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METHODS

An Alternative Ranking Order Method Accounting for Two-Step Normalization (AROMAN)–A Case Study of the Electric Vehicle Selection Problem

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ABSTRACT Decision-making is a ubiquitous and paramount issue in the modern business world. Inappropriate decisions may lead to severe consequences for companies. Considering that the evaluation of alternatives is generally affected by several criteria, decision-making should be considered a very challenging task. From the 1945s to the present day, various multi-criteria decision-making (MCDM) methods have evolved, supporting people in the decision-making process. The main aim of this paper is to propose an original MCDM method and to demonstrate its applicability in an empirical case study that relates to the Electric Vehicle (EV) selection problem. To solve the electric vehicle selection problem for the last-mile delivery, we developed and applied a new MCDM method - the AROMAN (Alternative Ranking Order Method Accounting for Two-Step Normalization) method. The main contribution of the AROMAN method is coupling the linear and vector normalization techniques to obtain precise data structures used in further calculation. In addition, the original final ranking equation is developed. To demonstrate the robustness of the proposed method, a comparative analysis with other state-of-the-art MCDM methods is conducted. The results indicate a high level of confidence in the AROMAN method in the decision-making field. In addition, the sensitivity analysis is performed, and the results indicate a high level of stability. Nevertheless, based on the confident results, the managerial implications have also been indicated.

INDEX TERMS Multi-criteria decision-making (MCDM), normalization, electric vehicles, last-mile delivery, alternative ranking order method accounting for two-step normalization (AROMAN).

I. INTRODUCTION

The advance of modern electricity generation infrastructures and substantial improvement in the automotive industry make electric vehicles (EVs) a promising transportation alternative. The electrification of road transport is the solution to the arising challenges in the transport and power sector [1]. EVs are becoming increasingly popular in modern society, especially for the last-mile delivery (LMD) process [2]. Considering energy consumption and carbon emission issues, EVs are likely to become a promising solution [3]. Unlike traditional types of vehicles (gas-powered and diesel-powered vehicles), EVs operate with lower running costs, reduce greenhouse gas emissions, and make lower levels of noise [4]. According to a European Commission document [5], at least 30 million zero-emission vehicles will be in operation on European roads and 100 European cities will be climate neutral by 2030. Therefore, many countries around the world have been trying to adopt and establish the appropriate policies for EVs [6]. With the continuous improvement of battery technology, EVs have become the center of the drive for new energy automobiles. The development of EVs is an effective way to tackle

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concerns related to fossil resource depletion and environmental pollution deterioration. Their use is in accordance with the urban sustainable development goals.

Due to rapid e-commerce development, there has been an increase in online shopping. In addition, the COVID-19 pandemic forced people to buy products online. Joerss et al. [7] conducted a survey that refers to customers' preferences about LMD. They revealed that in most cases, the highest number of respondents expected fast parcel deliveries at home. Consequently, delivery companies are under enormous pressure in response to customer demands. A further reason for such high pressure is the electrification of road transport. LMD companies have needed to shift traditional transport power sources to electrically powered sources such as EVs. Shifting to these alternative sources creates operational challenges [8]. There is an emerging question for national postal operators and other stakeholders, such as city authorities or citizens, surrounding how to choose the best EV alternative for LMD purposes. As the decision is affected by numerous criteria, this is a typical kind of multi-criteria decision-making (MCDM) problem. This paper aims to address this issue.

Decision-making is part of everyday life and business. If a decision is affected by a high number of criteria, it is a challenging task for the decision-maker to choose the most appropriate option. As support, the researchers proposed various MCDM methods, which are frequently used in the modern business world. MCDM is a procedure that compounds alternative performance across various, qualitative and/or quantitative parameters [9]. In addition, real-world decision-making problems are very intricate, unstructured, and cannot be classed as a single criterion problem [10]. There are often several criteria affecting the decision-making process. Most of the criteria are conflictual, complex, and interrelated. Some of them are also hard to describe numerically. In addition, in a decision-making process, it is necessary to include expert opinions, which depend on the specific problem and circumstances related to the time and place under consideration. Expert knowledge and experience can positively and significantly impact the final ranking of the alternatives. Since the 1980s, the MCDM field has bloomed and continues to evolve rapidly. Various MCDM methods have been proposed by many authors to solve tasks in various fields.

In this paper, we introduce an Alternative Ranking Order Method Accounting for Two-Step Normalization (AROMAN). The main motivation to develop a new MCDM method is: *i*) to make a theoretical contribution to the decision-making field; *ii)* provide a decision-making tool for the EV selection problem; *iii)* Help managers make decisions easily. To demonstrate the functionality of the AROMAN, it is applied in the context of EV selection for the LMD process.

In this study, we identified (with experts' support) four EVs as possible alternatives for LMD. These four alternatives are further assessed according to the five criteria: price, payload, width, battery capacity, and volume. By applying the newly introduced AROMAN method, the best EV solution for the LMD purpose has been identified.

The study also performs a comparative analysis to compare the results obtained by the AROMAN method with other state-of-the-art MCDM methods. The same problem is resolved by TOPSIS, ARAS and EDAS methods. All methods ranked the EV-4 as the best possible solution, Therefore, the proposed AROMAN method showed a high level of compatibility. In addition, the sensitivity analysis is performed to check the robustness of the AROMAN method. The method was tested based on the variations in aggregated normalization matrix. The results of the sensitivity analysis revealed the high robustness of the AROMAN.

