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Integrated Entropy-EDAS Methods for the Electrified Car Selection Problem

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Abstract

Increasing air pollution affects the environment and life negatively. For a sustainable environment and life, people, voluntary organizations, and governments need to work on the solution of this problem. The biggest sources of air pollution are transportation vehicles. For this reason, many countries in Europe have stated that they will use solely electrified cars to reduce air pollution in the future. Therefore, in this study, it is aimed to determine the best electrified car. The result obtained can support consumers that to intend to buy an electrified vehicle in the decision-making process. This problem is a typical multi-criteria decision making (MCDM) problem and some MCDM techniques are used to solve these problems. Here, the Entropy method was used to determine the weights of the selection criteria. Selection criteria was determined according to comprehensive literature survey and interviews with sales representatives. The EDAS (Evaluation based on Distance from Average Solution) method was used to rank the electrified car alternatives that sold in Turkey. As a result of the evaluation, the most important criteria was determined by the price of the vehicle, the net battery capacity, and the electric motor power. According to these criteria, the electrified car manufactured in China was chosen as the best.

1. Introduction

According to the statement made by the World Health Organization, air pollution seriously threatens human life and causes the death of approximately two million people worldwide every year. Our world is becoming uninhabitable due to rapidly increasing population growth, unplanned urbanization, industrialization, and many reasons [1]. If cautions are not taken to solve this problem, there will be no world in which we can live in the future.

As a result of increasing greenhouse gases, climate change threatens the whole world. The biggest factor in the increase of greenhouse gases is due to the exhaust gases thrown into the air from transportation vehicles especially in big cities [2]. For this reason, automobile manufacturers have started to use electric motors instead of internal combustion engines in their cars for a cleaner environment. The world will become more livable due to the usage of electric vehicles with zero CO_2 emissions [3]. Not only manufacturers, but also governments have started to act. For this reason, many countries have announced that they will ban the sale of cars using gasoline and diesel fuel. In 2016, Norway announced that the sale of these cars would be banned as of 2025, while on the same dates it announced that it would implement a similar application in Germany from 2030. With this decision, the country aims to reduce its CO_2 emissions by 95% by 2050. Following these countries, France, England, Scotland, the Netherlands, and many European countries have announced that they will follow the same policy [4]. Such policies have brought the production, sale, and use of electric vehicles all over the world, especially in Europe, to the agenda. As a result of these sanctions, the determination of the most efficient electrified car is also an important issue.

In this study, it is aimed to determine the best electric cars among alternatives sold in Turkey. This is a typical multi-criteria decision making problem and integrated Entropy and EDAS methods are used to solve the problem.

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A limited number of studies have been reached in the literature on electric vehicles evaluation and selection process. Xue et al., in their study in 2008, tested six different types of drivetrain systems used in the engines of electric vehicles [5]. On the other hand, Baghdadi et al. examined the electric vehicles of two different brands such as Peugeot iOn and Ford Transit Connect in 2013 and tested their current battery capacities, ranges and battery charging times under real road and laboratory conditions [6]. In Scandinavia, an electrical car model was evaluated according to its range in the different weather conditions [7].

