Araştırma Makalesi/Research Article

UTILIZING MULTI-CRITERIA DECISION-MAKING TECHNIQUES IN THE SELECTION OF ELECTRIC VEHICLES: AN ANALYSIS FOR THE TURKISH ELECTRIC VEHICLE MARKET*

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ABSTRACT

Global warming and climate change are among the biggest problems of our time. The rapid depletion of fossil fuels and the harmful effects of internal combustion engines on the environment are increasing the interest in electric vehicles. These vehicles emit less carbon emissions than gasoline and diesel vehicles, reducing the emission of harmful gases such as greenhouse gases into the atmosphere. The use of electric vehicles provides significant benefits for human health and environmental health. The sale of electric vehicles in Turkey is very important in terms of sustainability and economy. This study aims to help rank the alternatives by using multi-criteria decision-making (MCDM) methods in the selection of the 11 most preferred electric vehicles in Turkey. Various criteria such as DC fast charging time, power (kW), range, price, battery capacity, electricity consumption (kWh) and number of services were considered in the study. Following the criteria provided by the Method based on the Removal Effects of Criteria (MEREC) weighting method, four different decision-making methods such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Multi-Objective Optimization by Ratio Analysis (MOORA) and Weighted Aggregated Sum Product Assessment (WASPAS) were applied and the outcomes were combined with the COPELAND approach to obtain a final ranking. The findings show that the X5 vehicle received the highest score according to the COPELAND method and that this vehicle ranked high in other methods as well, and its overall performance was remarkable. The X11 and X4 vehicles stand out as the second and third best alternatives, respectively. As a result of the study, it was concluded that the most important criterion among the 7 criteria is “charging time” and the least important criterion is “electricity consumption”. The results obtained from the COPELAND method are presented in a clear and understandable way. With this feature, decision makers can easily understand the comparisons between alternatives. These results help consumers considering purchasing an electric vehicle to determine which vehicles are more suitable, while also providing useful information for professionals in the industry to make strategic decisions.

Keywords: Electric Vehicle Selection, Multi-Criteria Decision Making, MEREC, TOPSIS, PROMETHEE, MOORA, WASPAS, COPELAND

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Elektrikli Araç Seçiminde Çok Kriterli Karar Verme Yöntemlerinin Kullanımı: Türkiye Elektrikli Araç Pazarı İçin Bir Araştırma

ÖZET

Küresel ısınma ve iklim değişikliği, günümüzdeki en büyük sorunlardan biri olarak karşımıza çıkmaktadır. Fosil yakıtların hızla tükenmesi ve içten yanmalı motorların çevreye zararlı etkileri, elektrikli araçlara olan ilgiyi artırmaktadır. Bu araçlar benzinli ve dizel araçlara göre daha az karbon salınımı yaparak atmosfere sera gazı gibi zararlı gazların salınımını azaltırlar. Elektrikli araçların kullanımı insan sağlığı ve çevre sağlığı için önemli faydalar sağlar. Türkiye'de elektrikli araçların satışının yapılması, sürdürülebilirlik ve ekonomik açıdan oldukça önemlidir. Bu çalışma, Türkiye'de en çok tercih edilen 11 elektrikli aracın seçiminde çok kriterli karar verme yöntemlerini kullanarak, alternatiflerin sıralanmasına yardımcı olmayı hedeflemektedir. Araştırmada, DC hızlı şarj süresi, güç (kW), menzil, fiyat, batarya kapasitesi, elektrik tüketimi (kWh) ve servis sayısı gibi çeşitli kriterler ele alınmıştır. Kriterlerin Etki Kaldırma Yöntemi (Method based on the Removal Effects of Criteria, MEREC) ile kriter ağırlıkları belirlenmiş; ardından İdeal Çözüme Benzerlik Sırasına Göre Tercih Tekniği (Technique for Order Preference by Similarity to Ideal Solution, TOPSIS), Zenginleştirme Değerlendirmesi için Tercih Sıralama Organizasyonu Yöntemi (Preference Ranking Organization Method for Enrichment Evaluation, PROMETHEE), Oran Analizi ile Çok Amaçlı Optimizasyon Yöntemi (Multi-Objective Optimization by Ratio Analysis, MOORA) ve Ağırlıklı Toplam ve Çarpımsal Değerleme Yöntemi (Weighted Aggregated Sum Product Assessment, WASPAS) gibi dört farklı karar verme yöntemi uygulanmış ve elde edilen bulgular COPELAND yaklaşımı kullanılarak birleştirilmiş ve nihai bir sıralama elde edilmiştir. Elde edilen bulgular, COPELAND yöntemine göre en yüksek skoru X5 aracının aldığını ve bu aracın diğer yöntemlerde de üst sıralarda yer alarak genel performansının dikkate değer olduğunu göstermektedir. X11 ve X4 araçları ise sırasıyla ikinci ve üçüncü en iyi alternatifler olarak öne çıkmaktadır. Çalışma sonucunda 7 kriter arasından en önemli kriterin "şarj süresi", en az önemli kriterin "elektrik tüketimi" olduğu sonucuna ulaşılmıştır. COPELAND yönteminden elde edilen sonuçlar açık ve anlaşılır bir şekilde sunulmaktadır. Bu özelliğiyle karar vericilerin alternatifler arasındaki karşılaştırmaları kolaylıkla anlayabilmesi sağlanmaktadır. Bu sonuçlar, elektrikli araç satın almayı düşünen tüketicilere hangi araçların daha uygun olduğunu belirlemelerinde yardımcı olurken, sektördeki profesyonellere de stratejik kararlar almalarında faydalı bilgiler sunmaktadır.

Anahtar Kelimeler: Elektrikli Araç Seçimi, Çok Kriterli Karar Verme, MEREC, TOPSIS, PROMETHEE, MOORA, WASPAS, COPELAND

INTRODUCTION

Electric vehicles have recently gained significant popularity both nationally and globally. Global warming and the resulting climate change have led both consumers and governments to take precautions in this regard. Electric vehicles have begun to be preferred more frequently due to reasons such as low emission values, contributions to fuel economy, and low tax rates by governments (Hamurcu et al., 2021: 2). However, various problems are also experienced with electric vehicles. Infrastructure deficiencies, battery life, charging times, station and maintenance networks that are not as common as fossil fuel vehicles, and second-hand problems stand out as the biggest problems with electric vehicles (Demirkale and Güven, 2017: 3). According to the latest data announced by TÜİK, the increase in electric vehicle sales in Turkey in recent years is striking. Table 1 shows how electric vehicle sales in Turkey have increased over the years. TÜİK, analyzed data on electric vehicle sales in Turkey between 2004 and 2024. According to this data, while there were 24 automobile sales in 2011, this number increased to 114,156 automobiles by 2024. This increase shows that the electric vehicle market is transforming due to environmental concerns and government incentives. In the last 13 years, automobile users have consciously preferred these environmentally friendly electric vehicles instead of internal combustion engines that cause environmental pollution, air pollution and increased carbon emissions, contributing to sustainability efforts. The rise in electric vehicle adoption is significantly important for both the economy and the environment.