A. STUDY NOVELTY AND CONTRIBUTIONS

The main contributions of this paper are as follows: i) A novel MCDM Method, AROMAN, is developed and appears for the first time in the literature; ii) The developed method is applied in the context of the EV selection problem for sustainable LMD purpose; iii) For the first time, two normalization techniques are coupled to obtain a more precise data structure for further assessment, and in addition, an original final ranking formula is developed; iv) The proposed method is compared with several existing MCDM methods and shows a high level of robustness. v) The introduced AROMAN method is general and is not limited to the EVs selection problem. It can be applied to any other MCDM problem.

The rest of the paper is structured as follows: Section II is a review of the literature. Section III elaborates on the AROMAN method. Section IV presents the application of the AROMAN meth-od to the EV selection problem for LMD and provides a comparative analysis with other state-of-the-art MCDM methods. Section V offers the paper's conclusions and highlights key avenues for future research and possible extension areas.

II. LITERATURE REVIEW

In modern society, there is an increasing interest in applying the MCDM methods in many areas, particularly in the economy [11] and transportation [12] fields. This section presents an overview of MCDM methods, especially in the field of LMD and EVs. One of the largest scientific databases, Web of Science, was the main research information source. Some of the existing MCDM methods, with their respective total number of citations since 1945, are examined and summarized in Table 1 and Figure 1.

Table 1 indicates that various MCDM methods have been proposed in the literature. This clearly shows the popularity of the MCDM field and demonstrates that it has a promising future. In addition, some of the early MCDM methods (TOPSIS, AHP, ANP, etc.) have a high level of citation indexes and are still being used by decision-makers. However, the MCDM methods, such as CoCoSo, MARCOS, BWM, and ARAS, are relatively newly developed methods and have great potential as there has been noticed an increasing trend in the number of citations.

TABLE 1. Research on the MCDM methods.

MCDM method	Publications (1945-2022)	Total Number of Citations
AHP	6.117	92.688
TOPSIS	3.151	64.969
ANP	3.157	34.214
CODAS	1.573	27.843
VIKOR	337	12.247
PROMETHEE	429	4.974
COPRAS	131	3.137
EDAS	255	2.921
ELECTRE	158	2.733
ARAS	229	2.626
WASPAS	115	2.363
MOORA	102	2.349
CoCoSo	29	440
BWM	33	514
MARCOS	9	202

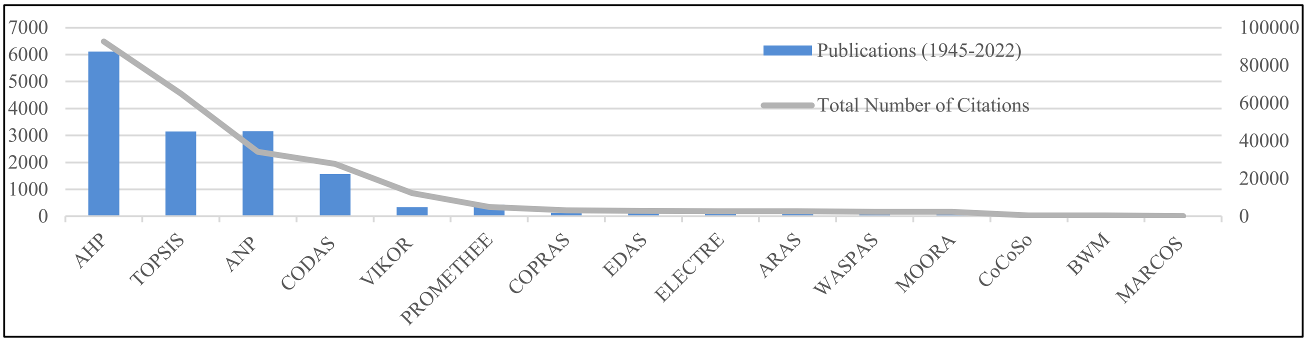

FIGURE 1. Overview of the MCDM methods with citations.

Considering that various MCDM methods were proposed between 1945 and 2022, many MCDM problems became easier to handle. As numerous MCDM methods appear in the literature, the decision-maker can choose the most appropriate according to the characteristics of the specific problem they face. For example, the Additive Ratio Assessment (ARAS) method was applied to assess a microclimate in an office [10]. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method was used to rank the forklift trucks for warehouse operations [13]. The Measurement Alternatives and Ranking according to the Compromise Solution (MARCOS) method was used in solving the sustainable supplier selection problem in the healthcare industry [14]. The Weighted Aggregated Sum Product Assessment (WASPAS) meth-od was applied in the manufacturing industry [15]. The multi-normalization multi-distance assessment (TRUST) approach was used to locate a battery swapping station for electric scooters [16].

The combinative distance-based assessment (CODAS) method was relevant to the robotics industry [17]. The Analytic Hierarchy Process (AHP) was used to rank third-party logistics providers in the automotive industry [18].

The Elimination and Choice Expressing Reality (ELECTRE) method was applied to evaluate 3PL performance and select the best one [19]. The Multi-Objective Optimization Ratio Analysis (MOORA) method was used to evaluate the industrial maintenance system [20]. The Analytic Network Process (ANP) method was used to assess employees [21]. The Combined Compromise Solution (CoCoSo) method was used to choose logistics and transportation companies [22]. Most of the methods mentioned above have been further ex-tended by various authors, mostly with the fuzzy sets which deal with uncertainty and linguistic information [23], [24], [25], [26], [27], [28], [29], [30].

