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Energy Efficiency Evaluation in Automotive Industry with AHP Method and Best&Worst Method

Otomotiv Endüstrisinde AHP Metodu ve Best&Worst Metodu ile Enerji Verimliliği Değerlendirmesi

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ABSTRACT
Energy is one of the most important elements for countries to exist in the competitive market in social, economic, technological and international areas. With the developing technology and increasing energy consumption, the importance of energy efficiency comes to the fore. In this context, the automotive industry, which is an important part of the industrial sector where energy is used intensively, was preferred in the study. Besides the automotive industry's need for energy, its interaction with other industries is the reason for preference. In the study, Energy Efficiency Strategy criterion weights in the Automotive Industry were calculated by using Multi-Criteria Decision Making methods. As a result of the literature research, nine main criteria and thirty-three sub-criteria were determined. The criteria weights of the Energy Efficiency Strategy in the automotive industry are analyzed separately with AHP, which is frequently used in the literature, and BEST & WORST, which is newly introduced to the literature. Comparing the solution results of the two methods is the aim of the study. In the light of the results obtained, it has been determined that the AHP and BEST & WORST methods give close results.
JEL Codes: C11, L15, S10

Keywords: Automotive Industry, Energy Efficiency, AHP, BEST& WORST, Efficiency Strategy

ÖZ
Enerji, ülkelerin sosyal, ekonomik, teknolojik ve uluslararası alanda rekabetçi piyasada var olabilmelerinin en önemli unsurlarından biridir. Gelişen teknoloji ve artan enerji tüketimi ile birlikte enerji verimliliğinin önemi ön plana çıkmaktadır. Bu kapsamda çalışmada enerjinin yoğun olarak kullanıldığı sanayi sektörünün önemli bir parçası olan otomotiv sektörü tercih edilmiştir. Otomotiv sektörünün enerji ihtiyacının yanı sıra diğer sektörlerle etkileşimi de tercih sebebidir. Çalışmada, Çok Kriterli Karar Verme yöntemleri kullanılarak Otomotiv Sektöründe Enerji Verimliliği Stratejisi kriter ağırlıkları hesaplanmıştır. Literatür araştırması sonucunda dokuz ana kriter ve otuz üç alt kriter belirlenmiştir. Otomotiv sektöründe Enerji Verimliliği Stratejisinin kriter ağırlıkları, literatürde sıklıkla kullanılan AHP ve literatüre yeni giren BEST & WORST ile ayrı ayrı analiz edilmiştir. İki yöntemin çözüm sonuçlarının karşılaştırılması çalışmanın amacıdır. Elde edilen sonuçlar ışığında AHP ile BEST & WORST yöntemlerinin birbirine yakın sonuçlar verdiği tespit edilmiştir.
JEL Kodları: C11, L15, S10

Anahtar Kelimeler: Otomotiv Endüstrisi, Enerji Verimliliği, AHP, Best & Worst, Verimlilik Stratejisi

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Introduction

Energy is the most important element that man needs to meet his primary and secondary needs in the world. The need for energy, which is one of the most important issues in Turkey and in the world, comes to the fore with the ever-increasing technology and fossil fuel consumption, revealing the importance of energy efficiency. For this reason, determining the factors affecting energy consumption in developing countries such as Turkey is of great importance in terms of ensuring energy efficiency (Cabak, 2018).

Towards the end of the 1970s, the relationship between energy consumption and economic growth was studied intensively. Considering that most of the costs in a manufacturing enterprise are composed of energy after raw material, it is obvious that reducing energy costs will increase the competitiveness of the company. Energy use is intense in the industrial area where competition is of great importance. The largest share in energy consumption belongs to the industrial zone with 25% (Cengiz & Mamiş, 2015). It aims to reduce energy consumption by effectively using the energy per unit service or product without causing a decrease in energy efficiency, production amount and production quality in the industry (Uylukçuoğlu, 2019). In addition to the energy to be used in the production processes, the efficient use of the energy required for the heating, cooling, ventilation and lighting needs of the production halls will also contribute to the country's economy and the protection of the environment. Paying attention to the energy consumption amounts of the industries that make up the industrial zone, giving importance to the efficient use of the energy required for the heating, cooling, ventilation and lighting needs of the production, as well as the energy to be used in the production processes, will provide the sectors with an advantage in terms of cost and competition.

