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APPLICATION OF NEW METHOD EVALUATION BY DISTANCE FROM IDEAL SOLUTION OF ALTERNATIVES IN THE ASSESSMENT OF ELECTRIC VEHICLES

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Abstract:
The objective of this study was to provide decision-making assistance in selecting electric vehicles (EVs). The multi-criteria decision-making methods (MCDM), criteria importance through inter-criteria correlation (CRITIC) and evaluation by distance from ideal solution of alternatives (EDISA), along with the technical specifications of EVs, were employed to facilitate the decision on purchasing an EV. A total of 14 minivans were analysed based on 10 criteria. The findings from the CRITIC method indicated that the most significant criteria are battery charging and vehicle consumption. The EDISA method indicated that EV11 exhibited the best characteristics and represented a prudent purchase decision. Nevertheless, the ultimate decision must consider additional factors beyond just the technical specifications, as numerous elements affect the final choice, necessitating an examination of other attributes of the EV.

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1. INTRODUCTION

Climate changes resulting from human activities have heightened awareness regarding the significance of environmental protection [1]. Business practices in various economic sectors, including the transport sector, are evolving [2]. This sector plays a vital role in the adoption of sustainable solutions [3]. There is a growing focus on electric vehicles (EVs), which have emerged as a symbol of change, contributing to a decrease in CO_2 emissions and enhancing energy efficiency [4]. All these efforts are aimed at promoting green transformation while considering the reduction of air pollution [5]. EVs are increasingly being viewed as an alternative to internal combustion vehicles, particularly within the logistics and mail industries [6]. For this reason, logistics and transportation companies are increasingly attaching importance to EVs [7]. This change has a significant impact on environmental protection, operational efficiency and the reputation of companies. More and more companies are switching to EVs. X Express is one of the first companies from Bosnia and Herzegovina to recognize the importance of using EVs in logistics, specifically express mail. These jobs involve delivering shipments and packages within a very short period [8,9].

EV vehicles are increasingly being used by companies that implement social responsibility in their business practices. By using EVs in their operations, they aim to reduce their impact on the environment and contribute to lowering air pollution. For this reason, EVs are being adopted more frequently, as they represent an ecological alternative to conventional vehicles. Studying EVs is significant from various aspects, particularly based on the environmental impact these vehicles have. A key characteristic of using EVs is that these vehicles use an electric motor and batteries that power this motor. As a result, EVs do not emit CO_2 or other harmful gases into the atmosphere, which is why

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they are increasingly adopted by businesses that want to contribute to environmental protection in this way. From all this, the importance of studying EVs becomes evident.

Transitioning to an EV requires significant financial commitments; therefore, it is essential to thoroughly evaluate which vehicle is acquired [10]. A detailed examination of the technical specifications of these vehicles is crucial to making an informed decision about the purchase of an EV. This is due to the fact that companies seek dependable vehicles. Furthermore, the cost of the EV significantly influences the decision-making process. Consequently, selecting these vehicles ought to be regarded as opting for an EV, which entails examining them from various perspectives based on specific criteria. Therefore, it is essential to utilize multi-criteria decision-making methods (MCDM) that provide an effective framework for assessing these EVs. When assessing criteria, conflicts frequently arise [11], as a single vehicle cannot excel in every category. If the criterion is the vehicle's range, it necessitates a larger battery capacity, which incurs higher costs, making it unlikely to be both the most affordable and the one with the greatest range. It is necessary to make a decision that represents a compromise between conflicting criteria. Based on that, a research question is posed: how to evaluate and select the most favourable EV based on conflicting criteria?

Company X Express aims to apply social responsibility in its business and has undertaken activities to convert its vehicles to EV. By the end of 2024, it has successfully changed 25% of its fleet. These activities are also planned for 2025, and the company has decided to purchase minivan vehicles for transporting smaller shipments. The goal of this research is to examine the technical performance of EVs in order to evaluate the observed vehicles and facilitate the decision-making process. In light of this primary objective, the specific aims of this research are established, namely:

- Choose criteria for evaluating EVs.
- Identify electric vehicles that fulfil particular requirements.
- Assess the significance of the criteria for selecting electric vehicles.
- Analyse EVs.

By achieving the established objectives, this study offers several scientific contributions.

Firstly, this study formulates a decision support model aimed at the procurement of EVs within the logistics industry, utilizing the novel MCDM technique known as EDISA. This model will assess the technical specifications of EVs and facilitate selection based on their rankings. Secondly, the implementation of the MCDM method in a practical case provides a clearer framework for evaluating EVs in relation to the shift towards sustainable business practices and environmental protection. Lastly, by identifying the technical characteristics of the vehicle, the efficiency of electric vehicle usage in express mail services is affected, which can establish a foundation for future studies focused on reducing environmental impacts during transportation.