Table 1: Vehicles Sold in Turkey by Fuel Type

Year	Gasoline	(%)	Diesel	(%)	LPG	(%)	Hybrid (2)	(%)	Electric	(%)
2004	4 062 486	75.2	252 629	4.7	793 081	14.7	-	-	-	-
2005	3 883 101	67.3	394 617	6.8	1 259 327	21.8	-	-	-	-
2006	3 838 598	62.5	583 794	9.5	1 522 790	24.8	-	-	-	-
2007	3 714 973	57.4	763 946	11.8	1 826 126	28.2	-	-	-	-
2008	3 531 763	52.0	947 727	13.9	2 214 661	32.6	-	-	-	-
2009	3 373 875	47.6	1 111 822	15.7	2 525 449	35.6	-	-	-	-
2010	3 191 964	42.3	1 381 631	18.3	2 900 034	38.4	-	-	-	-
2011	3 036 129	37.4	1 756 034	21.6	3 259 288	40.2	23	0.0	24	0.0
2012	2 929 216	33.9	2 101 206	24.3	3 569 143	41.3	53	0.0	175	0.0
2013	2 888 610	31.1	2 497 209	26.9	3 852 336	41.5	83	0.0	353	0.0
2014	2 855 078	29.0	2 882 885	29.2	4 076 730	41.4	113	0.0	412	0.0
2015	2 927 720	27.6	3 345 951	31.6	4 272 044	40.3	324	0.0	565	0.0
2016	3 031 744	26.8	3 803 772	33.6	4 439 631	39.2	517	0.0	643	0.0
2017	3 120 407	25.9	4 256 305	35.4	4 616 842	38.4	925	0.0	760	0.0
2018	3 089 626	24.9	4 568 665	36.8	4 695 717	37.9	4 415	0.0	952	0.0
2019	3 020 017	24.2	4 769 714	38.1	4 661 707	37.3	13 877	0.1	1 176	0.0
2020	3 201 894	24.4	5 014 356	38.3	4 810 018	36.7	33 690	0.3	2 797	0.0
2021	3 495 172	25.5	5 158 803	37.6	4 923 275	35.9	86 682	0.6	6 267	0.0
2022	3 817 104	26.8	5 261 876	36.9	5 005 563	35.1	134 662	0.9	14 552	0.1
2023	4 362 975	28.7	5 425 652	35.6	5 094 751	33.5	222 328	1.5	80 043	0.5
2024(1)	4 617 500	29.5	5 479 711	35.0	5 125 524	32.7	279 326	1.8	114 156	0.7

Source: TÜİK

This study aims to address the difficulties encountered in decision-making processes in this area, along with the increasing adoption rate of electric vehicles in Turkey, and to produce solutions to these problems. It is aimed to determine the importance weights of important criteria such as DC fast charging time, power (kW), range, price, battery capacity, electricity consumption (kWh) and number of services of the 11 best-selling electric vehicles in Turkey, and to analyze the decision-making processes of consumers who are considering purchasing an electric vehicle by ranking the vehicles from the most ideal to the least ideal using multi-criteria decision-making methods within the framework of these criteria. In addition, our study aims to better understand consumer behavior, reveal the possible effects of the obtained results on sector dynamics, environmental impacts and consumer preferences, and evaluate the effectiveness of multi-criteria decision-making methods.

The objective weighting method MEREC method is used when weighting the criteria in the selection of electric cars. The study compares 11 electric cars based on the following criteria: 80% charging time with a DC fast charging unit, power (kW), range on a fully charged battery, vehicle price, battery capacity, electricity consumption (kWh), and the number of available services. TOPSIS, WASPAS, PROMETHEE and MOORA methods from MCDM methods were used in the evaluation. The results derived from these four methods were integrated using the COPELAND method, resulting in a singular ranking. The features that distinguish this study from others are; while many studies in the literature are limited to the use of only one or two multi-criteria decision-making methods, the use of four different methods, namely Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Weighted Aggregated Sum Product Assessment (WASPAS), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and Multi-Objective Optimization by Ratio Analysis (MOORA), together in our study provided a more comprehensive and comparable approach in the ranking of alternatives. Combining the results obtained from these methods with the COPELAND method increased the originality of the study as an integrated analysis method rarely used in the literature. While subjective criterion weighting methods (such as AHP or Entropy) are generally used in the literature, MEREC, a completely objective method, was used in this study. The use of MEREC weighting is not seen very often in similar studies in the literature. The use of the MEREC method made an innovative contribution to the literature. MEREC provided reliable results thanks to its feature of determining the weights by eliminating the effects of the criteria. Our study did not only focus on the ranking and selection processes, but also evaluated the reflections of the results on consumer behavior, sector dynamics and environmental impacts. The study contributed to the literature both theoretically and practically by providing a broader perspective on decision support processes. AHP, Entropy and TOPSIS methods are frequently encountered in the literature. For example, Yavaş et al. (2014: 3) used AHP and ANP methods for criterion weighting in electric vehicle selection. In their study, Oflaz and Bircan (2022) also weighted the automobile preference problem with the AHP method and ranked alternative vehicle brands with TOPSIS, VIKOR and EDAS methods. Gavcar and Kara (2020: 4) used the Entropy method for criterion weighting and compared the vehicles with the TOPSIS method. Coşkun (2022: 5) used both objective and subjective methods in the evaluation of the criteria effective in electric vehicle selection; among these, Entropy and CRITIC were objective methodologies, whereas AHP and WINGS were subjective methodologies. Our study distinguishes itself from others in the literature by relying exclusively on objective methodologies. In their study, Güleryüz and Çokyaşar (2021: 2) applied to expert opinions to evaluate the criteria and gave scores between 1-6 to the selected cars. These data were processed with the TOPSIS method and contributed to the car selection process of consumers. However, in our study, unlike the methods frequently encountered in the literature, the Method based on the Removal Effects of Criteria (MEREC) weighting method was preferred. In the literature, it is generally seen that alternatives are ranked using one or two methods, but in our study, four distinct methods were employed, and the results derived from these methods were amalgamated utilizing the COPELAND method to establish a unified ranking. This variety of methods greatly contributes to the comprehensive, comparable and reliable results of our study. The COPELAND method is an effective voting method used to rank alternatives in multi-criteria decision-making problems. Each alternative is compared with other alternatives, and the superior alternative receives a score in each comparison. The alternative with the most wins is placed at the top of the ranking. This method allows alternatives to be easily compared and decision makers to clearly state their preferences.

The obtained rankings were combined with the COPELAND method, as in our study, and a final solution was presented.

Our study comprises five principal sections. Following the introduction, a literature review is conducted to analyze the current methods and criteria employed in the selection of electric vehicles. The third section contains methodological explanations of the Method based on the Removal Effects of Criteria (MEREC), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Weighted Aggregated Sum Product Assessment (WASPAS), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Multi-Objective Optimization by Ratio Analysis (MOORA) and COPELAND methods. The fourth section presents evaluations of multi-criteria decision-making methods that are weighted using the Method based on the Removal Effects of Criteria (MEREC), with the results compiled in conjunction with the COPELAND method. The fifth section discusses the findings and presents the results.