One of the sectors where energy is used intensively is the automotive sector. The automotive industry is one of the sectors of use of the entire economy of the industrialized region. This is because of its very close relationship with other sectors of the economy. It has impressive properties in basic industries such as the automotive industry, iron and steel and other light metals, petrochemicals, glass and rubber (Cengiz & Mamiş, 2015). All kinds of motor vehicles required by the tourism, infrastructure, construction, transportation and agriculture sectors are provided with automotive sector products. For this reason, changes in the sector closely affect the entire economy. The energy usage rate of such an important sector should not be ignored. All elements that involve energy use within the scope of the automotive industry, especially the press, welding, paint and assembly departments, which are among the production processes, are of great importance in terms of providing energy efficiency (Cengiz & Mamiş, 2015). Considering that competition is indispensable in the automotive sector; Energy efficiency studies to be carried out in the automotive industry will contribute to revitalizing both their own and the country's economy by putting automotive companies ahead. In this respect, energy efficiency has a strategic importance (Uylukçuoğlu, 2019). The main objective of the study is to determine the most important and least important criteria by determining the criteria aimed at preventing energy consumption in the automotive industry and increasing energy efficiency. The most important motivation source of the study is to determine which criteria should be taken into account in order to provide energy efficiency for the country and the sectors that want to contribute to their own economy. In the literature, there are studies to ensure energy efficiency in the automotive industry, but there are not many studies on criterion weighting in the automotive industry. In the study, the parameters required for automotive energy efficiency were determined by literature research and criteria weighting was made with the Analytical Hierarchy Process (AHP) and BEST&WORST, which are the next multi-criteria decision-making methods. The criteria rankings obtained from the two methods were compared. Although the results of the literature research have the feature of widespread use in foreign sources, the use of automotive industry has not been encountered much. In this respect, the study will contribute to the literature. At the same time, the result of the study will guide companies that want to provide energy efficiency and investors who aim to make a new investment in terms of which criteria they should focus on.

Literature Review

While conducting the literature research, research was carried out in the fields of energy efficiency, AHP, Best & Worst, efficiency index and automotive sector (Table 1).

ISO 50001 referred to the energy management system. It aims to provide efficient energy and cost savings with waste energy management system applications in the textile industry. He concluded that energy saving practices can be applied not only in the textile industry but also in many industries (Yacout et al., 2014). Asoğlu and Eren (2018) carried out cargo selection in their study. Today, companies' cargo selection is important in terms of cost and service. In this study, criteria that the company attaches importance to in the selection of cargo were determined by the experts. The importance levels of the criteria were determined by the AHP method. TOPSIS and PROMETHEE methods were used to compare Koca and Akçakaya (2021). In their study, with the development of technology, not only computers and smart phones, but also the clothes and accessories we use can turn into smart devices. Performing user data exchange with smaller devices by mounting on the user's body provides convenience in many ways. For this reason, the factors to be considered in the design of wearable technological products should be examined. The aim of this study is to evaluate the factors that are effective in the design of wearable technological products with the Best-Worst method, which is one of the subjective criteria weighting methods. For this reason, evaluations were made by a team of five experts in the design of wearable technological products. Rezaei (2015) proposed BWM to solve multi-criteria decision making problems in her study. It has benefited from numerical examples such as the mobile phone selection problem. It has been interpreted that BWM consistency analysis yields better results than AHP (Rezaei, 2015). Rezaei (2016) In the study, interval analysis was recommended for many optimum analyzes. How the criteria can be weighed and ranked is shown in this study. A linear model has been proposed for BWM (Rezaei, 2016). Moslem et al. (2020) In the article, the relationship between driver behavior factors and road safety was examined by AHP and BWM (Moslem et al., 2020).

Table 1: *Importance Scale Proposed by Saaty is Used for This Comparison (Adıgüzel, 2009)*

Importance Degree	Definition
1	The two criteria contribute equally to the goal
3	One criterion contributes slightly more to the goal than the other
5	One criterion contributes considerably more to the goal than the other.
7	One criterion contributes more to the goal than the other
9	One criterion contributes significantly more to the goal than the other
2,4,6,8	Intermediate values (values between two consecutive judgments to be used when compromise is needed)

Methodology

The automotive industry is one of the sectors with a high energy usage rate. Energy efficiency studies to be carried out in the automotive industry will also provide financial returns to the company. In this study, energy efficiency criteria will be determined and ranking will be made. od, which is one of the Multi-Criteria Decision Making method that emerged in the literature, and the Best & Worst method, which is a Multi-Criteria Decision Making method, which has just been introduced to the literature. People need to make decisions at every moment of life. Multiple criteria should be considered when making a decision (Koca and Akçakaya, 2021). This complicates the decision-making process. MCDM is a method for determining and choosing one among a series of alternatives and criteria. The decision maker aims to select the most appropriate criterion/alternative by using MCDM methods.