2. MATERIALS AND METHODS

The purpose of utilising EVs is to mitigate the environmental impact of the transportation sector [12]. Nevertheless, EVs lack the features typical of traditional internal combustion engine vehicles [13]. This is particularly evident in the distance that EVs can cover on a single charge, which remains inferior to the distance that conventional vehicles can achieve on a full tank. Another significant factor hindering the broader adoption of EVs is the issue of battery charging [14], along with the cost and weight associated with these vehicles. Due to the battery, EVs are heavier than their conventional counterparts, and the time required for charging the battery is considerably longer than the time needed to refuel a gasoline tank [15]. Despite these drawbacks, the practical use of EVs continues to rise [16].

When selecting potential vehicles, the company X Express initially established several criteria that EVs must meet. The primary criterion pertains to the pricing of these vehicles. Only those vehicles priced below 50,000 euros were taken into account. For these vehicles, an authorized service must be available within the territory of Bosnia and Herzegovina to address any faults that may arise. A total of 14 vehicles met these criteria, representing potential alternatives to minivan vehicles. To ensure that certain vehicles are not misrepresented and that others with poorer results do not receive a bad reputation, these vehicles will be marked with labels from EV1 to EV14. The evaluation of these vehicles will be based on the following ten criteria:

- Acceleration (C1) represents the time it takes for an EV to reach a speed of 100 km/h from a standstill. The importance of EV acceleration is reflected in its ability to enable quick reactions in traffic and when overtaking other vehicles.

- Range (C2) represents the distance that an EV can travel on a single battery charge. The greater the range, the higher the mobility of the EV. It is worth noting that various factors, such as driving style, speed, and weather conditions, affect the range.
- Power (C3) denotes the strength of the motor in kilowatts (kW). Engine power is very important for acceleration and towing capacity [17]. Increasing motor strength results in higher energy consumption, which may lead to a shorter range for the EV. Therefore, it is crucial to balance between power and range.
- Torque (C4) is important for the operation of the engine and is measured in Nm. The higher the torque, the better the vehicle's acceleration; additionally, it impacts towing strength. A distinctive feature of EVs is their ability to reach maximum torque even at zero revolutions [18]. This characteristic also affects the towing capacity of the EV, a critical factor for trucks.
- The battery capacity (C5) is expressed in kW and reflects the amount of energy that can be stored within the batteries. Greater battery capacities result in an extended range for the EV. Nevertheless, as the battery capacity increases, so does the weight and cost of the vehicle [19], which further impacts the energy consumption of these EVs.
- Cargo maximum (C6) is the maximum volume of goods that can be loaded into an EV. It is measured in liters. This is particularly important if the focus of the EV is on transporting goods, that is, packages for express mail services. The larger the capacity, the more packages can be transported at once. Therefore, this is especially important for freight vehicles [20].
- Carrying capacity (C7) is the maximum load capacity of an EV in kilograms. This weight represents not only the load capacity for goods but also for passengers. For freight vehicles such as minivans, it is crucial to determine how much load the EV can transport. With an increase in load, the range of the EV decreases.
- Charging (C8) represents the time required to charge the EV battery. There are different chargers with varying power levels for charging EV batteries. If the charger's power is higher, the battery can be charged faster. However, this poses a problem as it is necessary to adapt the electrical installations to that charger.
- Consumption (C9) will be quantified in Wh/km for this study, and this metric indicates the amount of energy the EV utilizes while driving. This is comparable to the fuel consumption observed in traditional vehicles [21]. Nonetheless, consumption can be influenced by numerous factors, including driving habits, vehicle load, and external temperatures. EVs tend to consume more energy at lower outside temperatures.
- The price (C10) is the sole criterion that is not technical in nature. The price represents the monetary counterpart that the buyer needs to pay the seller in order to receive the goods, in this case, EVs. The importance of price is reflected in the fact that the characteristics of EVs are similar in most cases, so the difference in these vehicles is sometimes only in price. This is because EV manufacturers do not produce all parts themselves, but rather buy, for example, batteries from specialized manufacturers, ensuring that the capacities of the batteries are similar. The value of EVs will be marked in euros.

After the criteria by which EVs will be considered are chosen, their evaluation needs to be carried out to assess these vehicles.

Given that there are ten criteria and fourteen EVs under consideration, this decision-making scenario qualifies as a Multi-Criteria Decision Making (MCDM) problem. In addressing this decision-making challenge, it is essential to ascertain the significance of the criteria by assigning weights, followed by ranking the alternatives based on their compliance with the established criteria [22].

