding to low-level trust or confidence of decision maker(s). To overcome the *doubt shortcoming* a model suggesting a set of composite indicators (weights) to harmonize the most popular ordering techniques weighted/ non-weighted sum, multi criteria analysis, *topsis* index and dea superior index is implemented.

2. BACKGROUND

2.1 Normalization

Before solve the ranking multivariable *dmus* problem, values should be assigned to their decision attributes. Values could be linguistics or number, crisp or fuzzy, weighted or non-weighted and could be in different scales. Therefore, an isomorphic transformation of values in an axiology ranking system (value and ordering) known as *normalization* (or regulation) is required. One main novelty of z-score method that is recommended as the best fit to non-linear homo complexus thinking, is the normalization from one to two dimensions transformation (*dmu/attribute and attribute/dmu*). The two common normalization models that are incorporated into proposed system are summarized in table- 1. Once the values are normalized, ordering methods should applied to rank *dmus*. The most popular methods are the one-axis attributes summary weighted or not (ws) method and the two-axis popular methods *dea and topsis*, which are outlined below.

¹Multiple Criteria Decision Analysis

Table 1: normalization methods

| Method | Formulas |
|---|--|
| <i>Min-Max Normalization:</i> For every feature, the minimum value of that feature is transformed to 0, the maximum value is transformed to 1, and every other value is transformed into a decimal between 0 and 1. <i>Guarantees the exact same scale but does not handle outliers well.</i> | $x' = \frac{x - \min x}{\max x - \min x}$ |
| Z-Score Normalization: Z-score normalization is a strategy of normalizing data that avoids this outlier issue. In the formula for Z-score normalization μ is the mean value and σ is the standard deviation. Handles outliers, but does not produce normalized data with the exact same scale. | $x' = \frac{x - \mu}{\sum_{i=1}^{n} \mu} = \frac{\sum_{i=1}^{n} x_i}{n}$ $\sigma = \sqrt{\sum_{i=1}^{n} (\chi_i - \mu)^2}$ |

2.2 Ordering techniques

2.2.1 Technique for Order of Preference by Similarity to Ideal Solution

TOPSIS is a multi-criteria decision analysis method, which was originally developed by Hwang and Yoon in 1981 and further developed by Hwang and Lai in 1993. *Topsis* is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution (*pis*) and the longest geometric distance from the negative ideal solution (*nis*). It is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalising scores for each criterion

$$s_{i} = \frac{d_{iw}}{d_{iw} + d_{ib}} \quad Topsis \ similarity \ with \ ideal \ index$$
$$d_{iw} = \left(\sum_{j=1}^{n} \left((t_{ij} - t_{wj})^{2}\right)\right)^{\frac{1}{2}} : \ d_{ib} = \left(\sum_{j=1}^{n} \left((t_{ij} - t_{bj})^{2}\right)\right)^{\frac{1}{2}}$$
$$t_{ij} : \ i = 1:n \ denotes \ alt. \ |j = 1:m \ denotes \ krit$$



and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. An assumption of *topsis* is that criteria are monotonically increasing or decreasing. Normalisation is usually required as the parameters or criteria are often of incongruous dimensions in multicriteria problems. Compensatory methods such as *topsis* allow trade-offs between

criteria, where a poor result in one criterion can be negated by a good result in another criterion. This provides a more realistic form of modelling than non-compensatory methods, which include or exclude alternative solutions based on hard cut-offs.

2.2.2. DEA: Data development analysis

Data envelopment analysis is a nonparametric method n operations research for the estimation of production frontiers. It is used to empirically measure productive efficiency of *dmus*. The *dea* is used for benchmarking in operations management, where a set of measures is selected to benchmark the service operations. In benchmarking, the efficient *dmus*, as defined by DEA, may not necessarily form a "production frontier", but rather lead to a "best-practice frontier" (Charnes A., et al: 1978)).