AHP Method

AHP was proposed by Myers and Alpert in 1968 and was developed by Professor Thomas Lorie Saaty in 1977 and used in multi-criteria decision-making problems (Yaralioğlu, 2001). The AHP method, which has been used for years and is frequently encountered in the literature, is used for criterion weighting (Akif et al., 2021). With the binary comparison technique, it is aimed to reach the best criterion and alternative by comparing both alternatives and criteria. One of the most important features of the AHP method is the possibility of decision makers to evaluate the situations both qualitatively and quantitatively. One of the most important features of the AHP method is the possibility of decision makers to evaluate the situations both qualitatively and quantitatively. In AHP, the problem is shown hierarchically. Figure 1. shows three levels of hierarchy (Ömürbek et al., 2013).

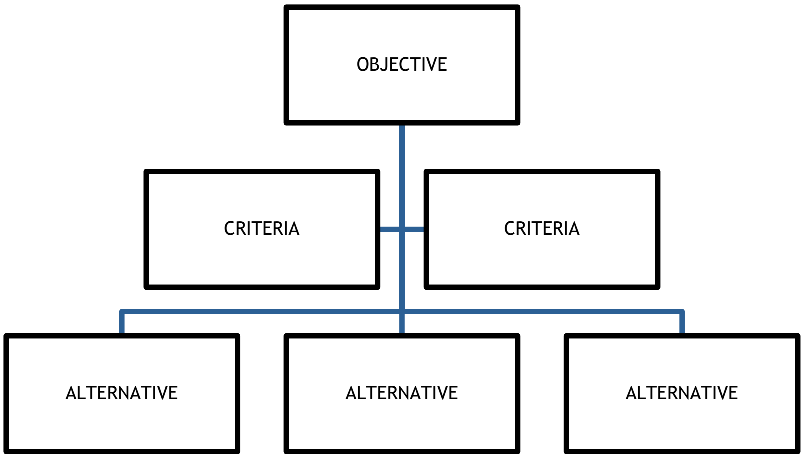

Figure 1. *Analytical Hierarchy Table*

The application steps of the method are as follows:

First, alternatives and criteria are determined in the decision problem. In order to determine the importance of the criteria among themselves, a pairwise comparison matrix is created. Importance Scale Proposed by Saaty in Table 2. is used for determining a pairwise comparison matrix.

Table 2. *Randomness Index Table (Akif et al., 2021)*

Number of Criteria (n)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Randomness Index (RI)	0	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49

If the number of criteria is "n"; As in equation (1), a square matrix of size "Nxn" with diagonal components of "1" is obtained (Akif et al., 2021).

$$A=\begin{bmatrix} 1 & a_{21} & a_{31} & \cdots & a_{n1} \\ 1/a_{21} & 1 & a_{32} & \cdots & a_{n2} \\ 1/a_{31} & 1/a_{32} & 1 & \cdots & a_{n3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1/a_{m1} & 1/a_{m2} & 1/a_{m3} & \cdots & 1 \end{bmatrix} \quad (1)$$

Then the weights of the criteria need to be found. For this, as stated in equation (2), firstly, each element is divided by the sum of all the values in the column and the arithmetic mean (W) of the row elements in the matrix and the criterion weights matrix are formed. criteria (C) elements (Akif et al., 2021).

$$cij = \frac{a_{ij}}{\Sigma_{i=1}^{n} a_{ij}} \rightarrow w_i = \frac{\Sigma_{i=1}^{n} c_{ij}}{n} \rightarrow w = \begin{bmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{bmatrix} \quad (2)$$

The consistency of the study should be examined. The consistency rate of the decision makers will ensure the accuracy of the answer (Adıgüzel, 2009). When calculating the consistency ratio, the comparison matrix (A) is multiplied by the priority matrix (W) to get the column vector (D). By dividing each element of the column vector D by the reciprocal elements in the column vector w, the elements whose arithmetic mean results give the base value of the comparison, as can be seen in equation (3) (Akif et al., 2021).

$$A*W=D=\begin{bmatrix} d_{11} & d_{12} & d_{13} & \cdots & d_{1n} \\ d_{21} & d_{22} & d_{23} & \cdots & d_{2n} \\ d_{31} & d_{32} & d_{33} & \cdots & d_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ d_{n1} & d_{n2} & d_{n3} & \cdots & d_{mn} \end{bmatrix} \rightarrow \lambda$$

$$\frac{\sum_{i=1}^{n} \frac{di}{w_i}}{n} \quad (i = 1, 2, \ldots, n) \quad (3)$$

After the λ value is found, it is necessary to measure the consistency of the study. The randomness index (RI) value is needed for the consistency calculation. The values for this index (n), which depends on the number of criteria, are shown in Table 3.