To offer realistic assistance in the decision-making process regarding EV procurement, objective methods will be employed to ascertain the significance of the criteria. Furthermore, there exist additional subjective methods wherein the importance of the criteria is established based on the evaluation of the decision maker [23]. These methods seek to identify the weights of the criteria by analysing the variability of the data derived from the initial decision-making matrix [24]. If the data is consistent and there are minimal deviations in a specific criterion, the significance of that criterion will be reduced. Conversely, if the data is inconsistent and there are greater deviations in a particular criterion, the significance of that criterion increases [25]. This occurs because when the values in one criterion are consistent, the alternatives are also consistent, resulting in no deviations among them.

In practice, various objective techniques exist for establishing weights, and this study will employ the CRITIC method. This method was initially introduced by Diakoulaki et al. [26]. The foundation of this method lies in calculating the deviation from the mean value of the alternatives using standard deviation, as well as examining the relationships among the criteria in the original decision matrix through correlation [27]. The method consists of the following steps:

Step 1. Establishing the initial decision-making matrix.

Step 2. Standardizing the initial decision-making matrix.

$$r_{ij} = \frac{x_{ij} - x_{j\,min}}{x_{j\,max} - x_{j\,min}}\text{, for benefit criteria} \quad (1)$$

$$r_{ij} = 1 - \frac{x_{ij} - x_{j\,min}}{x_{j\,max} - x_{j\,min}}\text{, for cost criteria} \quad (2)$$

Where: $x_{j\,min}$ – the minimum value of the alternative for a specific criterion, $x_{j\,max}$ – the maximum value of the alternative for a specific criterion.

Step 3. Determining the amount of information. In this phase, the standard deviation (σ) and the correlation value (r_{jk}) are computed.

$$C_j = \sigma \sum_{k=1}^{m} \left(1 - r_{jk}\right) \quad (3)$$

Step 4. Determining the weight of the criteria.

$$w_j = \frac{C_j}{\sum_{j=1}^{m} C_j} \quad (4)$$

After assessing the significance of the criteria, it is essential to rank the observed EV. The EDISA method will be employed for this ranking. This method is based on evaluating alternatives in terms of their deviation from both ideal and anti-ideal solutions. Ideal solutions denote the highest values of alternatives (other options) for each criterion. Conversely, anti-ideal solutions signify the lowest values of alternatives for specific criteria. The objective for each alternative to achieve a higher ranking is to ensure that its values are nearer to the ideal solution and further from the anti-ideal solution. Consequently, this method comprises the following steps:

Step 1. Creation of the initial decision-making matrix. This matrix comprises "n" criteria that evaluate "m" alternatives.

$$A = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (5)$$

Step 2. Normalization of data.

$$r_{ij} = \frac{x_{ij}}{x_{j\,max}}\text{, for benefit criteria} \quad (6)$$

$$r_{ij} = \frac{x_{j\,min}}{x_{ij}}\text{, for cost criteria} \quad (7)$$

Step 3. Weighting of the normalized data.

$$v_{ij} = n_{ij} \cdot w_j \quad (8)$$

Step 4. Identification of ideal and anti-ideal solutions. The ideal solution represents the maximum value of the alternatives for specific criteria, whereas the anti-ideal solution denotes the minimum value for certain alternative values.

$$v_{ij}^{+} = \max v_{ij}\text{, ideal solution} \quad (9)$$

$$v_{ij}^{-} = \min v_{ij}\text{, anti-ideal solution} \quad (10)$$

Step 5. Calculation of deviations from ideal and anti-ideal solutions. In this step, the weighted normalized values are compared against the anti-ideal solution, meaning that the weighted normalized value is deducted from the ideal solution.

$$S_i^{+} = \sum_{j=1}^{n} (v_{ij} - v_{ij}^{-}) \quad (11)$$

$$S_i^{-} = \sum_{j=1}^{n} (v_{ij}^{+} - v_{ij}) \quad (12)$$

Step 6. Calculating the value of the EDISA method

$$R_i = \frac{S_i^{+} - S_i^{-}}{S_i^{-}} \quad (13)$$

The optimal alternative is identified as the one with the highest EDISA method value, whereas the least favourable alternative is recognized as the one with the lowest EDISA method value. For the examination of the validity of the EDISA method results, a comparative analysis will be used, where the ranking of alternatives (EV) will be performed using various MCDM methods. Additionally, the effects of the dynamic decision matrix will be calculated, examining the stability of the ranking of alternatives.

3. RESULTS AND DISCUSSION

The first step in applying both methods is to form the initial decision-making matrix. The same initial decision-making matrix is used for both of these methods (Table 1). In this instance, the EV values are sourced from the EV database portal, where EVs undergo testing. The values of these criteria have been confirmed with other portals that have tested

EVs, such as EV test [28], myEVreview [29], Testev [30], and various other portals. This approach ensures consistency in the values of the alternatives, thereby preventing subjective evaluations from the EV manufacturer. EV manufacturers are aware that they tend to "enhance" the data regarding their cars by conducting tests under optimal conditions. Consequently, when selecting a vehicle or other technical equipment, it is crucial that the data remains impartial to ensure that no particular manufacturer is favoured.