 $\frac{\sum_{i=1}^{m} w_i * y_{ij}}{\sum_{i=1}^{m} w_i * v_{ij}} \leq 1 \quad \forall j \in (1:n) \\ w_i \leq \varepsilon \quad \forall i \in (1:m) \\ \text{Superior } dmus = \{j: E_J = 1\} \\ \text{BOD variation: DEA+} \sum_{l=1}^{r} v_i * x_{lj} = 1 \\ \text{Max } E_J = \sum_{i=1}^{m} w_i * y_{ij} \\ E_J = \sum_{i=1}^{m} w_i * y_{ij} \leq 1 \quad \forall j \in (1:n) \\ w_i \geq \varepsilon \quad \forall i \in [(1:m)] \\ m r: nr of output, input criteria, n DMUs, i criterion index, j DMU index. \\ v_{ij}, y_j: the values of i input and output criteria Efficiency off each j DMU is denoted as E \\ \end{bmatrix}$

Figure 2: DEA formulation

2.2.3 DEA – BOD variation



Witte & Rogge (2009) presented their benefit of doubt approach which is formally tantamount to the original inputoriented CRS-DEA3 model of Charnes et al.), with all questionnaire items considered as outputs and a dummy input equal to one for all observations". The corresponding ranking technique solves dea-BoD model solved n times, each for every dmu. The weights wi are the unknown variables that are estimated in favor of each alternative so to maximize its total performance. The first constraint allows the comparative assessment of all the alternatives. In conclusion, model discriminates two clusters of alternatives: Superior alternatives {EJ=1} and Non-Superior alternatives {EJ<1}. The factor *ɛ* in the last constraint is a parameter that prevents the weights to accept zero values. This condition allows the *dmus* to succeed even a small contribution to the

Figure 3: DEA coefficients

superiority index optimized score of the non-superior alternatives. A typical value that is usually set to ε is 10-6. Higher values affect the discriminating power of the method and may result to infeasibility. The constant $\boldsymbol{\varepsilon}$ seen as a parameter and assigned bigger, more significant values than the proposed -may serve as a discriminating mechanism enabling the reduction of the number of superior alternative decisions, thus limiting the alternatives proposed as suitable for the decision. The repeatitive process to define coefficients in order to find the best among the others is presented in figure 3. A new innovative variation calculating only one weight for all criteria nominated as varcoin with a single formula is below presented.

3. DOB=MIN (BOD): DECISION OF BEST: MIN(BOD)

3.1 DoB varcoin

Searching in DEA the best variation we found that there is a unique weight (varcoin) to be applied on normalized values suggesting the best among the others. The proposed variation finds the superior index value of all alternatives and the unique DMU with j=1 when all questionnaire items for all DMUs considered as outputs with varcoin weight \boldsymbol{w} equal to reciprocal of max e_j. The concept may be easily proved.

$$\max E : \sum_{i=1}^{n} \sum_{j=1}^{m} w_{ij} y_i$$

$$E_J = \sum_{i=1}^{m} w_i * y_{ij} \le 1 \quad \forall j \in (1:n)$$

$$e_j = \sum_{i=1}^{n} y_{ij} \ \varepsilon = \frac{1}{\max(e_j)} J: [1, m]$$

$$w_i \ge \varepsilon \quad \forall i \in (1:m)$$

Figure 4: DEA DoB index variation

3.2 e-DoB model

As mentioned before whenever alternate optimization techniques are used to rank the *dmus* often they provide solutions that are more or less different concluding to low-level trust or confidence of decision



maker(s). The aim of this work is to overcome the doubt shortcoming with an implemented interactive e-model proposing a set of composite indicators (weights) to harmonize the most popular ordering techniques weighted/ nonweighted sum, multi-criteria analysis, TOPSIS index and DEA matrix of superior indexes. Therefore, the novelty is that the solution satisfies all ranking methods by extracting the relative supreme relationships to adjust the suggested weights to his preferences. The previously mentioned DEA varcoin is also incorporated eliminating drastically the time and maximizing at the same time the confidence level. The presentation and