Table 3: *Consistency Index Table (Koca & Akçakaya, 2021).*

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
CI	0,00	0,44	1,00	1,63	2,30	3,00	3,73	4,47	5,23

In the last step, the consistency ratio (CR) is calculated using the values of λ, n and RI. The operations in equation (4), (5) and (6) are done. The upper limit for CR is counted as 0.1. If the value is too high, it is interpreted that there is an error at work or that the decision maker is inconsistent (Akif et al., 2021). In this case, Saaty and Vargas advised decision makers to reconsider their decisions (Dündar & Ecer, 2008).

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \tag{4}$$

$$\lambda_{max} = \frac{\Sigma_{i=1}^{n} E_i}{n} \tag{5}$$

$$CR = \frac{CI}{RI} \tag{6}$$

Finally, Mx1 sized matrices are created for each criterion, and when all are written side by side, an MxN sized decision matrix is created. By multiplying the resulting decision matrix with the criteria weights, the result vector (L) is obtained in Equation (7), which shows the weight of each item (Akif et al., 2021).

$$L= \begin{bmatrix} k_{11} & k_{12} & k_{13} & \dots & k_{1n} \\ k_{21} & k_{22} & k_{23} & \dots & k_{2n} \\ k_{31} & k_{32} & k_{33} & \dots & k_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ k_{m1} & k_{m2} & k_{m3} & \dots & k_{mn} \end{bmatrix} \times \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} l_1 \\ l_2 \\ l_3 \\ \vdots \\ l_m \end{bmatrix} \tag{7}$$

Best & Worst Method

The best & worst method is a method that has just taken its place in the literature. Best & Worst was preferred to determine the most important criterion for the energy efficiency strategy in the automotive industry, which is the aim of the study (Çakır&Melih, 2019). The reason why the Best & Worst method is preferred is that it provides the opportunity to evaluate the criteria according to the best and worst criteria, not each other. At the same time, in contrast to other subjective methods in which pairwise comparisons are made, BWM reduces the computation time by making fewer paired comparisons (Koca & Akçakaya, 2021). The Best & Worst method is one of the multi-criteria decision-making methods used in criterion weighting based on comparing the best criterion with other criteria and other criteria with the worst criterion. (2n-3) pairwise comparisons are performed, with n criteria (Çakır&Melih, 2019). Having the number of criteria in this way provides ease of use compared to AHP (Sadjadi & Karimi (2018). This method was introduced to the MCDM literature (Rezaei, 2015). Application steps of the method: First, criteria are determined. The best (most desirable, most important) criterion and the Worst (least desirable, least important) criterion are determined. It is based on the opinion of the decision maker and the values of the criteria are not taken into account in this step, so no comparison is made (Bircan & Demir, 2020).

It is passed to the stage of determining the priority of the best criterion. All other criteria (1: equally important, 3: moderately more important, 5: very important, 7: much more important, 9: most important) (Koca & Akçakaya, 2021).

$AB= (aB1, aB2, \dots, aBn)$;

Each aBj in the vector AB represents the preference of the best criterion B according to the j criterion.

Also, aBB= 1 means that the most important criterion is compared with it.

By using a value between 1 and 9, the stage of determining the preference rates of all other criteria according to the worst selected criterion is started. The value of the other criteria according to the worst criterion is determined by the decision maker. Using a number from 1 to 9, the worst of the vector should be as follows (Koca & Akçakaya, 2021).