Table 1. Initial decision-making matrix for EV selection [28-30]

Id	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
	cost	benefit	benefit	benefit	benefit	benefit	benefit	cost	cost	cost
EV1	12.6	225	95	245	45.0	2500	574	300	200	35850
EV2	11.0	200	100	290	43.6	2162	750	285	218	35999
EV3	12.6	225	90	245	45.0	1730	573	300	200	39990
EV4	11.7	235	100	270	50.0	3000	605	480	213	38440
EV5	11.7	235	100	260	50.0	3000	624	480	213	40960
EV6	11.7	235	100	260	50.0	3000	624	480	213	36940
EV7	13.3	220	90	245	45.0	1979	681	150	205	41613
EV8	11.7	230	100	270	50.0	3500	564	480	217	39440
EV9	12.6	225	90	245	45.0	1979	591	150	200	39623
EV10	13.3	220	90	245	45.0	1730	718	450	205	42790
EV11	13.3	220	90	245	45.0	3050	633	150	205	40250
EV12	11.7	230	100	260	50.0	3500	584	480	217	42380
EV13	11.7	230	100	260	50.0	3500	584	480	217	37940
EV14	11.3	230	100	260	50.0	3500	584	480	217	39600

When establishing the initial decision-making matrix, it is essential first to identify the type of criterion, whether it is a benefit or cost criterion (Table 1). Benefit criteria are those in which an alternative must possess a higher value to be considered superior. In contrast, cost criteria are those where a lower value is preferable for an alternative to be deemed better. For instance, a vehicle's acceleration is more favourable when it is lower, while the range of an electric vehicle should be higher, and so forth [31]. Once the type of criterion has been identified, the subsequent step in the MCDM method involves normalizing this data [32]. Normalization aims to allow the comparison of criterion values, as different measurement units are used. By applying normalization, all values are transformed into normalized values that range from zero to one. In this way, all criterion values are unified and suitable for analysis. Furthermore, normalization aims to transform all criterion values into equal values where the alternative value needs to be greater to be considered better. Thus, all criteria are transformed into benefit criteria. For conducting normalization using the CRITIC method, it is necessary to determine the minimum and maximum values of alternatives for each individual criteria and identify the type of those criteria to apply the correct normalization. For the criteria C1 and C2 and for EV1, normalization is calculated as follows:

$$r_{11} = 1 - \frac{12.6 - 11.0}{13.3 - 11.0} = 0.3044$$

$$r_{12} = \frac{225 - 200}{235 - 200} = 0.7143$$

Based on this example, it can be observed that different types of normalization were applied to these criteria. This is because criterion C1 is a cost criterion where it is desirable for the values of the alternatives to be as low as possible, while C2 is a benefit criterion where it is desirable for the values of the alternatives to be as high as possible.

The CRITIC method has been used in numerous studies and will not be explained in detail in this research. After the data normalization is performed, the calculation of the standard deviation and the mutual correlation between the used criteria is carried out. Subsequently, the inverse correlation is determined by subtracting the correlation values from one (1). The next step involves summing these inverse correlation values and multiplying the result by the standard deviation. Ultimately, the weight of the criteria is derived by dividing each individual value by the aggregate value (Table 2).

Table 2. Steps and results of the CRITIC method

		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
$1 - r_{jk}$	**C1**	0.000	0.859	0.078	0.148	0.404	0.434	1.146	1.617	1.825	0.544
	C2	0.859	0.000	0.674	1.217	0.196	0.454	1.732	1.568	1.123	1.164
	C3	0.078	0.674	0.000	0.214	0.235	0.254	1.191	1.759	1.885	0.610
	C4	0.148	1.217	0.214	0.000	0.675	0.632	0.753	1.426	1.816	0.563
	C5	0.404	0.196	0.235	0.675	0.000	0.162	1.521	1.821	1.688	1.048
	C6	0.434	0.454	0.254	0.632	0.162	0.000	1.509	1.592	1.725	0.901
	C7	1.146	1.732	1.191	0.753	1.521	1.509	0.000	0.756	1.043	1.068
	C8	1.617	1.568	1.759	1.426	1.821	1.592	0.756	0.000	0.321	0.991
	C9	1.825	1.123	1.885	1.816	1.688	1.725	1.043	0.321	0.000	1.125
	C10	0.544	1.164	0.610	0.563	1.048	0.901	1.068	0.991	1.125	0.000
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
$\sum_{k=1}^{m}(1 - r_{jk})$		7.054	8.987	6.899	7.445	7.750	7.665	10.721	11.851	12.552	8.016
σ_j		0.338	0.262	0.487	0.298	0.425	0.390	0.309	0.423	0.396	0.315
C_j		2.381	2.354	3.363	2.218	3.296	2.989	3.309	5.012	4.976	2.525
w_j		0.073	0.073	0.104	0.068	0.102	0.092	0.102	0.155	0.153	0.078