In this study, the selection problem was handled by using different MCDM techniques. In the literature, there are many studies that used these techniques for various sector. Zou and his colleagues used the Entropy method to determine the weights of the criteria in the water quality assessment in 2006 [8]. In 2017, the machines were evaluated according to twelve criteria to determine the best one among the three different machines. While the Entropy method was used to calculate the criteria weights, the best machine was determined by the SAW method [9]. To determine the appropriate supplier, it was aimed to weight the criteria objectively in the study using the Entropy and AHP-based TOPSIS method [10]. Lahsini evaluated smartphones in terms of seven qualitative features in his study in 2017. He solved the problem by using the Entropy and MAUT (Multi-Attribute Utility Theory) methods together [11]. In another study, performance criteria were determined as the first step in measuring the performance of companies operating in the automotive sector and traded on the Istanbul stock exchange. Entropy method was used to weight the performance criteria. The weights obtained were first used in MAUT and then in SAW methods, and the performances of the companies were evaluated and ranked [12]. Nyimbili and Erden developed a hybrid model to evaluate emergency facility planning in Istanbul in their study in 2020. AHP and Entropy methods were used to determine the weights of the criteria objectively and subjectively [13]. Kenger (2017) dealt with the bank personnel selection problem in his thesis. In the solution of the problem, he made evaluations by using different MCDM techniques together [14]. Özbek and Engür (2018) used the EDAS method to evaluate the websites of companies operating in the logistics sector. They determined criteria like web site language, customer relations, online ordering, visual content etc. and they assumed that all criteria have the same weight [15]. In energy sector, for high efficiency a MCDM model was developed to evaluate five renewable resources. The criteria weights were calculated by using Shannon Entropy method and EDAS method was applied for selection of energy resources [16]. Yalçın and Uncu (2019) applied EDAS method to validate industrial robot selection process. They examined four different examples in their study. They found that EDAS is suitable method for right industrial robot selection [17]. Mitra used EDAS method for cotton fabric selection process in 2020. 13 different alternatives were evaluated according to four different criteria (cover, thickness, areal density, porosity) [18]. He and his colleagues studied to determine and evaluate green supplier by using information entropy and EDAS under uncertainty. The novel model developed by them was very easy to understand and compute [19]. For a construction project, fuzzy EDAS was used to determine the best company among five according to four different criteria. Technical, management, financial and time are the main factors [20]. Mathew and Sahu (2018) compared four alternatives to determine the most suitable conveyor according to six different criteria. In the selection process, fixed cost, variable cost, conveyor speed, product width, product weight and flexibility criteria were used. They used to EDAS method for the selection process [21]. The EDAS method was also used in material selection in the automotive industry. Different alternatives were evaluated according to different criteria and the result was reached [22]. Different multi-criteria decision-making techniques and their application areas are summarized in Table 1.

Finally, it has been observed that multi-criteria decision-making methods are used in many different areas and in solving many different problems. During the solution process, it has been witnessed those different methods work together. However, no study has been found in the literature on which criteria are important in the selection of electric vehicles and in the measurement of their performance, and which of the existing vehicles is the best. This study was designed to fill this gap. In order to fill this gap, it is aimed to select the best electrified vehicles available in the market by using Entropy-based EDAS methods in the selection process. After the criteria were determined, the Entropy method was used to determine their weights. The Entropy method is one of the most frequently used and easy method for implementation. The higher difference in value between alternatives while evaluating on the same criterion, the more important that criterion is. The more useful a criterion is, it plays the greater role in decision making. If a criterion has equal value among the alternatives, that criterion is disabled during the evaluation process, indicating that the weight of that criterion will be zero. EDAS method, which is used to determine the best alternative by finding the distance from the average solution, is different from other MCDM methods based on the logic of the compromise approach.

Table 1. Different MCDM methods and application areas.

Author(s)	Methods	Application area
Caloglu Buyukselcuk [23]	AHP-VIKOR integrated method	Food industry
Hussain and Mandal [24]	Entropy based COPRAS and MOORA	Material selection
Ersoy [25]	Entrophy-TOPSIS and GRA integrated methods	White goods industry
Ocampo et. al. [26]	Fuzzy DEMATEL-ANP-TOPSIS	Food Manufacturing
Kaviani et. al. [27]	Grey-Shannon entropy, grey EDAS	Oil and gas industry
Yazdani et. al. [28]	FMEA, EDAS	Construction industry
Galankashi et. al. [29]	Mixed Balanced Scorecard and fuzzy AHP	Automobile industry
Liu et. al. [30]	DEMATEL based ANP with VIKOR	Evaluating employee care strategies
Prakash and Barua [31]	Fuzzy AHP and VIKOR	Indian electronics industry
Mohammed et. al. [32]	ELECTRE and TOPSIS	Vendor selection
Dweiri et. al. [33]	Integrated AHP based decision support system	Automobile industry in Pakistan
Merdivenci and Oğuz [34]	Entropy based EDAS method	Personnel selection in logistics sector
Özaydın and Karakul [35]	Entropy with MAUT, SAW and EDAS	Financal analysis in food and beverages sector
Ali et. al. [36]	Integrated Entropy and EDAS methods	Renewable energy technology selection in energy sector

