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Araştırma Makalesi / Research Article

Determination of Supplier Selection For 1-Phase Induction Motor Used in Hoods by Fuzzy TOPSIS Method

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Abstract

Hoods are the most important devices used in our kitchens that contribute to the ventilation of the environment. 95% of the electric motors used in hoods are single-phase asynchronous motors. There are many domestic and foreign electric motor manufacturers producing for the hood industry. Supplier selection in companies producing hoods is vital and critical for sustainable production. It is extremely important to make the right decision in the purchasing process of the supplied products. While the decisions taken can sometimes be clearly separated from each other, sometimes they can be intertwined and interconnected. Multi criteria decision making techniques are used when making decisions that cannot be clearly separated or explained with numerical data. The aim of this study was to determine the most suitable Supplier for the built-in appliance company operating in the Turkiye/Amasya region by using fuzzyTOPSIS method in the supply of 1-phase asynchronous motors used in hoods. After 5 experts working in the company were determined as decision makers, 4 criteria were determined: quality, system capacity, finance and logistics performance. The best supplier selection among 6 different suppliers was made using this method. For the first time, a solution proposal was presented with the fuzzyTOPSIS technique for the 1-phase induction motor supplier selection and a contribution was made to the literature.
Keywords: Topsis, Fuzzy, Hood, Induction motor.

Davlumbazlarda Kullanılan 1 fazlı Asenkron Motorun Tedarikçi Seçiminin Bulanık TOPSIS Yöntemiyle Belirlenmesi

Öz

Davlumbazlar mutfaklarımızda kullanılan ve ortamın havalandırılmasına katkı sağlayan en önemli cihazlardır. Davlumbazlarda kullanılan elektrik motorlarının %95'ini 1 fazlı asenkron motorlar oluşturmaktadır. Davlumbaz sektörüne yönelik üretim yapan yerli ve yabancı pek çok elektrik motoru üreticisi bulunmaktadır. Davlumbaz üreten firmalarda tedarikçi seçimi sürdürülebilir üretim için hayati ve kritik öneme sahiptir. Tedarik edilen ürünlerin satın alma sürecinde doğru karar vermek son derece önemlidir. Alınan kararlar bazen birbirinden net bir şekilde ayrılırken bazen de iç içe ve birbiriyle bağlantılı olmaktadır. Açıkça ayrıştırılamayan veya sayısal verilerle açıklanamayan kararların alınmasında çok kriterli karar verme teknikleri kullanılmaktadır. Bu çalışmada, davlumbazlarda kullanılan 1 fazlı asenkron motorların tedariğinde bulanık TOPSIS yöntemi kullanılarak Türkiye/Amasya bölgesinde faaliyet gösteren ankastre firması için en uygun tedarikçinin belirlenmesi amaçlandı. Şirkette çalışan 5 uzmanın, karar verici olarak belirlenmesinin ardından kalite, sistem kapasitesi, finans ve sevkiyat performansı olmak üzere 4 kriter belirlendi. 6 farklı tedarikçi içinden en uygun seçim gerçekleştirilmiştir. 1 fazlı asenkron motorun tedarikçi seçimi için ilk defa Bulanık TOPSIS yöntemi ile çözüm önerisi sunularak literatüre katkı sağlanmıştır.

Anahtar Kelimeler: Topsis, Bulanık, Davlumbaz, Asenkron motor.