Regarding MCDM methods in LMD, there are several publications in the Web of Science database. For example, a novel hybrid MCDM model was developed to evaluate sustainable LMD solutions [28], where the Delphi, Factor Relationship (FARE), and VIKOR methods were coupled into the fuzzy environment. The methodology was tested in Belgrade. The optimal solution regarding the LMD mode was considered by using the Picture Fuzzy CODAS method [23]. In addition, the Picture Fuzzy MCDM approach in the logistics industry was used to clarify the sustainable LMD mode [2]. A Bayesian BWM-based multi-criteria was used to assess the competence of delivery personnel [31]. The TOPSIS method was used to optimize the location of freight consolidation facilities in inner-city areas [32]. Research on the MCDM methods in the context of LMD is summarized in Table 2.

Nevertheless, EVs as a modern transportation mode have gained increasing popularity in the literature which is confirmed by numerous papers about MCDM methods. For example, hybrid MCDM methods were used to evaluate fuel cell technology for the next generation of hybrid-powered cars [33]. MCDM techniques such as EDAS, SAW, TOPSIS, and PROMETHEE II were applied to evaluate public infrastructure for EVs in cities and resorts in Lithuania [34]. The fuzzy MCDM approach (Fuzzy-AHP, Fuzzy-TOPSIS, and Fuzzy-COPRAS) was used to rank the sites of EV charging stations [35]. An integrated approach, based on group MCDM (TOPSIS and MOORA), was implemented to assess the sustainability of charging stations [36]. A consolidated MCDM framework to evaluate the performance of the EV battery based on ranking strategies (MARCOS, CoCoSo, ARAS, COPRAS, SECA, and MAIRCA) has also been developed [37]. Das et al. [38] compared the performance of EVs using the evaluation of mixed data. Conversely, the TOPSIS method was used for the reducer housing of EVs [6]. The Fuzzy logic and AHP methods were integrated to evaluate the sustainable location selection of EV fast-charging stations [39]. The AHP and the MABAC approaches were coupled to select the EV [40]. The DEMATEL and Multi-MOORA approaches were integrated to help to plan the location of the EV charging stations [41]. Costa et al. [42] carried out spatial planning of EV infrastructure for Belo Horizonte in Brazil using MCDM methods. The impact and cost-effectiveness of the Chinese plug-in electric vehicles (PEV) were considered, and a vehicle choice model was used to predict PEV market share under various policies [43]. In addition, research concerning the drivers of recent improvements in Saudi Arabia's fleet fuel economy for cars and light-duty trucks has also been conducted [44]. The manufacturing facility location problem for automotive lithium-ion batteries was solved by applying an integrated neutrosophic decision-making approach (type-2 neutrosophic numbers, BWM, and CODAS) [45]. The research on MCDM in the context of EVs is summarized in Table 3.

By summarizing the results of the literature review, the following conclusions have been reached:

1) Between 1945 and 2022, many MCDM methods have been developed and applied in various contexts.

2) Various MCDM methods have been applied in the context of LMD for solving problems such as sustainable LMD mode selection, delivery staff competence assessment, and locating freight consolidation facilities in inner city areas.

3) Concerning the use of MCDM in the field of EVs, some papers have considered public infrastructure evaluation, EV charging station evaluation, EV battery performance evaluation, and other issues. However, no papers have addressed the EV selection problem for LMD. The most similar research was performed by Sonar and Kulkarni [40]. These authors coupled the AHP with the Multi-Attributive Border Approximation Area Comparison (MABAC) method to identify the best EV solution. However, they applied the methodology in the general case, private use, rather than in the context of LMD.

4) Regarding methodological issues and the research gap, we solve the EV selection problem with a novel approach: by applying the newly proposed AROMAN method and using criteria closely related to LMD. The main difference between the AROMAN method and other state-of-the-art MCDM techniques is in the way the data are normalized and how the final ranking is calculated. First, we will explain the issues related to normalization. Data normalization is a process where the input data of a decision-making matrix is transformed within an interval from 0 to 1. This procedure often helps decision-makers to obtain the same structure of the data, which makes further calculation easier and more relevant. Normalization should be particularly used to facilitate alternative comparison when different types of numerical values are assigned to criteria [46]. The normalized value depends on the relative position of the criterion value within the range of values. Therefore, it is highly important to determine the correct normalization technique as it affects further calculation in a decision-making process. Many MCDM methods are largely based on one type of normalization. However, using only one normalization technique could lead to false information, due to its simple and subjective way of normalizing [16]. In the newly proposed AROMAN method, two types of normalization are conducted, and the obtained normalized values are aggregated into the averaged normalized decision-making matrix. We tested how combining two types of normalization may affect the final ranking alternatives. The first type of normalization used was the linear type, where the normalized value of any criterion gives either the distance from the worst alternative (criterion max-type) or the best alternative (criterion min-type). The second type of normalization used was vector normalization.

This type of normalization is symmetric, computationally efficient [47], and was used in the TOPSIS decision-making technique. In the study [47], several normalization techniques (min-max, vector, linear, and logarithmic) were compared, and the ranking of alternatives differs as a consequence of changing the normalization technique. Driven by this conclusion, the authors of this paper decided to couple two normalization techniques (the linear and vector) using arithmetic means to obtain more precise normalized data. This is because coupling the two methods is expected to lead to a more accurate description of empirical data. Furthermore, the final ranking results were compared to the other MCDM techniques to notice the differences between the considered techniques. This will be elaborated on in the results section.

5) Alongside the difference in the normalization, the AROMAN method also proposes an original final ranking calculation. We examined the MCDM methods listed above regarding their normalization techniques and their calculations for obtaining the final ranking of the alternatives. All the considered MCDM methods use only one type of data

TABLE 2. MCDM methods used in the context of LMD.