Aw= $(a1W, a2W, a3W, \dots, anW)\ T$, aWW = 1 means that the worst criterion

is compared with it. Weight $(W1*, 2*, W3*, \dots, Wn*)$ should be determined for each criterion (Koca & Akçakaya, 2021). In order to obtain the maximum absolute differences, the optimal weights of the criteria must be reached. The optimal weight is made by operations with equations (8), (9) and (10), respectively.

$$WB/Wj=aBj \tag{8}$$

$$Wj/WW=aj/W \tag{9}$$

$$WB\ /Wj \text{ ve } Wj\ /WW \tag{10}$$

J value should be found

$$\{|wB\text{-}aBjwj|,|wj\text{-}ajwww|\} \tag{11}$$

Here the maximum absolute differences are minimized. Therefore, it has been converted to the min - max model below.

$$minmaxj\{|wB\text{-}aBjwj|,|wj\text{-}ajwww|\} \tag{12}$$

$$\Sigma_j w_j = 1 \tag{13}$$

$$w_j \geq 0 \tag{14}$$

$$min\xi^L$$

$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi \tag{15}$$

$$\left|\frac{W_j}{W_W} - a_{jw}\right| \leq \xi \tag{16}$$

$$\Sigma_j w_j = 1 \tag{17}$$

$$w_j \geq 0 \tag{18}$$

After the operations in equations (15), (16), (17) and (18), the consistency of the final evaluations should be tested. The consistency ratio is obtained by using the consistency index values in Table 4. (Koca & Akçakaya, 2021).

Table 4. *Row Totals Table*

Manufacturing Criterion (Geo)	Resource Sustainability	Supplementary Sources	Production Capacity	TOTAL
Resource Sustainability	0,661	0,792	0,567	2,021
Supplementary Sources	0,220 (D)	0,264	0,314	0,798
Production Capacity	0,086	0,062	0,074	0,224

$$\text{Consistency Ratio} = \frac{\xi}{\text{Consistency}} \textbf{Index Value} \tag{19}$$

When the result obtained in Equation (19) is evaluated, it is concluded that as the consistency ratio approaches 0, the evaluations of the decision makers are more consistent, and as it approaches 1, it is less consistent (Koca & Akçakaya, 2021).

Application

AHP Application

First, the criteria are determined. At this stage, a literature search on the energy efficiency strategy in the automotive industry was conducted and the criteria were determined. Energy, efficiency, strategy and automotive industry are the filters used when searching literature.

In AHP, it is necessary to create a pairwise comparison matrix in order to determine the importance levels of the criteria among themselves (Adıgüzel, 2009). In order to determine their importance, the opinions of three experts working in three different factories in the automotive industry were used. The experts used the Table 2. Saaty Significance Scale for comparison. The process was started by taking the geometric mean of the evaluations of the three experts (A). It is formed by summing the column values after the geometric mean is calculated. Then each element is divided by the sum of the values in the column. The criterion weight (W) is calculated by taking the arithmetic average of the new criterion values (C) obtained by dividing each element by the sum of the values in the column. As a result, normalized tables are obtained.

Each value in the table formed by the geometric averages is multiplied by the criterion weight value of that row, and new table values are obtained in Table 5. For example; 0.220 (D) = 0.333 (A) * 0.661 (W). Then the row values are summed to get the TOTAL values.

Table 5. *Total and Criteria Weight Table*

Total	Criteria Weight	Total / Criteria Weight
2,021	0,661	3,055
0,798	0,264	3,024
0,224	0,074	3,005

After the λ value is found, it is necessary to measure the consistency of the study. Table 2. randomness index (RI) value is needed for consistency calculation.

To find the λ value, the arithmetic mean of the sum/criteria table is calculated. Finally, Equation (20) CI and Table 2. RI values are needed for consistency calculation.

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \tag{20}$$

To find the λ value, calculate the arithmetic mean of the total / criterion Table 6.

Table 6. *ξ (ksi) Values*

Decision Makers	W Source Sustainability	W Substantial Source	W Production Capacity	ξ	Consistency Ratio (TO)	Consistency index (TE)
KV1	0,740	0,090	0,168	0,104	0,104	1
KV2	0,261	0,076	0,661	0,123	0,123	
KV3	0,736	0,186	0,076	0,197	0,198	

The result of the calculation is λ = 3.028.

CI = (3,028– 3) / (3-1) = 0.014

It is seen that the RI value for n = 3 (Table 2) is 0.58 by looking at the random index table. Finally, CI / RI is performed and the consistency calculation is calculated to find CI / RI = 0.024. Since 0.02 < 0.10, it can be interpreted that the values are consistent. The overall rankings are obtained by sorting the final weights from largest to smallest. In Table 8, the criteria weights of the sub-criteria and the final weights used in the ranking are shown.