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1. Introduction

Due to factors such as rising quality expectations, financial difficulties, shrinking competitiveness and similar factors, supplier selection has become an even more important issue for manufacturers in recent years. Manufacturers must consider profitability, growth, stability and similar factors when determining their suppliers. The decision-making process can be extremely challenging for companies engaged in supply-based production. Because some criteria and comments may cause uncertainty in the procurement process. These uncertainties need to be eliminated to ensure the selection of the best possible supplier. Many methods are suggested in the literature to eliminate uncertainties. One of these methods is the FuzzyTOPSIS method (Tekez, 2016). The most important component of the hood is the electric motor. There are many uncertainties in electric motor supply, such as quality, system capacity, financing and logistics performance, and this causes problems in making the right decision. Fuzzy TOPSIS algorithm is used in many similar supplier selection studies. The multi criteria decision making method has been widely used since the 1980s. (Hwang, 1981). This algorithm can be used to make powerful decisions in uncertain environments. The aim of the algorithm is to select the best alternative which is closest to the (FPIS) fuzzy positive ideal solution and furthest from the (FNIS) fuzzy negative ideal solution. Therefore, closeness coefficients vary between 0 and 1. While ranking the alternatives, closeness coefficients are taken into consideration. The closer result is to 1, the higher the candidate's probability of being selected (Chen, 2000). In another study, an 8-year literature review was conducted, and it was revealed that cost, delivery and quality were the most important issue in supplier selection (Ho et al., 2010). In another study, the necessity of a multi-stage and multifaceted evaluation was emphasized and the importance of taking past performance into account in supplier selection was emphasized (Mamavi et al., 2015). Another study proposed the fuzzy TOPSIS method for flow control in a production system (Rudnik et al., 2017). Using sequential fuzzy numbers, uncertain and imprecise data related to flow control parameters such as queue lengths, waiting times and processing times were created. Criteria such as minimizing total cycle time, maximizing throughput, and minimizing the number of backlogs were taken into account. Another study used this method to evaluate reverse logistics (Han et al., 2018). In another study, a method that takes into account multiple sustainability criteria using environmental, economic and social factors was proposed and heuristic fuzzy sets were used to account for uncertainty (Memari et al., 2019). In another study, a new fuzzy TOPSIS method was proposed to solve MCDM problems involving uncertainty. This method is developed using emergent interval valued global fuzzy sets (EIVSFS) (Gündoğdu et al., 2019). In another research, the fuzzy TOPSIS method was applied in a case study on supplier selection in the automotive industry (Aydemir et al., 2020). In another study, a case study on selecting a new milk supplier was conducted to evaluate the proposed supplier selection process. The results of the research show that the proposed process is an effective method to select the most suitable supplier according to criteria important in the dairy industry (Cakar et al., 2021). In another research, a study is presented on the introduction of renewable energy alternatives in Turkey using the intuitive fuzzy TOPSIS method. The study aims to provide a comprehensive and effective decision-making tool for policy makers, investors and other stakeholders in the involved sectors (Bilgili et al., 2022). In another study, a study of the ideal software development process was put forward. An effective decision making tool is presented to software development managers and other stakeholders involved in the software development process (Govil et al., 2022). Fuzzy TOPSIS appears as a popular choice for supplier selection in many studies as it is a flexible and effective method that can address uncertainty, ambiguity ext.

In the second part of the article, the techniques used are explained and in the third part, the application of the fuzzy TOPSIS algorithm to the 1-phase electric motor supplier selection problem for company is included. The findings and results obtained are evaluated in the last section.

2. Materials and Methods

In the literature, the fuzzy TOPSIS decision making technique is used in this study for situations where uncertainty exists. An attempt was made to contribute to the literature by using this method for supplier selection of single-phase asynchronous motors for hoods. Supplier selection is vital to the success of a business. Along with the performance and safety standards of the single-phase asynchronous motor used in hoods, parameters such as quality, system capacity, finance and shipping performance affect the decision-making process. In this study, the relevant method was used for the first time in the selection of single-phase asynchronous motor suppliers for hoods. The application of the relevant method to special problems is explained step by step. This method uses fuzzy sets to represent ambiguity and uncertainty. Triangular fuzzy numbers were used to represent fuzzy sets. The vertex method was used to determine the distances of an alternative from ideal positive and ideal negative solutions. Closeness coefficients are used to determine the distances of alternatives to the ideal solution. In this section, the application of fuzzy TOPSIS is explained in detail by touching on the basic principles of fuzzy logic.