According to the results from the CRITIC method, it can be inferred that two criteria are particularly prominent compared to the others, specifically the filling (w = 0.155) and consumption (w = 0.153) criteria. This prominence arises from the fact that the values of these criteria significantly differ from those of the other criteria, resulting in a negative correlation value with respect to the other criteria. Consequently, the total of the inverse correlation was greater than that of the different criteria, indicating that the values of these criteria surpass those of the others [33]. However, if subjective assessments had been used, the result of the criteria's weight would have been different. The criteria for range would have gained more weight, as it is very important for companies engaged in express delivery to use electric vehicles as much as possible during the day to deliver as many packages as possible.

After establishing the significance of the criteria through the CRITIC method, the next step is to compute the EV ranking. This computation is carried out using the EDISA method. This method uses the same initial decision matrix but a different normalization in the first step. Using the same criteria and alternatives as in the CRITIC method, the normalization is calculated as follows:

$$r_{11} = \frac{11.0}{12.6} = 0.873; \;\; r_{ij} = \frac{225}{235} = 0.957$$

The next step of this method is the adjustment of the normalized decision-making matrix. In this step, the normalized values of the alternatives are multiplied by the corresponding criterion weights calculated using the CRITIC method. Using the same example, this is executed as follows:

$$v_{11} = 0.873 \cdot 0.073 = 0.064; \;\; v_{12} = 0.957 \cdot 0.072 = 0.070$$

Once the data has been normalized, the ideal and anti-ideal solutions are identified. The ideal solution is ascertained by locating the maximum value of the challenging normalized data for each criterion, whereas the anti-ideal solution is determined by identifying the minimum value of the challenging normalized data for each criterion (Table 3).

The subsequent step involves determining the deviation from both the anti-ideal and ideal solutions. In this step, the values of the anti-ideal solutions are first subtracted from the weighted values to calculate the distance from the anti-ideal solutions, while the values of the weighted data are subtracted from the ideal solutions to calculate the deviation from the ideal solutions. For an alternative to be ranked better, it is preferable for it to be closer to the ideal solutions and further from the anti-ideal solutions. Therefore, the distance from the anti-ideal solutions should be greater, while the distance from the ideal solutions should be smaller. In the case of the alternative EV1, this deviation is calculated as follows:

$$S_1^+ = (0.064 - 0.061) + (0.070 - 0.062) + (0.099 - 0.093) + (0.058 - 0.058) + (0.091 - 0.089) + (0.066 - 0.046) + (0.078 - 0.077) + (0.077 - 0.048) + (0.153 - 0.141) + (0.078 - 0.065) = 0.095$$

$$S_1^- = (0.073 - 0.064) + (0.073 - 0.070) + (0.104 - 0.099) + (0.068 - 0.058) + (0.102 - 0.091) + (0.092 - 0.066) + (0.102 - 0.078) + (0.155 - 0.077) + (0.153 - 0.153) + (0.078 - 0.078) = 0.166$$

Table 3. Weighted decision-making matrix and ideal and anti-ideal values

Id	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
EV1	0.064	0.070	0.099	0.058	0.091	0.066	0.078	0.077	0.153	0.078
EV2	0.073	0.062	0.104	0.068	0.089	0.057	0.102	0.081	0.141	0.078
EV3	0.064	0.070	0.093	0.058	0.091	0.046	0.078	0.077	0.153	0.070
EV4	0.069	0.073	0.104	0.064	0.102	0.079	0.082	0.048	0.144	0.073
EV5	0.069	0.073	0.104	0.061	0.102	0.079	0.085	0.048	0.144	0.068
EV6	0.069	0.073	0.104	0.061	0.102	0.079	0.085	0.048	0.144	0.076
EV7	0.061	0.068	0.093	0.058	0.091	0.052	0.093	0.155	0.150	0.067
EV8	0.069	0.071	0.104	0.064	0.102	0.092	0.077	0.048	0.141	0.071
EV9	0.064	0.070	0.093	0.058	0.091	0.052	0.080	0.155	0.153	0.070
EV10	0.061	0.068	0.093	0.058	0.091	0.046	0.098	0.052	0.150	0.065
EV11	0.061	0.068	0.093	0.058	0.091	0.080	0.086	0.155	0.150	0.069
EV12	0.069	0.071	0.104	0.061	0.102	0.092	0.079	0.048	0.141	0.066
EV13	0.069	0.071	0.104	0.061	0.102	0.092	0.079	0.048	0.141	0.074
EV14	0.071	0.071	0.104	0.061	0.102	0.092	0.079	0.048	0.141	0.071
v_{ij}^{+}	0.073	0.073	0.104	0.068	0.102	0.092	0.102	0.155	0.153	0.078
v_{ij}^{-}	0.061	0.062	0.093	0.058	0.089	0.046	0.077	0.048	0.141	0.065