2. Materials and Methods

In this study, it is aimed to measure the performance of electric cars offered for sale in Turkey by using integrated Entropy and EDAS methods. In the first step, because of literature review and research, the criteria to be considered when buying an electric car were determined and these criteria were grouped according to beneficial and non-beneficial. Then, electrified car of different brands and models sold in Turkey were determined. For the criteria of these cars determined in the second step, a decision matrix was created by obtaining data from the official web sites and catalagoues of the vehicles. The weights of all variables were determined using the Entropy method. In the third step, the performances of existing electrified cars were evaluated using the EDAS method and these vehicles were ranked. As a result of this ranking, the best electrical cars sold in the market were determined. In this section, the beneficial and non-beneficial variables considered in the study and the techniques used in problem solving will be discussed. The flow chart for this problem was represented (Figure 1).

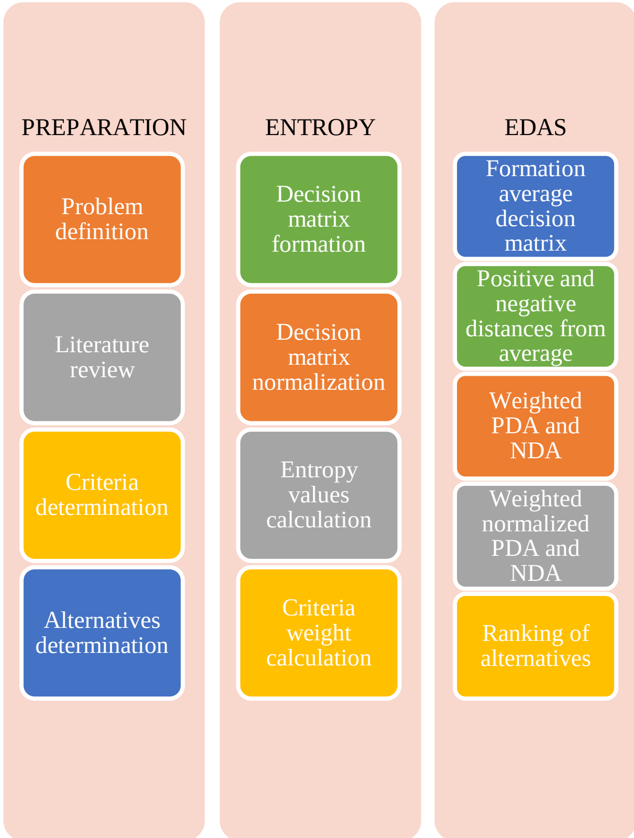

Figure 1. Flow chart of the problem

2.1. Determination of Criteria

By reviewing the literature on the subject and examining the forum pages of electric vehicles, the official websites and technical catalogs of brands that sell electrified cars, and by interviewing car sales representatives, it has been determined which criteria should be considered when buying electric vehicles.

The guarantee of the battery used in the vehicles, the net battery capacity, the charging time of the battery, the power of the electric motor, the maximum torque of the electric motor, the unloaded weight of the vehicle, the price of the vehicle, the vehicle's range, maximum speed, acceleration performance and energy consumption are considered as selection criteria. Since the CO_2 emission value of the vehicles is zero in all electric vehicles, this parameter is not considered as a criterion.

Criteria are summarized and categorized due to beneficial or non-beneficial (Table 2).

Table 2. Criteria definitions, codes, and types.