1. LITERATURE REVİEW

Vehicle selection and MCDM methods have attracted significant attention in both academia and industry in recent years. In this context, many studies have been conducted on different methods and criteria used in electric vehicle (EV) selection. These studies in the literature differ in terms of the methods used and the criteria considered. Studies based on entropy and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)approaches are among the methods frequently used in EV selection. For example, Gavcar and Kara (2020: 4) analyzed 11 different electric cars in Turkey with Entropy and TOPSIS. The study uses the entropy method for criteria weighting and the TOPSIS method as a multi-criteria decision making tool Pal et al. (2023: 2). According to criteria such as battery capacities, horsepower, aerodynamic coefficients, ranges and sales prices. The results showed that models with high horsepower, range and battery capacity were the best alternatives. Important criteria such as charging time and width of the service network were not included in the study. However, these deficiencies were eliminated in our study and criteria such as charging time and number of services, which are critical in electric vehicle selection, were also included in the analysis. Similarly, Özgüner and Ovalı (2022: 17) used Entropy, ARAS and TOPSIS methods to rank five alternatives in a logistics company's vehicle selection dilemma and obtained comparable results with both methodologies. Güleryüz and Çokyaşar (2021: 6) provided a guiding and facilitating approach in decision-making processes by using the TOPSIS method for consumers who will choose a car. The "degree of love" criterion used in the study is a subjective criterion. Such criteria may be insufficient in terms of providing an objective evaluation. In order to eliminate this deficiency, the analysis was carried out by focusing only on objective criteria in our study and the evaluation processes were made impartial. These studies show that TOPSIS and Entropy are among the frequently used methods in EV selection. In the weighting studies conducted with the AHP method, it is seen that the criteria in EV selection are weighted according to expert opinions. Güleryüz and Çokyaşar (2021: 8) determined criteria such as price, resale value, fuel efficiency, acceleration, comfort, safety, maintenance costs, MTV fee and user satisfaction through expert consultancy and then evaluated these criteria with the TOPSIS method. Similarly, Oflaz and Bircan (2022: 3) made criteria weighting with AHP in automobile selection and ranked alternative vehicles with TOPSIS, VIKOR and EDAS methods. The final ranking was obtained by combining with the COPELAND method. Studies conducted with AHP find a wide range of applications by providing weighting according to the subjective evaluations of decision makers. In these studies, the AHP method was used while weighting. In our study, instead of using this weighting method, an innovative method, Method based on the Removal Effects of Criteria (MEREC) weighting, was used and contributed to the literature. The use of innovative and diverse methodologies is also emphasized in the literature. Coşkun

(2022: 5) presented various methodologies that use both objective and subjective evaluation techniques in electric vehicle selection. In the study, subjective methods such as AHP and WINGS were used together with objective methods such as Entropy and CRITIC. The findings showed that price was the most important criterion. Puska et al. (2023: 10) used the SAW method to rank alternatives using objective weighting techniques such as Entropy, CRITIC and MEREC in the selection of electric vehicles in urban logistics. These studies show that using more than one method provides decision makers with more comprehensive and reliable results. Studies focusing on battery selection evaluate the properties of batteries, which are a critical component for electric vehicles. Hamurcu et al. (2021: 6) weighted the battery selection of electric vehicles with the AHP method and ranked them with the Multi-Objective Optimization by Ratio Analysis (MOORA) method. Li-ion batteries were determined as the best option in the study. Similarly, Abdulvahitoğlu et al. (2022: 13) analyzed the properties of electric vehicle batteries with Integrated SWARA and TOPSIS methods and revealed that Lithium Nickel Manganese Cobalt Oxide (LNMCO) batteries were the best alternative. These studies show that MCDM methods can be used effectively in battery selection. Studies on the selection of electric vehicle chassis and components have also found a place in the literature. Alvalı et al. (2021: 3) used TOPSIS and VIKOR methods in the selection of electric vehicle chassis materials and obtained similar results in both methods. In addition, Güler (2024: 2) determined battery capacity as the most important criterion by using both subjective and objective weighting methodologies in the evaluation of electric vehicle components.

These studies show that MCDM methods are widely used in the selection of electric vehicle components. Finally, studies addressing general vehicle selection problems show that MCDM methods have a wide range of applications in the evaluation of vehicle performance and components. Kanmaz et al. (2024: 3) analyzed the top 10 best-selling electric vehicles of 2023 and ranked them using the PIPRECIA and CRADIS methods. Demirci (2024: 12) used the CRITIC method to weight them and compared the results of the ARAS and ARCAS methods. It was determined that both methods gave similar results. These studies show that the methods used in the evaluation of multiple criteria give reliable results. Traditional methods such as AHP and Entropy are frequently used in the literature, and the MEREC method used in our study offers an innovative contribution to the literature in this field. Unlike other methods, the MEREC weighting method is a method type that allows reliable results to be obtained thanks to its feature of determining weights by removing the effects of the criteria. The COPELAND method used in the ranking increases the originality of our study and facilitates a more comprehensive evaluation of the results. In addition, our study did not only focus on the ranking and selection processes, but also evaluated the reflections of the results on consumer behavior and sector dynamics. The study contributed to the literature both theoretically and practically, providing a broader perspective on decision support processes.

2. DATA AND METHODOLOGY

This study provides a solution to the decision-making problem faced by consumers considering purchasing an electric vehicle and evaluates alternatives using multi-criteria decision-making methods. In this study, data on the 11 best-selling electric cars in Turkey were evaluated by taking them from the official websites of the companies that produce these vehicles. The data used in the study was accessed between March and April 2024. Every criterion employed in the selection of an electric vehicle is crucial regarding the vehicle's performance, cost, and usability. For example, the charging time criterion has a direct impact on the daily usability and user experience of a vehicle. A short charging time minimizes time loss by allowing consumers to spend less time at charging stations and enables the vehicle to be used more efficiently. Consequently, factors like charging duration significantly influence the preference for electric vehicles. The criteria used in the study reflect the factors that are decisive in the decision-making processes of consumers considering purchasing an electric vehicle, considering performance, economy, and accessibility. Power and range performance, price represent the consumer's budget compatibility, battery capacity and electricity consumption represent energy efficiency, and the number of services represent accessibility to maintenance and repair services. The study employs diverse methods for weighting criteria and ranking alternatives. The MEREC method was selected for the criterion weighting process. MEREC offers an objective evaluation by considering the interdependence among the criteria, unlike other methods. The multi-criteria decision-making methods employed in the ranking of alternatives were Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Weighted Aggregated Sum Product Assessment (WASPAS), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), and Multi-Objective Optimization by Ratio Analysis (MOORA). In the combination of the methods used in the study, it was aimed to obtain a more comprehensive and reliable ranking by taking advantage of the different strengths of each method and the methods were used together in this direction. Each of these methods possesses advantages in evaluating the alternatives based on various criteria. The study's results were synthesized into a final ranking by integrating the outcomes of these four methods using the COPELAND method. The criteria used in the study were selected to evaluate the overall performance, cost and user-friendliness of the vehicle. These criteria and their respective importance levels are designed to assist decision-makers in vehicle selection. The criteria employed in this study are delineated in detail in Table 2.