The final stage of the EDISA method involves calculating the value associated with this method. In the EV1 example, this calculation is performed as follows:

$$R_1 = \frac{0.095 - 0.166}{0.166} = -0.427$$

Consequently, the results of the EDISA method are established (Table 4). The alternative values derived from the EDISA method can either be positive or negative, depending on the proximity of the alternatives to ideal or anti-ideal solutions. The greater the distance of the alternatives from anti-ideal solutions and the closer they are to ideal solutions, the higher their resulting value will be, and conversely. The results of this method indicate that EV11 is ranked the highest, followed by EV7, while EV10 is ranked the lowest (Table 4). The primary reason for EV11 being rated as the best EV is largely attributed to its rapid battery charging capability with a standard charger, in addition to its consumption efficiency. These two criteria carried the most significant weight, which is why this EV received the highest rating.

To validate the results of the EDISA method and demonstrate that its results do not significantly differ from those of other MCDM methods, a comparative analysis will be performed [34,35]. This analysis will utilize the same initial decision-making matrix and criteria weights to derive results through the application of the procedures of other MCDM methods [36,37]. Alongside the EDISA method, ten additional MCDM methods will be incorporated into this analysis, specifically: TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution), SAW (Simple Additive Weighting), VIKOR (multicriteria optimization and compromise solution), ARAS (Additive Ratio ASsessment), RAWEC (Ranking of Alternatives with Weights of Criterion), MABAC (Multi-Attributive Border Approximation Area Comparison), CRADIS (Compromise Ranking of Alternatives from Distance to Ideal Solution), MARCOS (Measurement of Alternatives and Ranking according to the Compromise Solution), WASPAS (Weighted Aggregated Sum Product Assessment) and CORASO (COmpromise Ranking from Alternative SOlutions).

Table 4. Results of the EDISA method

Id	S_1^{+}	S_i^{-}	R_i	Rank
EV1	0.095	0.166	-0.427	11
EV2	0.116	0.145	-0.203	4
EV3	0.061	0.200	-0.692	13
EV4	0.098	0.163	-0.398	9
EV5	0.094	0.167	-0.438	12
EV6	0.101	0.160	-0.366	7
EV7	0.149	0.112	0.321	2
EV8	0.100	0.161	-0.382	8
EV9	0.148	0.113	0.316	3
EV10	0.042	0.219	-0.808	14
EV11	0.173	0.089	0.949	1
EV12	0.095	0.166	-0.427	10
EV13	0.103	0.158	-0.350	5
EV14	0.102	0.159	-0.357	6

According to the results obtained from these methods, it is evident (Fig. 1) that the EDISA method shares the same ranking order as four other methods: SAW, CRADIS, MARCOS, and CORASO. In contrast, the ranking order of the remaining methods diverges from that of the EDISA method. The analyses indicate that the VIKOR and MABAC methods exhibit the most significant differences in their ranking orders. This discrepancy arises from the fact that these methods employ complex normalization techniques; specifically, MABAC utilizes this as a normalization approach, whereas the VIKOR method incorporates it as one of the compromise solutions [38]. This normalization creates a distinction whereby the optimal value of the criterion is assigned a value of one (1), whereas the alternative with the least value is assigned a value of zero (0). Consequently, a significant disparity is established between the values of the alternatives concerning the criteria. A further examination of the results obtained (Fig. 1) indicates that the EDISA method demonstrates a strong correlation with other methods and that its outcomes are representative. Moreover, this analysis revealed that EV11 achieved the highest ranking in as many as 9 methods, while EV7 secured the second position in 10 methods.