Criteria Name and Code	Type
Battery warranty (km)-C1	Beneficial
Net battery capacity (kW-h)-C2	Beneficial
Charging time (minute)-C3	Non-beneficial
Electric motor power (BG)-C4	Beneficial
Maximum torque (Nm)-C5	Beneficial
Unloaded weight (kg)-C6	Non-beneficial
Price (TL)-C7	Non-beneficial
Range (km)-C8	Beneficial
Maximum speed (km/h)-C9	Beneficial
Acceleration time (second)-C10	Non-beneficial
Consumption (kW-h/100 km)-C11	Non-beneficial

Electric car manufacturers guarantee their batteries for a certain year or a certain range of use. In general terms, battery capacity is the energy contained in the battery in the electric vehicle. This value is as important as the torque and engine power of the vehicle because the size of the battery used, its capacity and how efficiently it is used affect the range of the vehicle [37]. There are different types and levels of charging for the battery to charge. In this study, the type of long-term charging is considered [38]. The task of the electric motor in electric vehicles is to give traction to the wheels by converting the energy provided by the battery into mechanical energy. The driving force for an electric motor is torque. The unit of torque is expressed in Newton-meters. Torque is the parameter that enables vehicles to reach higher speeds in a short time during acceleration and ensures that the traction of the vehicle is strong [39]. Weight is also an important criterion in electric vehicles. Higher efficiency is achieved by producing vehicles with less weight by using lighter materials with the same battery capacity. In addition to all performance-related criteria, the price of the vehicle is one of the criteria considered by the end users. Continuous improvement efforts are being made to increase range in electric vehicles [40]. The maximum distance that the vehicle can travel with a fully charged battery is another criterion considered by users. One of the questions frequently asked by users during vehicle purchase is the maximum speed of the vehicle. The acceleration value of the vehicle is determined by expressing the time in seconds for the vehicle to reach 100 km speed from the moment of stopping [41]. Another critical point that users pay attention to when purchasing a vehicle is how much energy the vehicle will consume for a range of 100 km.

2.2. Entropy Method

In this part, the steps of the Entropy method used to determine the weights of the criteria will be explained. The entropy method is one of the objective weight methods and is frequently used in the literature. One of the most important advantages of the entropy method is that it eliminates the necessity of using the intuitive approach and verbal judgments of decision makers [42]. The steps of the method are as given below [43, 44]:

Step 1. The decision matrix is created by determining the performance values of each of the alternatives for different criteria.

$$X = [x_{ij}] = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

where x_{ij} is the performance value of i_{th} alternative according to j_{th} criterion $(i = 1,2, \ldots, m$ and $j = 1,2, \ldots, n)$.

Step 2. The decision matrix is normalized using the following equation so that all variables that make up the decision matrix are comparable and dimensionless. Eq. (2) is used for this purpose.

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (2)$$

Step 3. Entropy values are calculated for each criterion by using Eq. (3). e_j is the entropy value of j_{th} criterion. e_j values must satisfy the condition of $0 \leq ej \leq 1$.

$$e_j = -k \, . \sum_{i=1}^{m} r_{ij} \, . \, ln\,(r_{ij}) \quad (3)$$

where k is the entropy coefficient and is calculated by using Eq. (4).

$$k = (ln\,(n))^{-1} \quad (4)$$

Step 4. By using Eq. (6), entropy weights are determined.

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n}(1 - e_j)} \quad (5)$$

$$\sum_{j=1}^{n} w_j = 1 \quad (6)$$

$1 - e_j$ represents the degree of difference of each criterion's intrinsic information. The normalization of $1 - e_j$ values, the final entropy weights of criteria are determined. If a criterion has the smallest entropy value, it will have the greatest entropy weight.

2.3. EDAS Method

EDAS was developed by Keshavarz Ghorabaee and his colleagues in 2015 [45]. They tested the validity of the method by comparing it with other MCDM techniques such as VIKOR, TOPSIS, SAW and COPRAS. The steps of EDAS are given below [15, 46]:

Step 1. After the decision matrix containing the values of the alternatives according to the criteria is created, the average value due to all the criteria is determined using Eq. (7).

$$AV_j = \frac{\sum_{i=1}^{m} x_{ij}}{m} \tag{7}$$

$$AV = [AV_j]_{1xn} \tag{8}$$

Step 2. The positive distance and negative distance matrices from the average for each criterion are shown as expressed in the Eq. (9) and Eq. (10). Positive and negative distances from the average are calculated using Eq. (11), Eq. (12), Eq. (13) and Eq. (14) according to the types of criteria.