2.1. Fuzzy Logic

Fuzzy set theory is used to solve problems involving uncertain and imprecise data (Zadeh, 1965). Sets with fuzzy boundaries and fuzzy membership degrees are called fuzzy sets. Membership functions that show the degree of belonging to the elements of a fuzzy set are defined using the proximity approach. Triangular membership functions are the most commonly used type of this approach. Fuzzy sets are used to mathematically represent uncertain or ambiguous situations. (Zimmerman, 1997). Thanks to the modeling feature of uncertainties, it is facilitated to transform qualitative expressions into quantitative expressions (Sun, 2010). In studies in the literature on fuzzy sets, triangular membership functions are widely used due to their ease of calculation. Figure 1 shows triangular membership function defined as $\tilde{A} = (a, b, c)$ and a triangular fuzzy set element. The membership of $\tilde{A}$ is determined using $\mu A : x \rightarrow [0,1]$. Membership functions have membership degrees between 0 and 1, which is the basis of fuzzy set theory (Bozdağ et al., 2003).

$$\mu(x) = \left\{ \begin{array}{c} 0,\ x \leq a \\ \frac{x-a}{b-a},\ a \leq x \leq b, \\ \frac{c-x}{c-b},\ b \leq x \leq c, \\ 0,\ c \leq x \end{array} \right\}$$

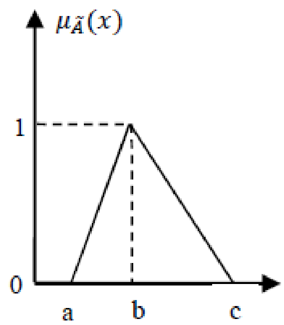

Figure 1. Triangle Membership Function

2.2. Decision Making Method with Fuzzy TOPSIS Analysis

The fuzzy TOPSIS technique is carried out in 10 steps. Table 1 shows the relevant steps. To identify the criteria that are important for supplier selection and to define the expressions that will be used to evaluate the alternatives against each criterion. These expressions should be clear, concise, and unambiguous. The next step is to have EDMs evaluate the alternatives against each criteria. The experts can use their knowledge and experience to provide subjective evaluations, or they can use objective data, such as past performance data, to provide more quantitative evaluations. The experts' assessments are then converted into numerical expressions. This allows the fuzzy TOPSIS technique to be applied in a quantitative manner. The fuzzy decision matrix is a table that shows the evaluations of each alternative against each criterion in the form of triangular fuzzy numbers. Normalization is then applied to the fuzzy decision matrix to ensure that all criteria are of equal importance. It is done by dividing each element of the fuzzy decision matrix by the column total. To create the weighted and normalized fuzzy decision matrix, each element of the normalized fuzzy decision matrix needs to be multiplied by the corresponding criterion weight. In fuzzy decision making problems, FPIS and FNIS, which represent the best and worst states desired for each criterion, are defined respectively. The FPIS is the best possible alternative, and the FNIS is the worst possible alternative. The FPIS and FNIS are determined by selecting the highest and lowest triangular fuzzy numbers from each column of the weighted normalized fuzzy decision matrix, respectively. The distance between each alternative and the FPIS and FNIS is then calculated using the distance between vertex method. This method calculates the distance between a point and a fuzzy number by taking the minimum distance between the point and all vertices of the fuzzy number. The proximity coefficient for each alternative is then calculated. The proximity coefficient is a measure of how close an alternative is to the FPIS and how far it is from the FNIS. The proximity coefficient is calculated by dividing the distance between the alternative and the FNIS by the sum of the distances between the alternative and the FPIS and FNIS. The alternatives are then ranked in decreasing order of their proximity coefficients. The alternative with the highest proximity coefficient is the best alternative. By following the steps outlined above, decision makers can use the fuzzy TOPSIS method that is most likely to meet their needs. In this study, 6 suppliers were evaluated by 5 decision makers according to 4 main subject such as quality, system capacity, finance and shipping performance. A method was developed and applied in decision making and elimination by transmutationing the linguistic evaluations into fuzzy numbers.

Table 1. Fuzzy TOPSIS steps

1	• Determination of expressions to be used in the evaluations
2	• Evaluation by expert decision makers
3	• Converting assesments to numerical expressions
4	• Creating a fuzzy decision matrix
5	• Generating a fuzzy decision matrix with normalized
6	• Generating a fuzzy decision matrix with weighted normalized
7	• Defining (FPIS) and (FNIS)
8	• Distance between vertex method and positive fuzzy numbers
9	• Calculation of proximity coefficients
10	• Determining the rankings of alternatives