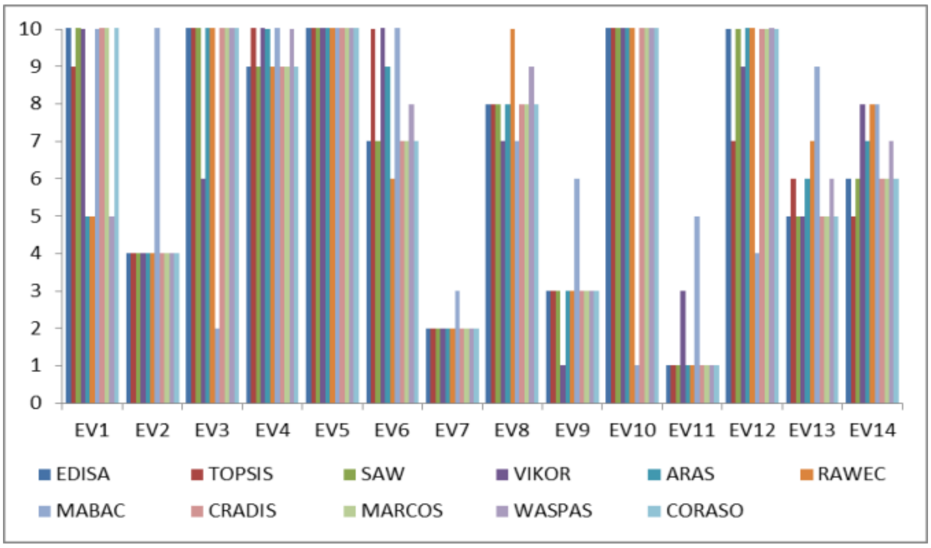

Fig. 1. Results of the comparative analysis

To better compare these methods, the value of the Spearman correlation coefficient will also be calculated (Table 5). This correlation coefficient is used to determine the relationship between ranking orders; in this case, these are ranking orders obtained by applying different MCDM methods. The results of this analysis show that there is a significant correlation between the ranking orders of the EDISA method and those of nine other methods. Only in the case of the MABAC method (-0.108) is there no significant correlation in the ranking orders of alternatives. In these two methods, the negative value of the correlation indicates that there is no connection, as the correlation value is close to zero. This value signifies the absence of correlation between the two observed methods. The same is true for other methods when compared to the MABAC method; the value is either close to zero or negative, except when compared to the VIKOR method. Therefore, there is also a lower correlation between the ranking orders of the EDISA method and the VIKOR method (r = 0.741), but a significant statistical relationship remains.

Table 5. Results of Spearman correlation coefficient

	EDISA	TOPSIS	SAW	VIKOR	ARAS	RAWEC	MABAC	CRADIS	MARCOS	WASPAS	CORASO
EDISA	—										
TOPSIS	0.925	—									
SAW	1.000	0.925	—								
VIKOR	0.741	0.789	0.741	—							
ARAS	0.903	0.908	0.903	0.736	—						
RAWEC	0.881	0.824	0.881	0.618	0.960	—					
MABAC	-0.108	0.064	-0.108	0.420	-0.099	-0.235	—				
CRADIS	1.000	0.925	1.000	0.741	0.903	0.881	-0.108	—			
MARCOS	1.000	0.925	1.000	0.741	0.903	0.881	-0.108	1.000	—		
WASPAS	0.908	0.899	0.908	0.714	0.996	0.978	-0.130	0.908	0.908	—	
CORASO	1.000	0.925	1.000	0.741	0.903	0.881	-0.108	1.000	1.000	0.908	—

To determine the stability of the EDISA method in ranking alternatives, an analysis will be conducted to examine the effects of the dynamic decision-making matrix. This analysis proceeds as follows: EVs are initially ranked, after which the vehicle with the lowest rank is eliminated from consideration, and the ranking process is repeated. This procedure continues until only one vehicle remains for ranking. The findings of this analysis indicated (Fig. 2) that stability in the rankings was maintained, even though the evaluated EVs exhibited nearly identical indicators.