$$PDA = [PDA_{ij}]_{mxn} \tag{9}$$

$$NDA = [NDA_{ij}]_{mxn} \tag{10}$$

For beneficial criteria:

$$PDA_{ij} = \frac{max\ (0,(x_{ij} - AV_j))}{AV_j} \tag{11}$$

$$NDA_{ij} = \frac{max\ (0,\ (AV_j - x_{ij}))}{AV_j} \tag{12}$$

For non-beneficial criteria:

$$PDA_{ij} = \frac{max\ (0,(AV_j - x_{ij}))}{AV_j} \tag{13}$$

$$NDA_{ij} = \frac{max\ (0,\ (x_{ij} - AV_j))}{AV_j} \tag{14}$$

Step 3. The weighted total PDA and NDA are calculated for each alternative. v_j is the weight of j_{th} criterion.

$$SP_i = \sum_{j=1}^{n} v_j \,.\, PDA_{ij} \tag{15}$$

$$SN_i = \sum_{j=1}^{n} v_j \,.\, NDA_{ij} \tag{16}$$

Step 4. SP ve SN values are normalized for each alternative by using Eq. (17) and Eq. (18).

$$NSP_i = \frac{SP_i}{max_i\ (SP_i)} \tag{17}$$

$$NSN_i = 1 - \frac{SN_i}{max_i\ (SN_i)} \tag{18}$$

Step 5. Assessment score (AS_i) is calculated for all alternatives by using Eq. (19). AS_i values must satisfy the condition of $0 \leq AS_i \leq 1$.

$$AS_i = \frac{1}{2}\ (NSP_i + NSN_i) \tag{19}$$

Step 6. Alternatives are ranked by AS_i value from largest to smallest. The alternative in the first place is determined as the best one.

3. Results and Discussion

In this study, integrated entropy and EDAS methods were used to determine the best electric vehicles sold in Turkey. Electric SUVs available in the market were not among the alternatives in the study. Only electrified cars have been identified as alternatives. Three of these are vehicles from German, one from Chinese and the other from French automakers. As a result of the literature review, the criteria to be considered when buying an electric car were determined, and the Entropy method, which is one of the objective methods, was used to determine the weights of these criteria. Using the EDAS method, the best electrified car was determined.

3.1. Determination of the Criteria Weight via Entropy Method

After determining the initial decision matrix of the criteria and alternatives obtained from their technical catalogues and official web sites (Table 3), a normalized decision matrix was created by using Eq. (2) and Eq. (3). Normalized matrix results have been represented in Table 4. The entropy values and entropy weights for each criterion were calculated using Eq. (4) and Eq. (6) and have been shown in Table 5.

When Table 5 is examined, it is seen that the criterion with the largest entropy value has the least entropy weight value. According to these results, it is seen that the most important evaluation criterion is the price of the car ($w_j = 0.126$). It is followed by electric motor power, net battery capacity and battery charging time, respectively. Maximum speed, unloaded weight and battery warranty are the criteria with the lowest weight.

Table 3. Initial decision matrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	100,000	37.9	490	170	250	1345	704,000	310	150	7.3	14.2
A2	100,000	17.6	193	82	160	1085	156,000	160	130	12.7	16
A3	100,000	52	565	108	225	1577	368,900	395	135	11.4	17.2
A4	150,000	40	500	114	270	1460	283,000	320	130	9.5	15
A5	160,000	71	570	408	357	2130	2,200,000	390	230	5.4	28.7

Table 4. Normalized matrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	0.164	0.173	0.208	0.193	0.198	0.177	0.190	0.197	0.194	0.158	0.156
A2	0.164	0.081	0.084	0.093	0.127	0.143	0.042	0.102	0.168	0.274	0.176
A3	0.164	0.238	0.245	0.122	0.178	0.208	0.099	0.251	0.174	0.246	0.189
A4	0.246	0.183	0.217	0.129	0.214	0.192	0.076	0.203	0.168	0.205	0.165
A5	0.262	0.325	0.247	0.463	0.283	0.280	0.593	0.248	0.297	0.117	0.315