2.3. Determination of Expressions to be Used in Evaluations

After carefully selecting a panel of expert decision makers (EDMs) with the requisite knowledge and experience in the field, four critical criteria (Cr_1, Cr_2, Cr_3, and Cr_4) were identified and 6 alternatives (S_1, S_2, S_3, S_4, S_5, and S_6) were shortlisted. To ensure objectivity and transparency in the evaluation process, linguistic expressions for each criterion and their corresponding importance weights were defined in consultation with the EDMs. The linguistic expressions are translated into positive triangular fuzzy numbers to represent ambiguity and uncertainty situations. The EDMs then evaluated the alternative suppliers against each criterion using a numerical scoring system from 0 to 10, with 10 representing the highest possible performance. They also assigned importance weights to each criterion using a numerical scoring system from 0 to 1, with 1 representing the most suitable criterion. The method was used to synthesize the EDMs' evaluations and importance weights to rank the alternative suppliers. It is important to note that the linguistic expressions used in this method may vary depending on the specific application. Overall, the fuzzy TOPSIS method is a powerful and versatile MCDM technique that can be to determine the best alternative among candidates in the presence of uncertainty and ambiguity. By carefully selecting the EDMs, defining the criteria and importance weights, and using appropriate linguistic expressions and this method can be used to make informed and objective decisions.

Table 2. Linguistic expressions in the evaluation of criteria and alternatives

Linguistic expressions used in evaluating alternatives			Linguistic expressions used to determine weight of the criteria		
Too Bad	(TB)	(0,0,1)	Very Low	(VL)	(0,0,0.1)
Bad	(B)	(0,1,3)	Low	(L)	(0,0.1,0.3)
A Little bad	(ALB)	(1,3,5)	A Little Low	(ALL)	(0.1,0.3,0.5)
Middle	(M)	(3,5,7)	Medium	(ME)	(0.3,0.5,0.7)
A LittleGood	(ALG)	(5,7,9)	A Little High	(ALH)	(0.5,0.7,0.9)
Good	(G)	(7,9,10)	High	(H)	(0.7,0.9,1)
Very Good	(VG)	(9,10,10)	Very High	(VH)	(0.9,1,1)

2.4. Evaluation by Expert Decision Makers

Expert decision makers evaluate suppliers according to decision criteria in Table 2. Each of the alternatives defines a different supplier. Quality, system capacity, finance and shipping performance criteria are explained respectively**.**

Quality Criteria: Performance values of sample motors from different suppliers were measured in the laboratory, and their flow-pressure and efficiency were analyzed. According to the efficiency and stability values, the rating was made by considering the suppliers of the 1 phase induction motor with less clutter. While determining the quality score, laboratory measurements were the basis, as well as quality criteria such as packaging, quality systems, and turnaround times in case of problems.

System Capacity Criteria: System capacities were evaluated by expert decision makers, taking into account the annual production amount of suppliers and the completion of orders if requested.

Financial Criteria: Due to the increasing competitiveness, it is desirable for an engine to be both high quality and affordable. The motors were evaluated by the decision makers according to their financially affordable and expensive status.

Shipment Performance Criteria: A timely and complete shipment is a must for the consumer. Considering the delivery performance, it is a prominent criterion that the products arrive, checked and put into production on time.

Table 3. Linguistic evaluations made by decision makers according to the criteria

Supplier	***Quality*** **(Cr_1)**					***System Capacity*** **(Cr_2)**				
	EDM_1	**EDM_2**	**EDM_3**	**EDM_4**	**EDM_5**	**EDM_1**	**EDM_2**	**EDM_3**	**EDM_4**	**EDM_5**
S_1	G	ALG	M	VG	ALG	VG	G	VG	VG	VG
S_2	ALB	ALG	G	VG	G	M	G	G	VG	G
S_3	B	M	M	VB	VB	VG	G	G	VG	ALG
S_4	M	ALG	M	B	G	M	ALG	M	B	G
S_5	ALG	VG	G	G	VG	VG	ALG	G	M	G
S_6	VG	G	VG	VG	VG	ALG	ALG	M	G	G
Supplier	***Financial*** **(Cr_3)**					***Shipment Performance*** **(Cr_4)**				
	EDM_1	**EDM_2**	**EDM_3**	**EDM_4**	**EDM_5**	**EDM_1**	**EDM_2**	**EDM_3**	**EDM_4**	**EDM_5**
S_1	VG	G	G	ALG	VG	ALG	G	G	VG	VG
S_2	M	G	B	M	M	G	G	VG	VG	VG
S_3	VG	VG	G	ALG	VG	VG	G	G	G	M
S_4	G	G	M	B	G	VG	VB	M	B	G
S_5	G	G	B	M	M	G	G	ALG	VG	VG
S_6	G	VB	B	M	B	VG	G	G	VG	VG