Problem	Method	Authors and References
Sustainable LMD mode	Picture Fuzzy MCDM approach	Švadlenka, Simić, Dobrodolac, Lazarevic, and Todorovic [2]
Delivery staff competence assessment	Bayesian-based MCDM method	Li, Wang, and Rezaei [31]
Freight Consolidation Facilities in Inner City Areas	TOPSIS	Aljohani and Thompson [32]
LMD mode selection	Picture Fuzzy CODAS	Simić, Karagoz, Deveci, and Aydin [23]
Sustainable LMD solutions	Delphi, FARE, and VIKOR	Krstić, Tadić, Kovač, Roso, and Zečević [28]

TABLE 3. MCDM methods used in the context of EVs.

Problem	Method	Authors and References
Fuel Cell Technology Evaluation	Hybrid MCDM	Huang, Hung, and Tzeng [33]
Public Infrastructure Evaluation for Electric Vehicles in Lithuania	EDAS, SAW, TOPSIS, and PROMETHEE II	Palevičius, Podviezko, Sivilevičius, and Prentkovskis [34]
Electric Vehicle Charging Station Evaluation	DEMATEL, Multi-MOORA	Liu, Yang, Zhou, and Tian [41]
Sustainable Location Selection for the EV fast charging station	Fuzzy-AHP	Guler and Yomralioglu [39]
Electric Vehicle Charging Station Evaluation	F-AHP, F-TOPSIS, F-COPRAS	Ghosh, Ghorui, Mondal, Kumari, Mondal, Das, and Gupta [35]
Electric Vehicle Battery Performance Evaluation	SECA, MARCOS, CoCoSo, ARAS, COPRAS, and MAIRCA	Ecer [37]
Reducer Housing Evaluation of EVs	TOPSIS	Xu, Chen, Liu, Yang, Xu, Zhang, and Gao [6]
EV selection	AHP, MABAC	Sonar and Kulkarni [40]
Manufacturing Facility Location Selection for Automotive Lithium-ion Batteries	Type-2 neutrosophic numbers, BWM, and CODAS	Deveči, Simic, and Torkayesh [45]
Charging Station Assessment under Sustainability	TOPSIS, MOORA	Yagmahan and Yılmaz [36]
Electric Vehicle Selection for Last-Mile Delivery	**AROMAN**	**Our study**

normalization (min-max, vectors normalization, etc.) and mostly differ in the final ranking formula.

The differences are highlighted in Table 4. The presented comparison with other MCDM methods is not limited to those included in Table 4. The authors also analyzed other MCDM methods and found differences in final ranking formulas; however, their presence in the table would be too extensive. By reviewing the literature, we concluded that the newly proposed AROMAN method is original in its final ranking calculation.

III. METHODOLOGY

A decision-making problem is a problem where multiple criteria are considered to find the best alternative among a certain set, contrary to a single criterion approach [46]. Nowadays, many MCDM methods are being used to solve various problems such as TOPSIS [48], ARAS [10], CODAS [17], WASPAS and COPRAS [49], VIKOR [50], CoCoSo [22], and others. All these methods are mostly based on similar principles of decision-making. There is an initial decision-making matrix, which consists of several alternatives compared to multiple conflicting criteria. The result of any MCDM method is a final ranking of alternatives that helps decision-makers to select the best one.

In this paper, an Alternative Ranking Order Method Accounting Two-Step Normalization (AROMAN) is proposed. This method combines the normalized data from two-step normalization and obtains an average matrix from normalized data. The AROMAN method can be described in the following steps:

Step 1. Determine the initial decision-making matrix with the input data.

Before the decision-making procedure starts, it is necessary to define the initial decision-making matrix with the input data. Depending on the problem, the input data are mostly gathered in advance, regarding the alternatives and criteria. Therefore, let us suppose we have a decision matrix X_{mxn} with the input data $x_{11}, \ldots, x_{2j}, \ldots, x_{mn}$, (Equation 1):

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{21} & \cdots & x_{2j} & \cdots & x_{2n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}, \quad i = 1, 2, \ldots, m, \quad j = 1, 2, \ldots, \mathrm{n}; \tag{1}$$

Step 2. Normalize the input data.

After the decision-making matrix with the input data is defined, the second step is to normalize the input data. This means that the input data should be structured in intervals between 0 and 1. There are two types of normalization Equation 2 and 3:

TABLE 4. Compared MDCM methods with the AROMAN in the final ranking formula.

MCDM method	Final Ranking Formula	Description
TOPSIS	$R_i = \frac{d_i^-}{d_i^- + d_i^+}$	The relative closeness to the positive ideal solution.
ARAS	$K_i = \frac{S_i}{S_0}$	The degree of alternative utility.
WASPAS	$Q_i = \lambda Q_i^{(1)} + (1-\lambda)\, Q_i^{(2)}$	The aggregated measure for each alternative where: λ is the parameter of the WASPAS method and could be changed in the range of 0 to 1.
CoCoSo	$K_i = (K_{ia} \cdot K_{ib} \cdot K_{ic})^{\frac{1}{3}} + \frac{1}{3}(K_{ia} + K_{ib} + K_{ic})$	The final ranking of alternatives K_i, where: K_{ia} K_{ib} and K_{ic} are the Total Utility Strategies for all alternatives.
SWARA	$W_j = \frac{q_j}{\sum_{j=1}^{n} q_j}$	The final ranking of alternatives for each decision-maker. By determining the relative weight of each attribute, the values are arranged in descending order and the final ranking takes place.
EDAS	$AS_i = \frac{1}{2}(NSP_i + NSN_i)$	The appraisal score for each alternative, where NSP_i and NSN_i are the normalized values of the weighted Positive Distance from Average (PDA) and weighted Negative Distance from Average (NDA) of each alternative.
AROMAN	$R_i = L_i^{\lambda} + A_i^{(1-\lambda)}$	The final ranking of the alternatives (R_i), where λ represents the coefficient degree of the criterion type. We propose λ to be 0.5.