Best & Worst Application

First, the criteria are determined. Then the Best (most desired, most important) criterion and the Worst (least desired, least important) criterion are determined. Experts first determine the most important and least important criteria by evaluating the sub-criteria of each main criterion within themselves. After determining the best criterion in practice, the best criterion; The preference rate according to other criteria is determined by the experts. Table 2. The importance scale of 1-9 was taken into account for determination. After determining the best criterion in practice, the preference rate of the best criterion according to other criteria is determined by the experts. After determining the least important criteria, the preference rate of other criteria according to the least important criteria is determined by the experts. finally, the consistency of the assessments should be tested. The consistency ratio is obtained by using the consistency index values (Koca & Akçakaya, 2021). ξ (ksi) Values should be determined as shown in the Table 7.

Table 7. *Rankings and weights are obtained.*

Subcriteria	Global Weights of Best & Worst Sub-Criteria	Ranking	Sub-Criteria	Final Weights of AHP Sub-Criteria	Ranking
F11: RATIONALIZM	0,03	12	RATIONALIZM	0,125082	2
F12: TECHNOLOGIC MATURITY	0,085	3	TECHNOLOGIC MATURITY	0,073303	5
F13: FOREIGN DEPENDENCY	0,099	2	FOREIGN DEPENDENCY	0,048902	7
F14: ADOPTATION MODIFICATION	0,068	5	ADOPTATION MODIFICATION	0,016633	16
F21: DEPRECIATION	0,062	6	DEPRECIATION	0,127543	1
F22: INCENTIVES	0,109	1	INCENTIVES	0,047282	8
F23: SUPPLY DEMAND	0,012	24	SUPPLY DEMAND	0,016381	17
F31: EMPLOYMENT	0,017	19	EMPLOYMENT	0,111081	3
F32: SOCIAL ADDED VALUE	0,006	29	SOCIAL ADDE VALUE	0,034469	10
F33: COUNTRY DEVELOPMENT	0,037	9	COUNTRY DEVELOPMENT	0,013042	20
F41: GEOGRAPHICAL MATURITY	0,038	8	GEOGRAPHICAL MATURITY	0,076004	4
F42: AREA USAGE	0,023	14	AREA USAGE	0,023997	12
F43: ENVIRONMENTAL EFFECTS	0,007	28	ENVIRONMENTAL EFFECTS	0,011144	21
F51: RESOURCE SUSTAINABILITY	0,069	4	RESOURCE SUSTAINABILITY	0,05414	6
F52: SUPPLEMENTARY SOURCE	0,014	23	SUPPLEMENTARY SOURCE	0,02162	13
F53: PRODUCTION CAPACITY	0,036	10	PRODUCTION CAPACITY	0,006102	27
F61: ARMATURE SELECTION	0,004	32	ARMATURE SELECTION	0,041747	9
F62: LIGHTNING LEVEL	0,021	16	LIGHTNING LEVEL	0,021465	14
F63: LIGHTNING SOURCES	0,03	13	LIGHTNING SOURCES	0,008689	23
F71:MAINTENANCE	0,011	25	MAINTENANCE	0,026468	11
F72: LEAKAGE PREVENTION	0,023	15	LEAKAGE PREVENTION	0,013808	19
F73:ISOLATION	0,004	31	ISOLATION	0,007569	24
F74: REPLACEMENT	0,018	18	REPLACEMENT	0,005745	28
F75: MACHINE SELECTION	0,02	17	MACHINE SELECTION	0,002814	31
F81: DECREASING ENERGY DEMAND	0,014	22	DECREASING ENERGY DEMAND	0,014546	18
F82: COMPRESSOR USAGE SAVING	0,014	21	COMPRESSOR USAGE SAVING	0,009046	22
F83: ELECTRIC MOTOR USAGE SAVING	0,014	20	ELECTRIC MOTOR USAGE SAVING	0,007315	25
F84: PUMP USAGE SAVING	0,008	27	PUMP USAGE SAVING	0,004548	29
F85: ENERGY CONSUMPTION MEASUREMENT	0,005	30	ENERGY CONSUMPTION MEASUREMENT	0,002866	30
F86: DATA GATHERING	0,003	33	DATA GATHERING	0,001324	33
F91:WASTE RECYCLING	0,04	7	WASTE RECYCLING	0,016825	15
F92: CO_2 EMISSION	0,008	26	CO_2 EMISSION	0,006765	26
F93: ENVIRONMENTAL DAMAGE	0,033	11	ENVIRONMENTAL DAMAGE	0,001734	32

However, the criteria rankings should be determined according to the global weight. To calculate the global weights, the local weight of the main criterion and the local weights of the sub-criteria belonging to the main criterion are multiplied.