Table 2: Dataset Used in the Study

	CHARGING TIME	**POWER (KW)**	**RANGE**	**PRICE**	**BATTERY CAPACITY**	**CONSUMPTION (kWh)**	**NUMBER of SERVICE CENTERS**
X1	28	160	523	1823000	52,4	16,7	33
X2	29	150	474	2801606	64,8	17,2	44
X3	29	150	420	1790000	60,48	15,6	23
X4	30	100	560	1555000	54	15,5	64
X5	15	208	435	1731840	75	15,7	2
X6	28	185	566	2411568	82	16,9	33
X7	28	152,2	635	1780000	73,4	13,5	37
X8	32	140	481	2573500	70,5	18,1	66
X9	30	115	440	1839000	72,6	17,8	31
X10	41	114,6	512	1399000	48,4	14,6	46
X11	25	100	492	1340900	50	16,4	63

2.1. Method based on the Removal Effects of Criteria (MEREC)

The Method based on the Removal Effects of Criteria (MEREC), presented by Ghorabaee et al. (2021), is an objective weighting technique. The MEREC method employs the removal effect of each criterion on the performance alternatives to ascertain the criterion weights. The absolute deviation metric is employed to assess the impact of eliminating each criterion. The metric employed indicates the disparity between the overall alternative's performance and its efficacy in eliminating a criterion Yaşar and Ünlü (2023). The procedures involved in the computation of the MEREC method (Keshavarz-Ghorabae et al., 2021);

Step 1: Creating Decision Matrix: The representative decision matrix shown in Equation 1.

$$X = \begin{bmatrix} X_{11} & X_{1j} & \dots & X_{1m} \\ X_{21} & X_{2j} & \dots & X_{2m} \\ \dots & \dots & X_{ij} & \dots \\ X_{n1} & X_{nj} & \dots & X_{nm} \end{bmatrix} \quad \text{İ}=1,2\dots,n \quad j=1,\dots,m \tag{1}$$

Step 2: Normalizing Decision Matrix: To normalize the established criteria, Equality 2 is applied for benefit-oriented criteria, while Equality 3 is utilized for cost-oriented criteria.

$$n_{ij} = \frac{j^{min\, x_{ij}}}{x_{ij}} \tag{2}$$

- The value n_{ij} indicates the value of alternative i in criterion j.

$$n_{ij} = \frac{x_{ij}}{j^{max\, x_{ij}}} \tag{3}$$

Step 3: Determination of Overall Performance Value: Total performance values (R_i) of the alternatives are computed using Equation 4.

$$R_i = ln\,(1 + \frac{\sum_{j=1}^{n} |\ln(n_{ij})|}{n}) \tag{4}$$

Step 4: Criterion Effect Elimination: To eradicate the influence of each criterion, the performance value, which incorporates the criterion's effect, is computed using Equation 5.

$$R'_{ij} = ln\,(1 + \frac{\sum_{j=1,j=k}^{n} |ln(n_{ij})|}{n}) \tag{5}$$

Step 5: Computation of the Sum of Absolute Deviations: The sum of absolute deviations (E_j) is computed. This step assesses the impact of eliminating the criterion itself. Equation 6 is likewise presented.

$$E_j = \sum_{i=1}^{m} \left| R'_{ij} - R_i \right| \tag{6}$$

Step 6: Calculation of Criterion Weight: In the last step of the method, the criterion weights (W_j) are calculated with Equation 7.

$$W_j = \frac{E_j}{\sum_{j=1}^{n} E_j} \tag{7}$$

2.2. Weighted Aggregated Sum Product Assessment (WASPAS) Method

Weighted Aggregated Sum Product Assessment (WASPAS) approach is a synthesis of weighted summation and weighted multiplication models formulated by Zavadskas et al. in 2012. The WASPAS method is employed to prioritize alternatives. Step 1: Creating the decision matrix: In the decision matrix of the WASPAS method; m represents the alternatives (Ai, i = 1, 2, ..., m) and n represents the criteria (Kj, j=1, ..., n). The decision matrix illustrating the performance of the alternatives in relation to the criteria is presented in Equation 8.

$$x = \left[X_{ij}\right]_{m\times n} = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix} \text{i} = 1,2,\dots,\text{m}; \quad \text{j} = 1,2,\dots,\text{n} \tag{8}$$

x_{ij} denotes the efficacy of the ith alternative concerning the jth criterion Zavadskas et al. (2012: 1).

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Step 2: Criteria Weighting: At this stage, MEREC weighting results were used within the scope of our study.

Step 3: Normalization of the Decision Matrix: At this stage, if the benefit and cost attributes of the criteria are accessible, the benefit and cost equations are implemented. The criterion in the benefit case should be maximized, and the criterion in the cost case should be minimized. The calculation formulas are shown below.

For Benefit Criterias: $\bar{X}_{ij} = \frac{x_{ij}}{max_i x_{ij}}$ (9)

For Cost Criterias: $\bar{X}_{ij} = \frac{min_i x_{ij}}{x_{ij}}$

Step 4: Assessment of the overall relative significance value for each alternative utilizing the weighted sum model and the weighted multiplication model:

$Q_{i^{(1)}} = \sum_{j=1}^{n} \overline{x_{ij}}\ W_j$ → Weighted Sum Model (10)

W_j : Weight of j[th] criteria

$Q_i = \prod_{j=1}^{n} (1-\lambda)\ Q_i^{(2)}$ → Weighted Multiplication Model

λ is taken as 0,5

Step 5: Calculation of Combined Optimality Value: At this stage, the aggregate optimality value is computed for each alternative using the formula presented in Equation 11.

$Q_i = \lambda Q_i^{(1)} + (1-\lambda)\ Q_i^{(2)}$ (11)

As a result, the final ranking is made with Q_i values WASPAS in the method. The alternative with the highest Q_i value prioritized and ranked first.

2.3. Technique for Order Preference by Similarity to Ideal Solution (TOPSİS) Method

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach is one of the important MCDM methods. It was first introduced by Yoon and Hwang in 1980. In the method, the distances of all alternatives to the positive and negative ideal solution are calculated. The TOPSIS method was developed based on the principle that the optimal alternative is nearest to the positive-ideal solution and furthest from the negative-ideal solution (Chen, 2000: 2). The TOPSIS method is applicable in various domains. The method can be readily implemented on the data set. This method allows for the ranking of alternatives based on their proximity to the ideal solution, considering the maximum and minimum values of the criteria. Multiple decision options must exist for the method to be implemented Ekin and Dolanbay (2024: 9). The TOPSIS method comprises six steps. The equations pertaining to the steps of the TOPSIS method are provided between Equations 12 and 18 below.

Step 1: Constructing the Decision Matrix (A): Matrix A serves as the preliminary matrix, formulated using the information supplied by the decision maker. The representative decision matrix is presented in Equation 1.