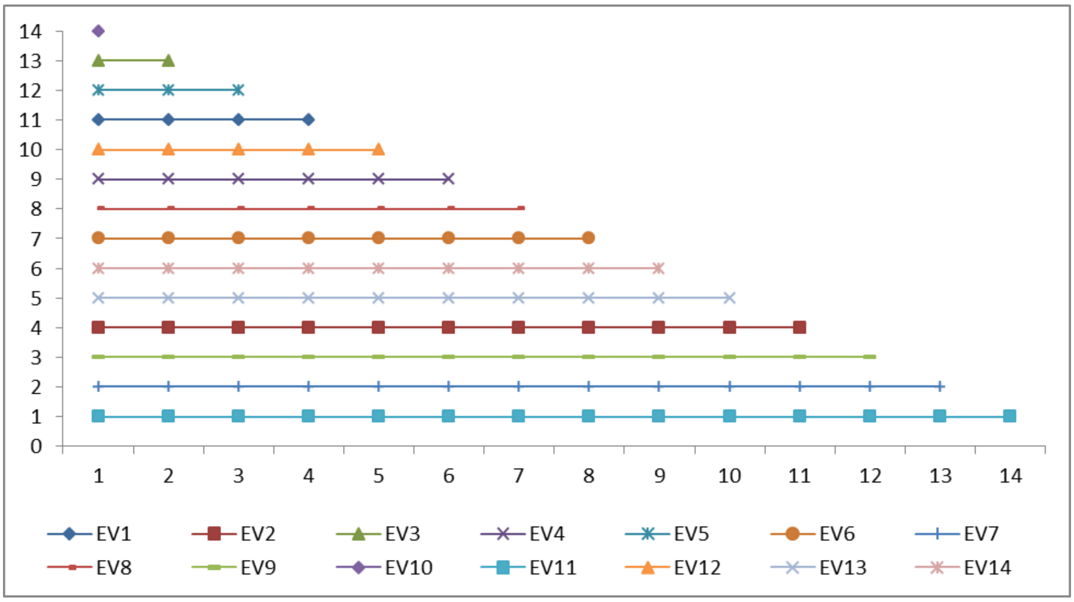

Fig. 2. Outcomes of the impacts of the dynamic decision-making matrix

4. CONCLUSION

The objective of this research was to analyse EVs and to assist in determining which of these vehicles X Express will select to enhance its fleet. The criteria for considering an EV included that the price must not exceed 50,000 euros and that the vehicle must have an authorized service centre within the territory of Bosnia and Herzegovina. Furthermore, the type of vehicle under consideration should have been a minivan. Based on these criteria, a total of 14 EVs were chosen for evaluation in this research. These vehicles were evaluated based on ten criteria, of which nine are technical and one is economic, namely the price. The price was chosen because certain technical criteria for some EVs were the same; therefore, to rank these EVs, their prices needed to be different. To ensure objectivity in decision-making, the CRITIC method was used, which is one of the methods for objectively determining weights. This method was chosen because it has been accepted through practical application and has been used in numerous studies. By applying the steps of this method, results were obtained showing that the criteria for battery charging time and energy consumption hold greater importance compared to other criteria.

To determine which EV possesses the most favourable technical specifications, the EDISA method was employed. This method was first applied in a practical setting. Consequently, it was essential to validate the results of this method. The results indicated that the top two ranked mini vans were EV11 and EV7, a conclusion that was corroborated by other methods utilized in the comparative analysis.

These EVs have a shorter battery charging time than other EVs, which is why they are chosen as the best option for purchasing a minivan EV. Although technical criteria are very important in choosing an EV, they cannot be the sole deciding factor, as many other factors influence the choice of EV, with technical characteristics being just one of them. However, considering the technical characteristics of EV can help make the final decision easier. Therefore, considering technical characteristics is essential before making a final decision. Thus, future research should incorporate additional criteria to mitigate the limitations of this study, which is based solely on technical characteristics.

This research has shown how the decision-making process for purchasing EVs can be conducted. However, although EVs represent an environmentally friendly alternative for transporting people and goods, they indirectly contribute to environmental pollution. This pollution is primarily due to the use of lithium batteries, as mining lithium is a complex process that leads to significant soil and water contamination. Therefore, it is necessary to develop newer batteries that will replace lithium batteries. The production of electricity used to charge these EVs primarily comes from fossil fuels, especially in developing countries, thus polluting the environment. It is essential to produce as much electricity as possible from sustainable sources to reduce the indirect pollution caused by EVs. Lastly, there is the consumption of electricity needed for charging the batteries. With the increasing number of EVs, electricity consumption also rises. Hence, it is necessary to develop newer versions of EVs that will consume less electricity while also covering greater distances on a single charge.

In this research, a new MCDM method for ranking alternatives, EDISA, was used. This method's steps resemble those of TOPSIS and CRADIS, but they differ from them. This is because both of these methods use the calculation of deviation in relation to ideal and anti-ideal solutions, as the EDISA method does. The EDISA method uses simple calculations, while the TOPSIS method uses Euclidean deviation. A different formula is used for ranking, where the values of the alternatives range from -1 to 1. The alternative with a negative value will have its values closer to the anti-ideal solution and further from the ideal solution. If the values of the alternatives are negative, it means that those alternatives have low values and do not influence the final decision. The closer the value is to one, the closer the values of the alternatives are to the ideal solution, and ideally, the best alternative would be exactly the same as the ideal solution. This way, that alternative would be the best in all criteria. However, due to conflicting criteria, it is challenging for one alternative to dominate over the others.

The results obtained by the EDISA method show that they do not differ significantly compared to the results of the SAW, CRADIS, MARCOS, and CORASO methods and partially differ from those of the TOPSIS, ARAS, and WASPAS methods. Based on this, it can be concluded that the EDISA method yields results that are similar to or identical to those of other accepted MCDM methods. What is specific to this method compared to CRADIS, MARCOS, and TOPSIS is the simpler calculation of the final ranking order. In CRADIS and MARCOS, in addition to deviation, utility functions are also calculated, which is not done in the EDISA method. Compared to the TOPSIS method, it differs in that it uses simpler calculations of deviation, making this method easier to implement in practice.

Therefore, in future research, it is necessary to develop new approaches to the EDISA method to facilitate the more efficient determination of a ranking that enables informed decision-making. Consequently, future research should continue to utilise MCDM methods, particularly the EDISA method, which has proven to provide a straightforward ranking that does not significantly differ from the well-established MCDM methods.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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