Step 2.1 Normalization 1 (Linear):

$$t_{ij} = \frac{x_{ij} - x_{ij}}{x_{ij} - x_{ij}}, \quad i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n; \tag{2}$$

Step 2.2 Normalization 2 (Vector):

$$t_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}; \quad i = 1, 2, \ldots, m, \; j = 1, 2, \ldots, n; \tag{3}$$

The normalization techniques in the step 2 are used for both criterion types (min and max).

Step 2.3 Aggregated averaged normalization

The aggregated averaged normalization is done by applying the following Equation 4:

$$t_{ij}^{norm} = \frac{\beta t_{ij} + (1-\beta) t_{ij}^{*}}{2}; \; i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n; \tag{4}$$

where t_{ij}^{norm} denotes the aggregated averaged normalization. β is a weighting factor varying from 0 to 1. In our case, we considered β to be 0.5. In the MCDM field, there are examples of different approaches to considering the aggregation procedure, such as geometric mean [51] or the centroid in a plane [52]. However, we decided to apply the arithmetic mean because, according to the authors' knowledge, it is the most used mean.

Step 3. Multiply the Aggregated Averaged Normalized decision-making matrix with the criteria weights to obtain a weighted DM matrix.

$$\hat{t}_{ij} = W_{ij} \cdot t_{ij}^{norm}; \quad i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n; \tag{5}$$

Step 4. Separately summarize the normalized weighted values of the criteria type min (L_i) and the normalized weighted values of the max type (A_i).

This can be calculated by applying Equation 6 and Equation 7:

$$L_i = \sum_{j=1}^{n} \hat{t}_{ij}^{(min)}; \quad i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n; \tag{6}$$

$$A_i = \sum_{j=1}^{n} \hat{t}_{ij}^{(max)}; \quad i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n; \tag{7}$$

Step 5. Calculate the final ranking of the alternatives.

To obtain the final ranking of the alternatives (R_i), it is necessary to apply Equation 8:

$$R_i = L_i^{\lambda} + A_i^{(1-\lambda)}; \quad i = 1, 2, \ldots, m; \tag{8}$$

where: R_i is the label of the ranked alternatives and λ represents the coefficient degree of the criterion type. Since we included both criterion types, we considered parameter λ to be 0.5.

However, there is a possibility to make variations of the parameter λ when considering the criteria type. For example, if the decision-making problem has two criteria of type min and 1 criterion of type max, this means that the coefficient λ should be 2/3. This logic can be followed to obtain the preference among the considered alternatives. A flowchart of the proposed AROMAN method is illustrated in Figure 2.

IV. APPLICATION TO THE ELECTRIC VEHICLE SELECTION PROBLEM

This case study assesses four EVs as possible alternatives using a novel proposed MCDM framework based on AROMAN. These four alternatives are estimated according to the five evaluation criteria: price, payload, width, battery capacity, and volume.

Price – the price of the electric vehicle on the market in the U.S. dollars. Payload – the maximum EV payload capacity, expressed in *kg*. Width - describes the width of the EV, expressed in meters. Battery Capacity – determines the EV running time with the full battery, expressed in the number of hours. Volume – expresses the volume of the EV in terms of the inside space (m^3). The criteria should be selected and sorted also from the literature. The EV selection problem is illustrated in Figure 3.

The procedure of selecting the criteria and alternatives was conducted based on discussions with experts from the fields of logistics and postal services. Two experts participated in the decision-making process, both of whom are university personnel. The first expert is an associate professor at the Postal Traffic Department with twelve years of experience. The second expert is a full professor in the Management, Marketing, and Logistics Department with seventeen years of experience. The experts were interviewed online due to the COVID-19 pandemic. Their names will not be displayed according to the privacy agreement. In addition, the EV alternatives should be identified by the companies' management considering the LMD process. The input data matrix, presented in Table 5, is formulated based on experts' opinions, where they agreed that the data correspond to the real conditions in the EV market.

After the decision-making matrix with the input data was created, it was important to define the type of each criterion.

Some criteria needed to be minimized while others needed to be maximized. In our case, the criterion price needed to be minimized and all the other criteria needed to be maximized. As mentioned above, the experts from the field expressed their opinion on the criteria weights. The highest importance was assigned to the price followed by width, payload, battery capacity, and volume. After the initial decision-making matrix was defined, the next step was to normalize the input data. The obtained normalized values were calculated by applying Equations 2-4. They are presented in the following tables (Table 6 – Table 8).

The next step was to multiply the Aggregated Averaged Normalized DM matrix with the criteria weights. It was computed by applying Equation 5 and is presented in Table 9. $\boldsymbol{L_i}$ and $\boldsymbol{A_i}$ values were calculated by using Equations 6 and 7. To obtain the final rank of the EVs, the *Ri* value was calculated according to Equation 8. In this case, we recommend parameter λ as 0.5 since we include both criterion types. Table 10 shows the computed values and final ranking of the alternatives. Nevertheless, we solved the problem by considering λ to be 0.2 since we have one out of five criterion type of min. In this case, the following ranking order was obtained: $EV_4(1.0161)$[[*space*]]> $EV_1(0.8270) > EV_2\ (0.7105) > EV_3$ (0.6497). The best EV solution was not changed neither in this case.