Step 2: Formulating the Standard Decision Matrix (r_ij): The standardized decision matrix, as outlined in Equation 12, is constructed utilizing the A matrix and the designated formula.

$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}$ (12)

In the r_{ij} matrix, the quantity of decision points is denoted as m, while the quantity of evaluations is represented as n.

Step 3: Formulating the Weighted Standard Decision Matrix (V): Initially, the decision maker calculates the importance weights W_j of the evaluation criteria.

Subsequently, each column of the R matrix is multiplied by the corresponding $W_i$value to generate the V matrix.

$$v_{ij} = w_j x r_{ij} \tag{13}$$

Step 4: At this stage, ideal positive A^+ and ideal negative A^- solutions are determined using the weighted decision matrix:

$$A^+ = \{(max v_{ij} \mid j \in J), (min v_{ij} \mid \in J')\} \tag{14}$$

$$A^- = \{(min v_{ij} \mid j \in J), (max v_{ij} \mid \in J')\} \tag{15}$$

To formulate the optimal solution set, the most significant weighted evaluation factors in the V matrix are chosen. If the pertinent evaluation criterion is focused on minimization, the least value is chosen. For the A^+ set, the maximum value in each column of the V matrix is chosen, while for the A^- set, the minimum values in each column of the V matrix are selected. In both equations, J denotes the benefit (maximization) and J' signifies the loss (minimization) value.

Step 5: Computation of Separation Metrics: The TOPSIS method employs the Euclidean Distance Approach to ascertain the evaluation factor value for each decision point and its discrepancies from the ideal and negative ideal solution sets. The deviation values related to the decision points identified here are referred to as the Ideal Separation S_i^+ and Negative Ideal Separation S_i^- measures. The computation of the ideal separation measure S_i^+ is presented in Equation 16, while the calculation of the negative ideal separation measure S_i^- is detailed in Equation 17.

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2} \tag{16}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2} \tag{17}$$

Step 6: Computation of Relative Proximity to the Optimal Solution: Ideal and negative ideal separation measures are employed to determine the relative closeness C_i^* of each decision point to the optimal solution. The C_i^*formula is presented in equation 18.

$$c_i^* = \frac{S_i^-}{S_i^+ + S_i^-} \tag{18}$$

The C_i^* value falls within a specific range, indicating the absolute proximity of the pertinent decision point to both the ideal solution and the negative ideal solution.

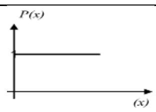
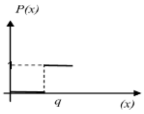
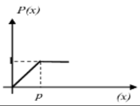
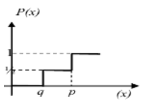
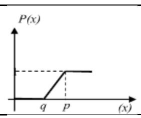
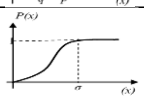
2.4. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) approach was developed by Brans (1982). The method was formulated in response to the challenges encountered during the application phase of existing prioritization techniques in the literature and has been utilized in numerous studies to date (Dağdeviren and Eraslan, 2008: 2). The PROMETHEE method is among the most efficient and straightforward approaches for addressing multi-criteria decision-making challenges. The extensive and effective application of the PROMETHEE method is attributed to its mathematical characteristics and user-friendliness. Alongside the PROMETHEE method, the PROMETHEE I and PROMETHEE II methods have been established. They are commonly referred to as PROMETHEE-I (partial ranking) and PROMETHEE-II (complete ranking). Moreover, various methodologies including PROMETHEE III, IV, V, and VI are documented in the literature (Ballı et al., 2007: 3). The PROMETHEE method comprises seven stages. In the initial phase, the identified alternatives and criteria are established, and a decision matrix is constructed with the importance weights of the criteria computed using the Entropy method. In the subsequent phase, preference functions are established for the criteria. Preference functions are established based on the criterion's structure and the attributes desired in the alternatives related to the criterion. Six distinct preference functions are delineated for application within the method. The formulas pertaining to the stages of the PROMETHEE method are provided below.

Step 1: Creating the Decision Matrix: A decision matrix consisting of alternatives, criteria and criterion weights is created.

Step 2: Determination of Preference Functions: After the creation of the decision matrix, one of the 6 preference functions previously determined for each criterion is selected according to the structure of the PROMETHEE method and the alternatives are compared with each other in pairs according to these preference functions. The selected preference function and the alternatives are compared on a criterion basis. In the comparison based on criteria, 6 preference functions put forward by Brans (1982) are used. The 6 preference functions are given in Table 3 (Genç, 2013: 6).

Table 3: Preference Functions Used in the PROMETHEE Method

Type	**Parameters**	**Function**	**Graph, p(x)**
First Type (Normal)	-	P(x)= $\begin{cases} 0, & x \leq 0 \\ 1, & x > 0 \end{cases}$	
Second Type (U-Type)	l	P(x)= $\begin{cases} 0, & x \leq l \\ 1, & x > l \end{cases}$	
Third Type(V-Type)	m	P(x)= $\begin{cases} \frac{x}{m}, & x \leq m \\ 1, & x \geq m \end{cases}$	
Fourth Type (Level)	q, p	P(x)= $\begin{cases} 0, & x \leq q \\ 1/2, & q < x \leq q+p \\ 1, & x > q+p \end{cases}$	
Fifth Type (Lineer)	s, r	P(x)= $\begin{cases} 0, & x \leq s \\ (x-s)/r, & s \leq x \leq s+r \\ 1, & X \geq s+r \end{cases}$	
Sixth Type (Gaussian)	σ	P(x)= $\begin{matrix} 0, & x \leq 0 \\ 1-e^{-x^2/2\sigma^2}, & x \geq 0 \end{matrix}$	

The objective of employing the first type preference function is to address scenarios lacking criteria preference, while the second type preference function serves a distinct purpose. In instances where it is desirable for the criteria to exceed a specified l parameter value, the application of the third type preference function is recommended; If the criteria are not meant to be assessed based on an average and values below this threshold are not to be disregarded, the application of the fourth type preference function; To ascertain a specific value range for the criteria, the application of the fifth type preference function is required. In instances where values exceeding the average are favored among the criteria, and the sixth type preference function is employed; in scenarios where the criteria are to be prioritized based on deviation from the average.