The consistency index value for n= 3 with the one shown in Equation (21) is 1.00. Based on this situation, the consistency ratio was calculated as 0.197. It is concluded that as the consistency ratio approaches 0, the evaluations of the decision makers are more consistent, and as it approaches 1, it is less consistent. If the consistency ratio is within the specified limits, it means that the criterion weight of each criterion can be used (Koca & Akçakaya, 2021).

In the last step; As a result of the evaluation of three expert opinions, the average of the criterion weights calculated for each sub-criterion was taken and the local weights of the criteria. Then, the consistency ratio calculation is made via Excel. For the consistency ratio, it is necessary to benefit from the consistency index values that vary according to the number of n.

$$TO = \xi / TE \qquad (21)$$

The consistency index value for n= 3 with the one shown in Equation (21) is 1.00. Based on this situation, the consistency ratio was calculated as 0.197. It is consistent that as the consistency ratio approaches 0, the evaluations of the decision makers are more, and as it approaches 1, it is less consistent. If the consistency ratio is within the specified limits, it means that the criterion weight of each criterion can be used (Koca & Akçakaya, 2021).

As a result of the evaluation of three expert opinions, the average estimation criteria of the criteria weights calculated for each sub-criterion were obtained. However, the criteria rankings should be determined according to the global weight. For the global weight calculation, the local weight of the main criterion and the local weights of the sub-criteria belonging to the main criterion are multiplied (Table 7).

Discussion

In the study, criterion weights were determined by AHP and BEST WORST methods. The main goal of the study is to determine the most important and least important criteria suitable for the energy efficiency strategy in the automotive industry. In this context, the most important and least important criteria were determined among nine main criteria and thirty-three sub-criteria. When we look at the literature, while criterion weighting processes with AHP are frequently encountered; In the automotive industry, criterion weighting with AHP has not been found much. In addition, the BEST&WORST method is a criterion weighting method that has been newly introduced to the literature. In this study, comparison was made by applying AHP and BEST&WORST methods. The fact that the criterion weighting method is not common in the automotive industry highlights the originality of the study. Comparison of AHP and BEST&WORST methods will contribute to the literature.

Conclusion and Recommendations

In the 21st century, human life has become more comfortable with the developing technology and as a result, the demand for energy has increased in parallel. It is important that Turkey, which is foreign-dependent in energy, meets this consumption by using energy economically in line with the principle of energy efficiency. As a way to get rid of foreign dependency in energy, it can be suggested to increase the number of existing energy sources and energy production. The more important and long-term one is; raising awareness of consumers about the scarcity and foreign dependency, raising awareness for consuming the scarce existing energy efficiently by avoiding waste. Reducing energy intensity in the industrial sector depends on improvements in energy efficiency and structural changes (Doğan & Yılankırkan, 2015).

In our country, the automotive sector is among the leading sectors in the manufacturing industry when its share in production and its economic contribution are evaluated. The domestic values created by the sector (the use of domestic inputs and the total value added) have a very important place in the economy. Its share in the total production of the manufacturing industry is above the manufacturing industry sector average (Directorate, 2020). The effect of the automotive industry on other sectors causes it to affect the economy of the country it is located in. For this reason, a change in the automotive industry will affect all sectors.

The issue of energy efficiency strategy has an important share in the automotive sector, as it does in all sectors. Thanks to the savings in the field of energy, not only the automotive sector will be affected, but also the country in which it is located. Considering this situation, the study aimed to integrate the automotive industry, which has a large share in the industry, and the energy issue, which is one of the problems of our age. Along with this target, the necessary criteria to provide an energy efficiency strategy in the automotive industry were determined by literature reviews and resolved with multi-criteria decision making methods. AHP, which is one of the criterion weighting methods, and BEST & WORST were preferred in the study. While the AHP method is the criterion weighting method frequently used in the literature; The BEST&WORST method is a method that has just taken its place in the literature. The reason why both methods are preferred is that the study has a comparative purpose. AHP and BEST & WORST joint work is available in the literature, but it is not very common in the automotive industry. This situation reveals the originality of the study.

The study has 9 main criteria and 33 sub-criteria as an application. In the study, AHP and BEST&WORST, which are among the MCDM methods, were preferred for criterion weighting purposes. The automotive industry has been chosen due to its connection with all sectors and its energy consumption rate. The solution was started by evaluating the criteria by three decision makers who are experts in the automotive sector. AHP and BEST&WORST solution steps were performed separately to reveal the ranking for both methods.