A. COMPARATIVE ANALYSIS

To test the robustness of the proposed AROMAN method, the EV selection problem was solved using other MCDM

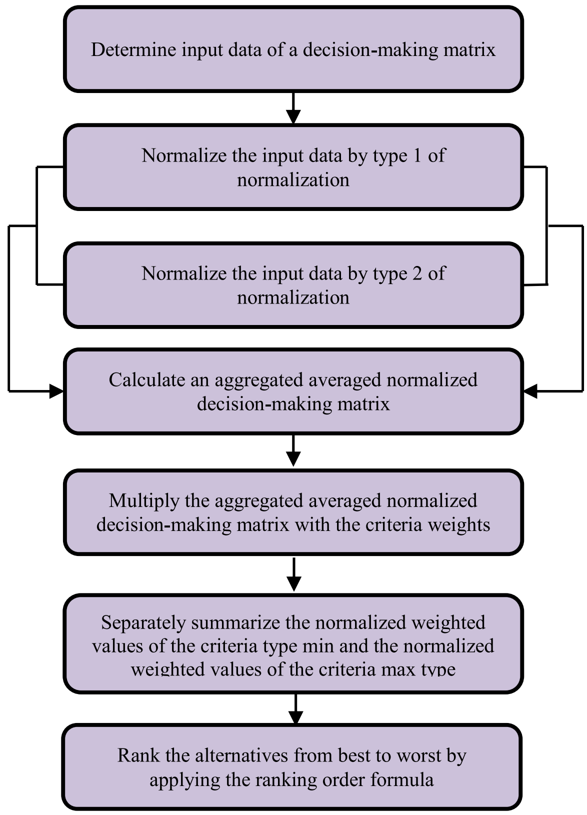

FIGURE 2. Flowchart of the AROMAN method.

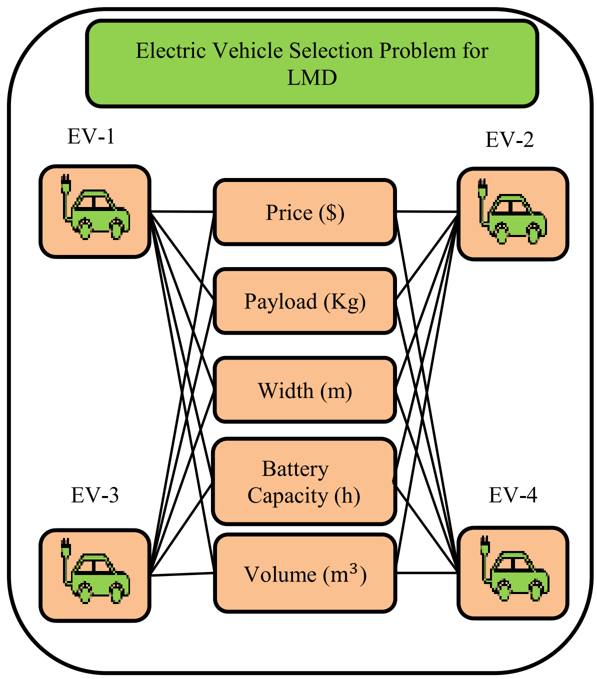

FIGURE 3. A simplified description of the problem.

methods such as TOPSIS, ARAS, EDAS, WASPAS and MARCOS. These results are presented in Table 11.

By analyzing the results of different MCDM methods, it can be noted that the newly proposed AROMAN method

TABLE 5. An Initial decision-making matrix.

	Price ($)	Payload (kg)	Width (m)	Battery capacity (h)	Volume (m^3)
EV-1	40000	1.200	1.4	8	9
EV-2	38500	1.150	1.2	6	6
EV-3	39400	600	1.1	7	5
EV-4	48000	1.300	1.6	10	12
min/max	min	max	max	max	max
Weight	0.2800	0.2200	0.2600	0.1500	0.0900

TABLE 6. Normalization type 1.

	Price ($)	Payload (kg)	Width (m)	Battery capacity (h)	Volume (m^3)
EV-1	0.1579	0.8571	0.6000	0.5000	0.5714
EV-2	0.0000	0.7857	0.2000	0.0000	0.1429
EV-3	0.0947	0.0000	0.0000	0.2500	0.0000
EV-4	1.0000	1.0000	1.0000	1.0000	1.0000
min/max	min	max	max	max	max
Optimal	38500	1300	1.6	10	12
	42000	600	1.1	6	5

TABLE 7. Normalization type 2.

	Price ($)	Payload (kg)	Width (m)	Battery capacity (h)	Volume (m^3)
EV-1	0.4802	0.5470	0.5228	0.5070	0.5322
EV-2	0.4622	0.5242	0.4481	0.3802	0.3548
EV-3	0.4730	0.2735	0.4108	0.4436	0.2957
EV-4	0.5762	0.5926	0.5975	0.6337	0.7096
min/max	min	max	max	max	max

TABLE 8. Aggregated Averaged Normalization (β =0.5).