Step 3: Determination of common preference functions and preference indices: At this stage, the common preference function is determined for the alternative pairs determined by taking the preference functions. The formula for determining common preference functions and preference indices is shown in equations 19 and 20.

$$p(a,b) = \begin{cases} 0, \ f(a) \le f(b) \\ p[f(a) - f(b)], \ f(a) \ge f(b) \end{cases} \tag{19}$$

$$\pi(a,b) = \frac{\sum_{i=1}^{m} W_i \times p_i(a,b)}{\sum_{i=1}^{m} W_i} \tag{20}$$

Step 4: Determining positive Φ^+ and negative Φ^- superiority values: Positive and negative superiority of the alternatives are determined. The formula shown in Equation 21 is used to determine the positive Φ^+ superiority value. The formula in Equation 22 is used to determine the negative Φ^- superiority value.

$$\Phi^+(a) = \sum \pi(a,x) \quad x = (a,c,d\ldots) \tag{21}$$

$$\Phi^-(a) = \sum \pi(x,a) \quad x = (b,c,d\ldots) \tag{22}$$

Step 5: Obtaining the partial order of alternatives with Promethee I: There are three cases in this stage, in the first case, if any of the conditions of Equation 23, 24 and 25 are met, alternative a is considered superior to alternative b.

$$\Phi^+(a) > \Phi^+(b) \quad \text{and} \quad \Phi^-(a) < \Phi^-(b) \tag{23}$$

$$\Phi^+(a) > \Phi^+(b) \quad \text{and} \quad \Phi^-(a) = \Phi^-(b) \tag{24}$$

$$\Phi^+(a) = \Phi^+(b) \quad \text{and} \quad \Phi^-(a) < \Phi^-(b) \tag{25}$$

In the second case, if the condition of Equation 26 is met, alternative a is no different from alternative b.

$$\Phi^+(a) = \Phi^+(b) \qquad \text{and} \qquad \Phi^-(a) = \Phi^-(b) \tag{26}$$

In the third case, if one of the conditions is met, the alternatives are not compared. The conditions are shown in Equation 27 and 28 below.

$$\Phi^+(a) > \Phi^+(b) \quad \text{and} \quad \Phi^-(a) > \Phi^-(b) \tag{27}$$

$$\Phi^+(a) < \Phi^+(b) \quad \text{and} \quad \Phi^-(a) < \Phi^-(b) \tag{28}$$

Step 6: Determining net priority values and establishing the precise sequence of alternatives using Promethee II: The precise priorities for the alternatives are determined using the formula outlined in equation 29. Based on the computed net priority values, all alternatives are assessed concurrently, establishing a definitive ranking for the options. The definitive sequence of the computed priority values is established. The Φ value is referred to as the net priority value.

$$\Phi^{+}(\text{a}) = \Phi^{+}(\text{a}) - \Phi^{+}(b) \quad (29)$$

2.5. Multi-Objective Optimization by Ratio Analysis (MOORA) Method

The Multi-Objective Optimization by Ratio Analysis (MOORA) method was developed by Brauers in 2004. It was developed similarly to the TOPSIS and VIKOR methods. Unlike these methods, MOORA does not deal with non-ideal solutions. Solutions are performed based on the reference point only. The relationship of each alternative to the reference point is determined by taking the difference for each criterion, not as the Euclidean distance as in the TOPSIS method. The formulas related to the application steps of the MOORA method are given below in equations 30-32.

Step 1: Creating the decision matrix: m denotes the quantity of alternatives, while n signifies the quantity of criteria.

$$X=\begin{pmatrix} X_{11} & \cdots & X_{1i} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ X_{j1} & \cdots & X_{ji} & \cdots & X_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ X_{m1} & \cdots & X_{mi} & \cdots & X_{mn} \end{pmatrix} \quad (30)$$

Step 2: Normalizing the Decision Matrix: While the total number of alternatives is expressed by "m", "n" signifies the total number of criteria. x_{ij} denotes the ith alternative corresponding to the jth criterion, where i ranges from 1 to n for the criteria and j ranges from 1 to m for the alternatives.

$$X_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^{2}}} \quad (31)$$

X_{ij}^{*}; is the normalized version of the value in the j[th] criterion of the i[th] alternative.

Step 3: Determining the maximum and minimum criteria and calculating the MOORA score: In order to reach the result, the scores targeting the largest must be added and the scores targeting the smallest must be subtracted.

$$y_{j}^{*} = \sum_{i=1}^{i=g} x_{ij}^{*} - \sum_{i=g+1}^{i=n} x_{ij}^{*} \quad (32)$$

i =1,2, ...,g are the objectives that target the largest and i=g+1,g+2, ..., n are the objectives that target the smallest. y_i is the value that represents the normalized jth alternative according to all objectives. The ranking process is performed according to the MOORA ratio method with the y_i values.

2.6. COPELAND Method

COPELAND method, Copeland method was put forward by Saari and Merlin (1996). The objective of this method is to demonstrate the outcomes obtained from different methods to decision makers in an integrated manner. In the method, comparison is made according to the superiority of the alternatives. The scores of each alternative are calculated according to their advantages and disadvantages and are ranked according to the obtained scores. When comparing between the alternatives, 1 point is given in case of victory and 0 point is given in case of defeat against other alternatives for each criterion. The victory and defeat scores are converted to a total score for each alternative and ranked. The COPELAND method consists of 4 stages.

Step 1: Alternatives (Ai and Aj) are arranged as pairwise comparison matrices and are given a value of "1" for victory and "0" for defeat, depending on their relative positions.

$$f_{s(i,j)} = \begin{cases} 1, s_k(Ai) < s_{k(Aj)} \\ 0, s_k(Ai) > s_{k(Aj)} \\ boş, s_k(Ai) = s_{k(Aj)} \end{cases} \qquad i \neq j \tag{33}$$

Step 2: The sum of the values obtained by the alternatives (Ai and Aj) is taken.

$$T\,(i,j) = \sum_{k=1}^{y} f_{s(i,j)}, \qquad i \neq j \tag{34}$$

Step 3: When the status of each alternative is examined in relation to the other alternative by looking at the S (i, j) values which represent the preference scores derived from the applied decision-making method of the alternatives the alternatives, "1" point is given if the result is a win, "1/2" point is given in case of a tie and "0" point is given in case of loss.

$$G(i,j) = \begin{cases} 1, & T(i,j) > (y - T(i,j)) \\ \frac{1}{2}, & T(i,j) = (y - T(i,j)) \\ -1, & T(i,j) < (y - T(i,j)) \end{cases} \qquad İ \neq j \tag{35}$$

Step 4: The negative and positive values of each alternative are added together over the G (i, j) values of the alternatives, and the victory (GP_i) and defeat (YP_i) scores are calculated. Then, the defeat scores are subtracted from the victory scores obtained, and the Copeland score (CP_i) is found. The Copeland score is also subjected to ranking, and the corrected integrated alternative ranking score is obtained.

$$GP_{ij} = \sum_1^n G(i,j), G(i,j) > 0, n \tag{36}$$

$$YP_{ij} = \sum_1^n G(i,j), G(i,j) < 0, n \tag{37}$$

$$CP_i = GP_i + YP_i \tag{38}$$

3. FINDINGS

In this study, data on the technical specifications of 11 different best-selling electric vehicles in Turkey were used. The data were obtained based on the technical specifications taken from the official websites of the electric vehicles included in the study. The criteria employed in the selection of electric vehicles were prioritized using the Method based on the Removal Effects of Criteria (MEREC) method. Electric vehicles were ranked utilizing the criteria weights derived from the MEREC method, employing the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Weighted Aggregated Sum Product Assessment (WASPAS), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), and Multi-Objective Optimization by Ratio Analysis (MOORA) methods, with the final ranking determined through the COPELAND method. The methodology employed in the study is illustrated in Figure 1.