To ensure the comprehensiveness and reliability of the fuzzy TOPSIS method, expert decision makers (EDMs) are typically consulted to evaluate the criteria and determine their importance levels. EDMs are individuals with specialized knowledge and experience at hand. Table 4 shows an example of how five EDMs assessed the importance of four main criteria using linguistic expressions. The evaluation matrix consisting of four criteria and five EDMs was then analyzed to for level of each criterion. One common approach for determining the importance level of criteria is to use a weighted average method. In this approach, each EDM's evaluation is assigned a weight, and the weighted averages of the EDMs' evaluations are calculated for each criterion. The weights can be assigned based on the EDMs' level of expertise, experience, or any other relevant criteria. Expert decision makers also evaluate criteria according to linguistic expressions. According to the expressions shown in Table 4, 5 expert decision makers make weight assessments on 4 main criteria. An evaluation matrix consisting of 4 criteria and 5 decision makers was obtained and the importance level about criteria was determined.

Table 4. Criteria by expert decision makers

	EDM_1	**EDM_2**	**EDM_3**	**EDM_4**	**EDM_5**
Cr_1	VH	VH	VH	H	ALH
Cr_2	ME	ME	ALL	L	L
Cr_3	ME	ALH	L	L	ME
Cr_4	H	ALH	H	ME	ME

2.5. Converting Evaluations to Numeric Expressions

Conversion of linguistic ratings into positive fuzzy numbers is usually done using a scale. In the triangular fuzzy number scale, all linguistic expression is linked with a triangular fuzzy number with three parameters: lower limit, possible value and upper limit. The lower bound and upper bound represent the minimum and maximum possible values of the linguistic expression, respectively. The most probable value represents the most probable value of the linguistic expression. In this way, the degrees of weight ratios are converted into numerical expressions with the evaluations made for the criteria.

Table 5. Conversion of criteria evaluations to positive fuzzy numbers

Supplier	***Quality* (Cr_1)**					***System Capacity* (Cr_2)**				
	EDM_1	**EDM_2**	**EDM_3**	**EDM_4**	**EDM_5**	**EDM_1**	**EDM_2**	**EDM_3**	**EDM_4**	**EDM_5**
S_1	(7,9,10)	(5,7,9)	(3,5,7)	(9,10,10)	(5,7,9)	(9,10,10)	(7,9,10)	(9,10,10)	(9,10,10)	(9,10,10)
S_2	(1,3,5)	(5,7,9)	(7,9,10)	(9,10,10)	(7,9,10)	(3,5,7)	(7,9,10)	(7,9,10)	(9,10,10)	(7,9,10)
S_3	(0,1,3)	(3,5,7)	(3,5,7)	(0,0,1)	(0,0,1)	(9,10,10)	(7,9,10)	(7,9,10)	(9,10,10)	(5,7,9)
S_4	(3,5,7)	(5,7,9)	(3,5,7)	(0,1,3)	(7,9,10)	(3,5,7)	(5,7,9)	(3,5,7)	(0,1,3)	(7,9,10)
S_5	(5,7,9)	(9,10,10)	(7,9,10)	(7,9,10)	(9,10,10)	(9,10,10)	(5,7,9)	(7,9,10)	(3,5,7)	(7,9,10)
S_6	(9,10,10)	(7,9,10)	(9,10,10)	(9,10,10)	(9,10,10)	(5,7,9)	(5,7,9)	(3,5,7)	(7,9,10)	(7,9,10)
Supplier	***Financial* (Cr_3)**					***Shipment Performance* (Cr_4)**				
	EDM_1	**EDM_2**	**EDM_3**	**EDM_4**	**EDM_5**	**EDM_1**	**EDM_2**	**EDM_3**	**EDM_4**	**EDM_5**
S_1	(9,10,10)	(7,9,10)	(7,9,10)	(5,7,9)	(9,10,10)	(5,7,9)	(7,9,10)	(7,9,10)	(9,10,10)	(9,10,10)
S_2	(3,5,7)	(7,9,10)	(0,1,3)	(3,5,7)	(3,5,7)	(7,9,10)	(7,9,10)	(9,10,10)	(9,10,10)	(9,10,10)
S_3	(9,10,10)	(9,10,10)	(7,9,10)	(5,7,9)	(9,10,10)	(9,10,10)	(7,9,10)	(7,9,10)	(7,9,10)	(3,5,7)
S_4	(7,9,10)	(7,9,10)	(3,5,7)	(0,1,3)	(7,9,10)	(9,10,10)	(0,0,1)	(3,5,7)	(0,1,3)	(7,9,10)
S_5	(7,9,10)	(7,9,10)	(0,1,3)	(3,5,7)	(3,5,7)	(7,9,10)	(7,9,10)	(5,7,9)	(9,10,10)	(9,10,10)
S_6	(7,9,10)	(0,0,1)	(0,1,3)	(3,5,7)	(0,1,3)	(9,10,10)	(7,9,10)	(7,9,10)	(9,10,10)	(9,10,10)