	Price ($)	Payload (kg)	Width (m)	Battery capacity (h)	Volume (m^3)
EV-1	0.1595	0.3510	0.2807	0.2517	0.2759
EV-2	0.1155	0.3275	0.1620	0.0951	0.1244
EV-3	0.1419	0.0684	0.1027	0.1734	0.0739
EV-4	0.3941	0.3981	0.3994	0.4084	0.4274
min/max	min	max	max	max	max
Weight	0.2800	0.2200	0.2600	0.1500	0.0900

TABLE 9. Aggregated Averaged Weighted Normalized matrix with summarized criterion types.

	Price ($)	Payload (kg)	Width (m)	Battery capacity (h)	Volume (m^3)	Sum of all min criteria L_i	Sum of all max criteria A_i
EV-1	0.0447	0.0772	0.0730	0.0378	0.0248	0.0447	0.2128
EV-2	0.0324	0.0720	0.0421	0.0143	0.0112	0.0324	0.1396
EV-3	0.0397	0.0150	0.0267	0.0260	0.0067	0.0397	0.0744
EV-4	0.1103	0.0876	0.1038	0.0613	0.0385	0.1103	0.2912
min/max	min	max	max	max	max		
Weight	0.2800	0.2200	0.2600	0.1500	0.0900		

TABLE 10. Final ranking of the EVs.

Sum of all min criteria L_i	Sum of all max criteria A_i	Final rank of EVs
0.0447	0.2128	**0.6727**
0.0324	0.1396	**0.5535**
0.0397	0.0744	**0.4721**
0.1103	0.2912	**0.8718**

offers a solution that is compatible with all compared MCDM methods.

AROMAN ranked the alternatives in the following ranking order: $EV_4[[space]] > EV_1 > EV_2 > EV_3$. The comparison with other MCDM methods is also presented in Figure 4.

The results of the comparative analysis reveal that the proposed AROMAN method is characterized by a high level of robustness, providing expected confidence in the decision-making process.

B. SENSITIVITY ANALYSIS

The sensitivity analysis is performed to check the stability of AROMAN method. The stability of the AROMAN method is tested based on the variations in the aggregated normalized matrix. When coupling two normalization techniques, the authors introduced a trade-off parameter β [0-1]. The original case was used the case when the trade-off parameter was β =0.5. However, the model is tested for all other scenarios with an increment value 0.1.

TABLE 11. Comparative Analysis of AROMAN with other MCDM methods.

Electric Vehicles	AROMAN	TOPSIS	ARAS	EDAS	WASPAS	MARCOS
EV-1	0.6727	0.6309	0.8830	0.6806	2.8834	0.7129
EV-2	0.5535	0.4378	0.7940	0.3847	2.7858	0.6463
EV-3	0.4721	0.0894	0.6844	0.0365	2.6564	0.5594
EV-4	0.8718	1.0000	0.9491	0.8830	2.9423	0.7587

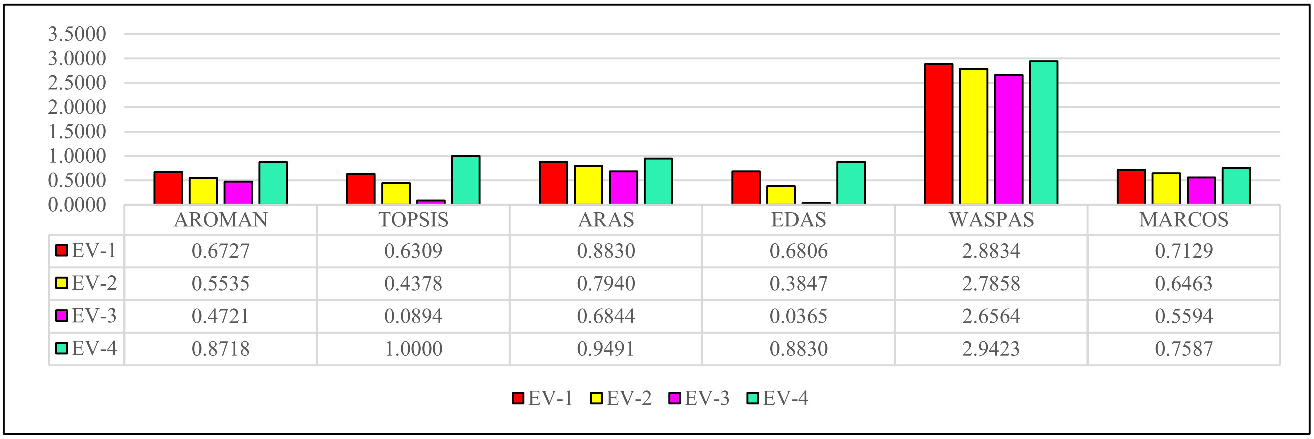

FIGURE 4. Comparative analysis with other methods.

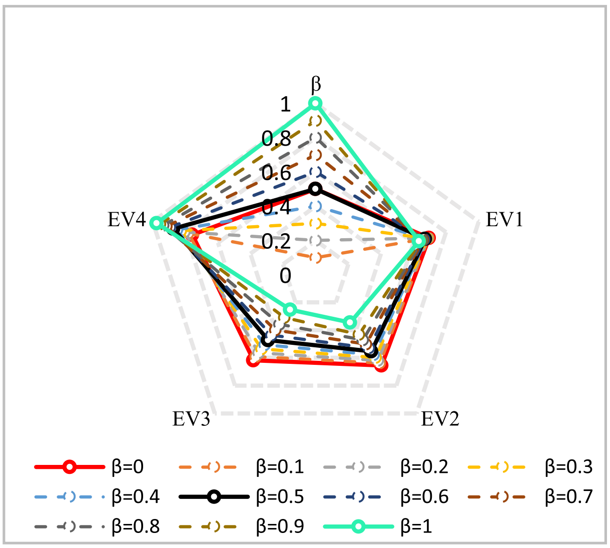

FIGURE 5. Sensitivity Analysis to changes in the trade-off parameter β.