Figure 1: Methodology used in the study

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3.1. Determination of Criteria Weights

The method based on the Removal Effects of Criteria (MEREC) method objectively assesses the relative significance of criteria. This study's criteria are founded on the vehicles' technical and economic attributes. The weight values for the criteria utilized in the study were established through the application of formulas derived from equations 1-7 of the MEREC method. Table 4 shows the criteria used below and the weight values obtained with the MEREC method. These criteria are the main factors affecting the technical performance and user experience of electric vehicles.

Table 4: Weight Values of Decision Criteria

CHARGING TIME	POWER (KW)	RANGE	PRICE	BATTERY CAPACITY	CONSUMPTION (kWh)	NUMBER of SERVICE CENTERS
0,258917	0,184442	0,087439	0,134985	0,109444	0,053939	0,170832

According to Table 4, charging time is the criterion with the highest weight (0.258917), because fast charging of a vehicle provides significant ease of use for users. Power (KW) and number of services are important criteria in terms of performance and ease of maintenance, with weights of 0.184442 and 0.170832, respectively. Electricity consumption has the lowest weight of 0.053939, which shows that electric vehicles are less prioritized than other criteria in terms of overall energy efficiency and cost. The electric vehicle alternatives were ranked using four distinct multi-criteria decision-making methods: TOPSIS, PROMETHEE, MOORA, and WASPAS, based on the specified weight values. Each method assesses vehicle performance based on various criteria, and the final ranking is integrated using the COPELAND method. The rankings of the alternative vehicles, based on the four multi-criteria decision-making methods employed in the study, are presented below.

3.2. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Results

The TOPSIS approach assesses the closeness of options to the optimal solution. This method calculates the distance of each alternative from a "ideal" solution and establishes a ranking accordingly. Table 5 presents the rankings derived from the TOPSIS methodology.

Table 5: TOPSIS method results

Alternatives	TOPSIS Score	Rank
X10	0,508389	1
X5	0,456997	2
X4	0,422116	3
X8	0,415006	4
X9	0,402400	5
X2	0,387093	6
X11	0,373816	7
X3	0,353576	8
X1	0,329015	9
X6	0,323153	10
X7	0,308652	11

When the evaluation results made according to the TOPSIS method are examined, the X10 vehicle was determined to be the electric vehicle closest to the ideal solution by receiving the highest score with 0.508389 points. The high score of this vehicle shows that it has achieved superior results especially in the criteria that are critical in terms of performance such as charging time, power and range. The X5 vehicle, which came in second, also showed a good performance with 0.456997 points. The X4, X8 and X9 vehicles, ranked third, fourth and fifth respectively, showed a reasonable level of performance compared to the ideal solution. On the other hand, the X7 vehicle received the lowest score with 0.308652 points and was evaluated as the vehicle farthest from the ideal solution, which reveals that the vehicle remains weak in terms of performance criteria.

3.3. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) Results

The PROMETHEE method evaluates the superiority relationships between alternatives. The method ranks each alternative based on the positive and negative superiority degrees. The PROMETHEE results are categorized based on the positive and negative superiority values derived from the preference distribution in vehicle comparisons. This ranking provides decision makers with information about the most preferred and least preferred vehicles. The outcomes derived from the PROMETHEE method are presented in Table 6.

Table 6: PROMETHEE method Results

Alternatives	PROMETHEE Score	Rank
X7	0,411386	1
X5	0,354913	2
X6	0,276700	3
X11	0,191065	4
X1	0,094507	5
X4	-0,036750	6
X2	-0,175610	7
X8	-0,230720	8
X3	-0,231870	9
X10	-0,242070	10
X9	-0,411570	11

According to the PROMETHEE method results, vehicle X7 is ranked first with the highest positive superiority score and has the best performance in terms of preferability. Vehicles X5 and X6 are also ranked second and third, respectively, and are generally evaluated positively. However, X11 and X1 have an average performance but no negative superiority. On the other hand, vehicles from X4 onwards have negative superiority ratings; especially vehicles X10 and X9 have the lowest performance, ranking tenth and eleventh, respectively. These results show that some vehicles are clearly more preferred, while others have negative performance.

3.4. Multi-Objective Optimization by Ratio Analysis (MOORA) Results

The MOORA method assesses the overall performance of each alternative by examining the normalized values based on benefit and cost criteria. The method aims to determine the most suitable alternatives by maximizing the benefits and minimizing the costs. This ranking provides information to

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decision makers about the most suitable and least suitable alternatives by showing how efficient the tools are in terms of cost-benefit balance. The outcomes derived from the MOORA method are presented in Table 7.

Table 7: MOORA method Results

Alternatives	**MOORA Score**	**Rank**
X11	0,051255	1
X5	0,050187	2
X7	0,045871	3
X4	0,041098	4
X6	0,037943	5
X8	0,033829	6
X1	0,023573	7
X2	0,012928	8
X3	0,006006	9
X9	0,003381	10
X10	-0,004940	11

According to the MOORA method results, the X11 vehicle ranked first by obtaining the highest score. This shows that the X11 exhibited the best performance in terms of cost-benefit balance. The X5 vehicle ranked second and showed a very successful result in terms of cost and performance. The X7 vehicle ranked third and showed a generally positive performance. The X4 and X6 vehicles ranked fourth and fifth and showed an acceptable performance in terms of cost-benefit balance. On the other hand, vehicles X1, X2 and X3 showed an average performance and ranked seventh, eighth and ninth, respectively. Vehicles X9 and X10 showed poor performance and ranked last; especially X10 received a negative score and was evaluated as the least preferable vehicle. The results indicate significant disparities among the vehicles regarding cost-benefit equilibrium.

3.5. Weighted Aggregated Sum Product Assessment (WASPAS) Results

The WASPAS method assesses the overall efficacy of alternatives by integrating the weighted sum and weighted multiplication models. This approach yields a more equitable and accurate ranking by integrating the outcomes derived from both summation and multiplication models. The WASPAS method provides a thorough analysis of vehicle performance across various criteria. The outcomes derived from the WASPAS method are presented in Table 8.

Table 8: WASPAS method Results

Alternatives	WASPAS Score	Rank
X5	0,419570	1
X11	0,415398	2
X7	0,409812	3
X4	0,400850	4
X6	0,399570	5
X8	0,395774	6
X1	0,375862	7
X2	0,369359	8
X10	0,361859	9
X3	0,352970	10
X9	0,351110	11

According to the WASPAS method results, the X5 vehicle ranked first with a score of 0.419570 and was determined as the most ideal electric vehicle. This result shows that the X5 vehicle is a high-performance model and stands out as the most suitable choice in terms of various criteria. The X11 vehicle achieved a score of 0.415398, securing second place, whereas the X7 vehicle obtained a score of 0.409812, placing third. These vehicles attained favorable outcomes regarding the equilibrium of cost and performance. The X4 and X6 vehicles ranked fourth and fifth, respectively, and exhibited above-average performance. The X8 vehicle ranked sixth, and its overall performance remained at a relatively good level. The X1 and X2 vehicles exhibited average performance, ranking seventh and eighth, respectively. On the other hand, the X10, X3 and X9 vehicles achieved lower scores, ranking ninth, tenth and eleventh, respectively. The X9 vehicle was determined as the vehicle with the lowest performance, with a score of 0.351110. As a result, the WASPAS method revealed that consumers prefer high-performance and cost-effective electric vehicles. X5, X11 and X7 vehicles ranked highest in terms of cost and performance balance and stood out as preferable alternatives.