Figure 5: DEA TOPSIS for two attributes

communication layer is presented in screenshot-xx. The input values of the decision problem formulated in a two-dimension matrix of dmus (sc) and their assigned

attributes (*ko*): (*sci, koj*) and are entered in the left-hand data layer. Attributes may be weighted or not and weights are entered on top of matrix. Data (values and eventual weights) may be entered either manually or from a file or related data base table. Weighted sum is calculated and in next step, are normalized, if required and the z-scores are presented. DEA indexes using the varcoin (which is calculated and displayed in yellow above DEA head) are also calculated in corresponding column. Finally, *topsis* indexes are calculated and presented in corresponding column. Running the program, the concept is proved since ranking based on *dea, topsis,* normalized or none, weighted or none sum indexes indicate usual different winning dmus. At this point, the simple but novelty idea to aggregate the two main indexes (*topsis and dea*) for each *dmu* is formulated and applied. The model is formulated as dynamic programming with the objective to minimize the sum of dmus *dea* index standard deviations from corresponding *topsis index* by changing the applied weights:

$$\min \sum_{i}^{nr \ of \ dmus} (tops_i - w_i dea_i)^2) \ subject \ to: w_i > 0$$

3.3 e-max (DoB) MCDA personalized option

Further to the above aggregation that improves the confidentiality level in decision, making the model will provide further also the option for more personalized decision based on decision maker in a sample ranking preference order (relationship of superiority). In column with label f he fills with numbers (1, 2, 3) his preference order and push *prefer* button. Preferences are saved on a table **f**. An Ip model is asked to find correction factor zj of weight wj for all j attributes. For each k non-selected i dmu the f(i) is set to k+3. An LP model has been formulated to find the weights, which will satisfy the decision maker preferences.

$$\begin{split} \min \sum_{j=1}^{\#attributes} (zw)_j k=3: & [i=1: \#dmus \ if \ f(i)="" then \ [f(i)=k:k=k+1] \} \\ score(f(i)) &= \sum_{j=1}^{\#attributes} (zwv)_{f(i)j} \quad score(f(1)) > score(f(2)) > score(f(3)) \\ &\forall k \ \{1: \#dmus-3\} \}: score(f(3) > score(f(i)) \end{cases} \end{split}$$

Figure 6: Multiple Criteria Decision making according to decision makers' preferences

3.4 DoB: EMERGE case study

| Table 2: Emis: | sions monitoring | weights |
|----------------|------------------|---------|
|----------------|------------------|---------|

| Argument | Weight |
|--|--------|
| ARM (availability reliability, maintenability) | 99 |
| AI estimation and prediction | 87 |
| Installation time | 71 |
| Response time for decision making | 65 |
| Vessel specific | 59 |
| Operation specific | 48 |
| expandability | 30 |
| Open architecture | 18 |
| Modbus , nmea etc. interoperability | 17 |
| Installation & maintenance cost | 10 |

New methodologies and systems for ship emissions measurments, prediction and pollution footprint minimization have been developed taking the advantages provided from shipping 4.0 in order to replace or improve the conventional statistical and generic solutions as outlined from EEOI (energy efficient operation index), STEAM (Ship traffic emission assessment model) and MRV (monitoring, reporting and verification). Attributes of IoT (Internet of things) network topology: architecture, wireless, autonomy, applied big data analytics, prediction potential, availability, reliability and maintainability are identified

and evaluated for a numerus of alternate solutions² (DeepSea Casandra, Danaos waves, METIS, LAROS, EMIRAM, COSMOS, STEAM). TOPSIS and DEA suggest different solutions while the DoB method suggests a solution satisfying both of ranking techniques. According to DoB the top-10 attributes are ordered according to their weights are presented in table 2.

² www.deepsea.ai , www.metis.tech , www.danaos.gr , https://www.wartsila.com/voyage , www.laros.gr

4. CONCLUSIONS

This work was inspired from the golden rule "how to the Bod is reduced to naught" as was defined by **Muhammad Luqman** (<u>https://pg.punjab.gov.pk/benefit_of_doubt</u>). The application of DoB **coins** (composite indicators) to aggregate and satisfy the most known ordering techniques TOPSIS and DEA transparently as black box from decision makers was evaluated with lowest BoD. Eventually the integration of other techniques could be a future enrichment. An extension could be the use of noise elimination techniques for further confidence level improvement.

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Screenshot 1: DoB presentation and interaction screen

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³ vesselife.com: European Maritime and Fisheries Funds EMFF under GA No 863565/2019. emerge-h2020.eu: Evaluation, control and Mitigation of the Environmental impacts of shippinG Emissions, received funding from the European Union's Horizon 2020 research and innovation program under GA No. 874990. smart-sea.eu: The Surveying & Maritime internet of thingS EducAtion (SMARTSEA) funded by EU Erasmus+





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