The results of the sensitivity analysis are presented in Figure 5.

According to Figure 5, the same ranking of EVs in the analyzed decision-making context is generated in all created problem instances, i.e., the ordering is EV_4[[space]]$> EV_1 > EV_2 > EV_3$. The ranks of all four EVs are stable to changes in the trade-off parameter.

C. MANAGERIAL IMPLICATIONS

The increasing number of EVs, especially on European roads, leads to a variety of decision-making issues where the AROMAN method can be applied. Within the EV industry, alongside the EV selection problem that has been addressed in this paper, there is also a possibility to apply the AROMAN method to determine EV charging station locations in cities.

In addition, customers' preferences for charging station locations should also be considered as a separate problem. Moreover, the AROMAN method can be applied by decision-makers (managers) in various branches of industry such as logistics, automotive, medicine, commerce, food, construction, education, and others. One of the advantages of the AROMAN is its simplicity of implementation, which means that managers all around the world can use it to solve their decision-making problems. By following the procedure step-by-step, the decision-maker identifies the best alternative according to the previously defined criteria. The first prerequisite is to adequately identify the decision-making problem in terms of possible alternatives and criteria that describe them and further determine their type. Before the decision-making problem is formulated, managers should create a team of experts and discuss the criteria according to their importance. As not all the criteria are equally important to each decision-maker, a change in criteria weight may negatively affect the final ranking of alternatives. The AROMAN method has presented a high level of robustness when compared to some of the verified decision-making methods such as TOPSIS, ARAS, EDAS, WASPAS, and MARCOS. It is highly useful in complex decision-making problems where multiple interrelated criteria affect the decision.

V. CONCLUSION

In the future, EVs will have many benefits for cities and society, reducing air and noise pollution and offering environmentally friendly solutions. EVs, as a part of the sustainable LMD process, have become increasingly popular in modern urban distribution systems. Internationally, sustainable urban cities all around the world are shifting from traditional transport means to EVs because these vehicles are environmentally cleaner, reliable, flexible, and are likely to meet future standards and procedures. By 2035, according to the European Commission, all new cars and vans registered in Europe will be zero-emission. Consequently, this will significantly positively affect the European cities.

The objective of this paper was to propose a novel method for solving MCDM problems. It is named the Alternative Ranking Order Method Accounting for Two-Step Normalization (AROMAN). The method is characterized by the coupling of two normalization techniques to obtain the normalized data used further in a decision-making process. In addition, an original formula for the calculation of final rankings has been developed. The novel AROMAN method has been applied to the EV selection problem for sustainable LMD.

Currently, there are several types of EVs for LMD in the market. Nevertheless, an increasing number of EV types is expected in the future. For an efficient postal and logistics process, it is crucial to identify and select the best possible alternative for the LMD process. This was the main motivation to address the EV selection problem by proposing the novel AROMAN methodology. The methodology is also suitable to address the cargo bike selection problem, or any other LMD mode.

The implementation of AROMAN in the case of the EV selection problem offered the following results: the best-ranked EV was the EV-4 with a preference of 0.8718, followed by the EV-1, EV-2, and EV-3, respectively. To verify the results of the newly proposed AROMAN method, a comparative analysis with other MCDM methods was performed. The TOPSIS, ARAS, and EDAS ranked the alternatives in the same manner as the AROMAN. A high level of confidence in the AROMAN method was therefore proven. In addition, the robustness of the AROMAN method was tested based on the variations in the aggregated normalized matrix. The results of the sensitivity analysis presented a high level of robustness.

This paper offers several contributions: 1) The original MCDM method, AROMAN, is proposed; 2) The AROMAN method appears for the first time in the literature for solving MCDM problems, combining two normalization techniques to obtain more precise data structure for further evaluation; 3) The application of the AROMAN method is used in the EV selection problem for sustainable LMD. However, the AROMAN can be applied to any other problem considering multiple interrelated criteria of both min and max type; 4) The proposed methodology is compared with several existing MCDM methods and presents a very high compatibility index and a high level of robustness. 5) The AROMAN method is relatively easy to use, which makes it a convenient tool for managers across all fields of business.

However, this paper has some limitations. The proposed AROMAN method uses crisp input values. It is not suitable to deal with uncertainty. Nevertheless, it is possible to overcome this limitation by integrating the AROMAN within the fuzzy logic environment.

Moving forward, future research should aim to 1) Apply the AROMAN method in various contexts and fields of decision-making problems; 2) Extend it on fuzzy sets and expand its applicability in the decision-making field; 3) Couple it with other MCDM methods to determine criteria weights, such as CRITIC, ENTROPY, BWM, AHP, and others.

A. AVAILABILITY OF DATA AND MATERIALS

Not Applicable.

B. FUNDING

Not Applicable.

AUTHOR AGREEMENT

Sara Bošković: conceptualization, investigation, methodology, software, formal analysis, writing-original draft, review and editing. Libor Švadlenka: resources, project administration, writing-original draft, review and editing. Stefan Jovčić: investigation, formal analysis, visualization, data curation, writing-original draft, review and editing. Momčilo Dobrodolac: investigation, data curation, writing-original draft, review and editing. Vladimir Simić: investigation, visualization, writing-original draft, review and editing. Nebojša Bacanin: investigation, visualization, writing-original draft, review and editing.

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