As a result of the solution stages of the AHP method, the depreciation sub-criteria of the economy main criterion was determined as the most important criterion with a weight of 0.127; As a result of the BEST & WORST method solution stages, the incentives sub-criterion of the economy main criterion was determined as the most important criterion with a weight of 0.109 criteria. It is recommended that companies work on that field by considering important criteria. Incentive opportunities can be explored by companies.

As a result of the solution stages of the AHP method, the data collection sub-criterion of the main criterion of energy scanning was determined as the least important criterion with a weight of 0.001; As a result of the BEST & WORST method solution stages, the data collection sub-criteria of the main criterion of energy scanning was determined as the least important criterion with a weight of 0.003 criteria. Firms are advised to reduce their work on data collection criteria.

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Yazar Katkıları: İDA; Tasarım- İDA, İNC; Denetim - İDA; Kaynaklar - İNC; Malzemeler - İNC; Veri Toplama ve/veya İşleme - İNC; Analiz ve/veya Yorum – İDA, İNC; Literatür Taraması - İNC; Yazma – İNC, İDA; Eleştirel İnceleme - İDA
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Extended Abstract

Enerji, ülkelerin sosyal, ekonomik, teknolojik ve uluslararası alanda rekabetçi piyasada var olabilmelerinin en önemli unsurlarından biridir. Gelişen teknoloji ve artan enerji tüketimi ile birlikte enerji verimliliğinin önemi ön plana çıkmaktadır. Bu kapsamda çalışmada enerjinin yoğun olarak kullanıldığı sanayi sektörünün önemli bir parçası olan otomotiv sektörü tercih edilmiştir. Otomotiv sektörünün enerji ihtiyacının yanı sıra diğer sektörlerle etkileşimi de tercih sebebidir. Çalışmada, Çok Kriterli Karar Verme yöntemleri kullanılarak Otomotiv Sektöründe Enerji Verimliliği Stratejisi kriter ağırlıkları hesaplanmıştır. Literatür araştırması sonucunda dokuz ana kriter ve otuz üç alt kriter belirlenmiştir. Otomotiv sektöründe Enerji Verimliliği Stratejisinin kriter ağırlıkları, literatürde sıklıkla kullanılan AHP ve literatüre yeni giren BEST & WORST ile ayrı ayrı analiz edilmiştir. İki yöntemin çözüm sonuçlarının karşılaştırılması çalışmanın amacıdır. Çalışma uygulama olarak 9 ana kritere ve 33 alt kritere sahiptir. Çalışmada ÇKKV yöntemlerinden AHP ve BEST&WORST kriter ağırlıklandırma amacı ile tercih edilmiştir. Tüm sektörler ile bağlantısı olması ve enerji tüketim oranı nedeniyle otomotiv endüstrisi seçilmiştir. Otomotiv sektöründe uzman olan üç karar verici tarafından kriterler değerlendirilerek çözüme başlanmıştır. AHP ve BEST&WORST çözüm adımları ayrı ayrı gerçekleştirilerek iki yöntem için de sıralama ortaya çıkarılmıştır. AHP yöntemi çözüm aşamaları sonucunda ekonomi ana kriterine ait amortisman alt kriteri 0,127 kriter ağırlığı ile en önemli kriter olarak belirlenirken; BEST& WORST yöntemi çözüm aşamaları sonucunda ekonomi ana kriterine ait teşvikler alt kriteri 0,109 kriter ağırlığı ile en önemli kriter olarak belirlenmiştir. Firmalara, önemli kriterleri dikkate alarak o alan üzerine çalışmalar yapması tavsiye edilir. Teşvik imkanları firmalar tarafından araştırılabilir. AHP yöntemi çözüm aşamaları sonucunda enerji taraması ana kriterine ait veri toplanması alt kriteri 0,001 kriter ağırlığı ile en az önemli kriter olarak belirlenirken; BEST& WORST yöntemi çözüm aşamaları sonucunda enerji taraması ana kriterine ait veri toplanması alt kriteri 0,003 kriter ağırlığı ile en az önemli kriter olarak belirlenmiştir. Firmalara veri toplanması kriteri üzerine çalışmalarını azaltmaları tavsiye edilir. Elde edilen sonuçlar ışığında AHP ile BEST & WORST yöntemlerinin birbirine yakın sonuçlar verdiği tespit edilmiştir.