3.6. Combining Results with the COPELAND Approach

The COPELAND approach provides a final ranking based on the results of comparisons between alternatives. This method assesses the victories and defeats of each alternative relative to others and derives a score. Positive scores indicate that the alternative is superior to the others, while negative scores indicate that it is weak compared to other alternatives. The final ranking obtained with the COPELAND method provides a more comprehensive assessment by combining the results of various decision-making methods. Table 9 below shows the final ranking obtained with the COPELAND method.

Table 9: COPELAND method Results

Alternatives	COPELAND Score	Rank
X5	34	1
X11	20	2
X4	14	3
X7	12	4
X6	2	5
X8	0	6
X1	-8	7
X2	-10	8
X10	-14	9
X3	-24	10
X9	-26	11

According to the COPELAND method results, the X5 vehicle showed the best performance by ranking first with 34 points. This shows that X5 is the most successful alternative in various decision-making methods and achieves more wins compared to other alternatives. The X11 vehicle, which ranked second, showed a positive performance with 20 points, followed by the X4 vehicle with 14 points. The X7 and X6 vehicles ranked fourth and fifth, respectively, and these vehicles generally showed a good performance. The X8 vehicle ranked sixth with 0 points, indicating a neutral performance among the alternatives. Among the vehicles evaluated with negative scores, X1, X2, X10 and X3 showed lower performance and ranked seventh, eighth, ninth and tenth, respectively. The X9 vehicle ranked eleventh with the lowest score of -26 points and emerged as the least preferred alternative in terms of its overall performance. The COPELAND method assessed these outcomes, identified the most and least successful vehicles, and offered decision-makers a comprehensive perspective by integrating results from various methodologies. X5, X11 and X4 vehicles ranked at the top of the overall ranking, proving to be more preferable than other alternatives.

RESULTS AND DISCUSSION

Electric vehicles (EVs), as an important part of sustainable transportation, have begun to replace internal combustion engine vehicles and offer environmentally friendly alternatives. Increasing domestic automobile production in Turkey can reduce dependency on fossil fuels by increasing the use of electric vehicles. This study aims to offer solutions to the decision-making challenges encountered by consumers intending to purchase an electric vehicle, utilizing multi-criteria decision-making methods and enumerating the alternatives. This study analyzed the 11 top-selling electric car models in Turkey based on seven criteria: charging time, power (kW), range, price, battery, electricity consumption (kWh), and number of services. Various multi-criteria decision-making methods (TOPSIS, PROMETHEE, MOORA, and WASPAS) were utilized, and the resultant data were integrated with the COPELAND method. According to the evaluation process, the X5 vehicle has the highest performance score and the safety of the most ideal vehicle has been established. The X5 vehicle has the shortest charging time with 15 charging times. It offers ease of use with the ability to be charged in a short time. Another important feature of the X5 vehicle is its 208 kW engine power. The battery capacity of the X5 is strong, but in terms of electricity consumption, the X5 shows a medium level of performance. Although there are vehicles with lower electricity consumption than the X5 vehicle, the X5 can provide balance with its battery capacity. The X5 vehicle, which is at a normal level in terms of price, exhibits a limited performance in terms of range and number of services. The findings derived from the analyses are collectively presented in Table 10:

Table 10: Ranking Obtained by Multi-Criteria Decision-Making Methods

Alternatives	COPELAND Rank	TOPSIS Rank	PROMETHEE Rank	MOORA Rank	WASPAS Rank
X5	1	2	2	2	1
X11	2	7	4	1	2
X4	3	3	6	4	4
X7	4	11	1	3	3
X6	5	10	3	5	5
X8	6	4	8	6	6
X1	7	9	5	7	7
X2	8	6	7	8	8
X10	9	1	10	11	9
X3	10	8	9	9	10
X9	11	5	11	10	11

Table 10 presents the rankings derived from various multi-criteria decision-making methodologies. The final ranking, utilizing the COPELAND method, designated vehicle X5 as the alternative with the highest score. This indicates that X5 is a significant metric of its overall performance, having attained high rankings in alternative methodologies as well. Vehicles X11 and X4 are significant alternatives, positioned second and third in the COPELAND ranking. For instance, vehicle X10 attained the highest ranking using the TOPSIS method, whereas vehicle X7 achieved the top position in the PROMETHEE and MOORA methods. These discrepancies illustrate the impact of subjectivity in the assessment of alternatives by each method and the prioritization of criteria. The COPELAND method stands out as a very effective voting method in ranking alternatives. This method provides a clearer result to decision makers by creating a final ranking based on the victories obtained by comparing each alternative with the others. This supports decision-making processes by providing a more systematic approach in the evaluation of alternatives. The different formulas used in the application stages of multi-criteria decision-making methods may lead to differences in the rankings of the alternatives. The COPELAND method is used to express these different rankings by combining them in a common way. In our study, a common ranking was created from the rankings obtained from four different methods using this method. The MEREC method is an innovative method among multi-criteria decision-making methods (Keshavarz-Ghorabaee et al., 2021: 7). This method is in the category of objective weighting methods used in determining the criteria weights. In this method, it is necessary to determine the performance of the alternatives first. In our study, MEREC was preferred in order to objectively weight the criteria used in the selection of electric vehicles and to obtain more reliable and comparable results. MEREC has a wide range of applications thanks to its objectivity. For example, it can be used in decision-making processes in areas such as supply chain management, the healthcare sector, and the tourism sector. Consequently, a more objective and systematic assessment was conducted utilizing the MEREC method in the study, and the results furnish data that will assist consumers contemplating the purchase of an electric vehicle in identifying which models are more appropriate. Moreover, integrating the outcomes derived from various multi-criteria decision-making methods with the COPELAND method enhances the clarity and reliability of alternative comparisons. The COPELAND method provides a more comprehensive and systematic evaluation to decision makers by creating a final ranking based on the victories obtained by comparing each alternative with the others. This facilitates consumers to make conscious decisions, while also guiding sector managers in strategic planning. The diverse methodologies employed render the study a novel contribution to the literature. The results assist consumers contemplating the acquisition of an electric vehicle in identifying the most suitable options. The findings of the study constitute an important resource for automobile buyers and professionals in the sector. Consumers who are considering purchasing an electric vehicle can make more conscious choices by considering the criteria importance levels of the alternatives. In addition, automobile sector managers can use the data obtained from this study in determining product development and marketing strategies. In future studies, it is suggested to increase the number of alternatives and add new criteria. For example, it may be useful to include additional criteria such as vehicle traction capacity, weight and SCT rates in the study. In addition, more up-to-date and innovative decision-making models can be created by integrating different multi-criteria weighting methods. Such an approach will pave the way for more systematic and effective decisions in both academic and applied fields. The study's findings will enhance strategic decision-making for industry participants by establishing a robust knowledge foundation for electric vehicle procurement processes.

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