Table 5. Entropy values and entropy weights.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Entropy values (e_j)	0.661	0.636	0.649	0.591	0.658	0.661	0.494	0.654	0.660	0.653	0.655
Entropy weights (w_j)	0.0841	0.0904	0.0872	0.1016	0.085	0.0842	0.1256	0.0858	0.0845	0.086	0.0856

3.2. Determination of the Best Electrified Car via EDAS

The performances of these cars according to the evaluation criteria have been obtained from the official websites. The data set and the average value of the decision problem (by using Eq. (7)) have been given in Table 6. Positive and negative distance values from the average (PDA and NDA) were calculated using Eq. (11)-Eq. (12) and have been shown in Table 7 and Table 8. Weighted total PDA and NDA values for each alternative were calculated using Eqs. 15 and 16. The criteria weights used here were predetermined by the Entropy method. The obtained SP_i and SN_i values were normalized using Eq. (17)-Eq. (18) and the results are summarized in the Table 9.

Table 6. Data set of the problem and average values.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	100,000	37.9	490	170	250	1345	704,000	310	150	7.3	14.2
A2	100,000	17.6	193	82	160	1085	156,000	160	130	12.7	16
A3	100,000	52	565	108	225	1577	368,900	395	135	11.4	17.2
A4	150,000	40	500	114	270	1460	283,000	320	130	9.5	15
A5	160,000	71	570	408	357	2130	2,200,000	390	230	5.4	28.7
Average	122,000	43.7	461.6	176.4	252.4	1519.4	742,380	315	155	9.26	18.22

Table 7. Positive distance values from average (PDA_{ij}).

PDA_{ij}	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	0	0	0	0	0	0.115	0.052	0	0	0.212	0.221
A2	0	0	0.582	0	0	0.286	0.790	0	0	0	0.122
A3	0	0.190	0	0	0	0	0.503	0.254	0	0	0.056
A4	0.230	0	0	0	0.070	0.039	0.619	0.016	0	0	0.177
A5	0.311	0.625	0	1.313	0.414	0	0	0.238	0.484	0.417	0

Table 8. Negative distance values from average (NDA_{ij}).

NDA_{ij}	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	0.180	0.133	0.040	0.036	0.010	0	0	0.016	0.032	0	0
A2	0.180	0.597	0	0.535	0.366	0	0	0.492	0.161	0.371	0
A3	0.180	0	0.224	0.388	0.109	0.038	0	0	0.129	0.231	0
A4	0	0.085	0.083	0.354	0	0	0	0	0.161	0.026	0
A5	0	0	0.235	0	0	0.402	1.963	0	0	0	0.575

Table 9. SP_i, SN_i and normalized NSP_i, NSN_i values.

	SP_i	NSP_i	SN_i	NSN_i
A1	0.053	0.153	0.039	0.888
A2	0.184	0.529	0.242	0.308
A3	0.107	0.307	0.117	0.665
A4	0.123	0.352	0.067	0.810
A5	0.348	1	0.350	0

After the normalized SP and SN values were determined, the assessment score was calculated for each alternative using Eq. (19).

Considering all criteria, it has been determined that the electric car produced in China is the best. In the second and third place, it was determined that the electrified cars produced in Germany were the best (Figure 2). While some researchers discuss that the use of electric vehicles will prevent air pollution, some researchers argue the opposite. However, it is clear that the use of electric vehicles in the long term is one of the important steps to be taken in preventing air pollution [47, 48, 49].

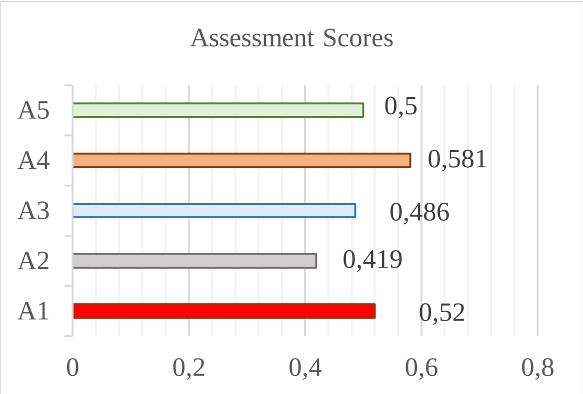

Figure 2. Assessment scores of alternatives.

4. Conclusions

With this study, it has been underlined once again that some necessary precautions for a sustainable life should be taken. To put a stop to air and environmental pollution that threatens the whole world, governments need to take urgent measures and impose sanctions on a local and global scale. In recent years, some measures should be taken urgently to prevent air pollution, which adversely affects the health of the whole world. While the rapidly increasing population, wrong urbanization, a noticeable increase in the use of pesticides and chemicals cause air pollution, another factor is the exhaust gases from the vehicles. Especially in the last eighteen months, there have been serious decreases in human activities due to the COVID-19 pandemic all over the world. This gave nature the opportunity to renew itself. One of the biggest factors in air pollution is undoubtedly vehicle traffic, and as it can be seen, the decrease in vehicle use plays an important role in air pollution control. Alternative ways to reduce emissions need to be found not only in automobiles, but also in factories, vehicles such as aircraft and ships. At this point, experts argue that with the increase in the use of electric cars, air pollution will decrease significantly. For this reason, many countries, especially Europe, have declared that they will ban the use of electric cars in the future and encourage their citizens to use these cars.

For this reason, most of the automobile manufacturers have produced and sold vehicles such as cars and SUVs that work with 100% electricity. For consumers, the critical question here is which vehicle will they buy? This problem is a multi-criteria decision-making problem and can be solved using MCDM techniques. In this study, the problem of choosing the best one among only electric cars sold in Turkey is discussed. First, it was determined which criteria would be considered while making the selection. The weights of these criteria were calculated using the Entropy method. As a result of the calculation, it has been determined that the first criterion to be considered in the process of purchasing and choosing an electrified car is the price. Other important criteria are electric motor power, net battery capacity and battery charging time, respectively.

Five electric cars of different brands sold in Turkey have been identified. After determining the data of these cars for the determined criteria, it was aimed to select the best one using the EDAS method. As a result of the evaluation, it has been determined that the vehicle produced in China is the best. In fact, this selected car is the second-cheapest car among all other models. The fact that price is the most important criterion is also a factor of this result. Although the second alternative is the cheapest vehicle in terms of price, however it is the weakest among the other models in terms of net battery capacity and electric motor power.

Since the price is such an important factor, the reorganization of taxes in terms of incentives for the sale of electric vehicles will ensure that these vehicles are sold and used more. Another important criterion is the charging time of the battery. At this point, it is important to increase and expand the number of charging stations. There are still deficiencies in the number of charging stations in our country, especially in the Central Anatolia and Eastern Anatolia Regions on highways. It is inevitable to take measures for a sustainable life in Turkey. The use of electric vehicles should be encouraged, and the necessary infrastructure opportunities should be expanded, and new regulations should be made on taxes. Thus, activities aimed at reducing air pollution will be supported.

The lower performance of electric cars compared to internal combustion engine vehicles is a limiting factor. For this reason, research and development activities regarding electric vehicles continue intensively. When the performance of vehicles is increased with technological developments, the use of these vehicles may become more common. In the future, this problem can be solved under different evaluation criteria. In addition, comparisons can be made by evaluating with different MCDM techniques. The sale of electrified vehicles in Turkey is still very new and not very common. For this reason, the experiences and feedbacks of the users were not included in the evaluation and determination of the criteria. In the next study, it is planned to expand the evaluation criteria pool by taking into account the user feedback and the advantages and disadvantages of the use of electrified vehicles. In addition, there are currently a limited number of electric vehicles from a limited number of automakers. In the future, it will be possible to work with a wider alternative pool of electric vehicles of different brands and models.

Declaration of Ethical Standards

The author of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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