Evaluations regarding the criteria were expressed using triangular fuzzy numbers shown in Table 6. This was done to allow for corporation with uncertainty and ambiguity for decision making process. The triangular fuzzy numbers were defined using the same scale as the linguistic expressions.

Table 6. Conversion of criteria to triangular fuzzy numbers by extension decision makers

	EDM_1	EDM_2	EDM_3	EDM_4	EDM_5
Cr_1	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.7,0.9,1)	(0.5,0.7,0.9)
Cr_2	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0,0.1,0.3)	(0,0.1,0.3)
Cr_3	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0,0.1,0.3)	(0,0.1,0.3)	(0.3,0.5,0.7)
Cr_4	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.7,0.9,1)	(0.3,0.5,0.7)	(0.3,0.5,0.7)

2.6. Creating a Fuzzy Decision Matrix

Once the scores have been converted into numerical expressions, the average score for each alternative is calculated by EDMs. The importance weights of the criteria ($\tilde{W}j$) and the alternative evaluations ($\tilde{X}ij$) are calculated by using equations (2) and (3), which are used to define the weights criteria and the alternatives evaluations for all criteria.

$$\tilde{W}j = \frac{1}{K}\left[\tilde{W}j^1 + \tilde{W}j^2 + \cdots + \tilde{W}j^K\right] \tag{2}$$

$$\bar{X}_{ij} = \frac{1}{K}\left[\tilde{X}_{ij}{}^1 + \tilde{X}_{ij}{}^2 + \cdots + \tilde{X}_{ij}{}^K\right] \tag{3}$$

Table 7. Fuzzy decision matrix of supplier evaluations

	Cr_1	Cr_2	Cr_3	Cr_4
S_1	(5.8,7.6,9)	(8.6,9.8,10)	(7.4,9,9.8)	(7.4,9,9.8)
S_2	(5.8,7.6,8.8)	(6.6,8.4,9.4)	(3.2,5,6.8)	(8.2,9.6,10)
S_3	(1.2,2.2,3.8)	(7.4,9,9.8)	(7.8,9.2,9.8)	(6.6,8.4,9.4)
S_4	(3.6,5.4,7.2)	(3.6,5.4,7.2)	(4.8,6.6,8)	(3.8,5,6.2)
S_5	(7.4,9,9,8)	(6.2,8,9.2)	(4,5.8,7.4)	(7.4,9,9.8)
S_6	(8.6,9.8,10)	(5.4,7.4,9)	(2,3.2,4.8)	(8.2,9.6.10)

To evaluate supplier alternatives (S_1, S_2, ..., S_6) and determine the weights of criteria, the numerical average of evaluations made with each decision maker should be calculated. This is a common step in this methods. By calculating the numerical average of the evaluations, we can obtain a more robust and representative assessment of each alternative's performance against each criterion. This information can then be used to weight the criteria and rank the alternatives.

Table 8. Fuzzy decision matrix of criterion weights

Criteria	Weight
Cr1	(0.78, 0.92, 0.98)
Cr2	(0.14, 0.3, 0.5)
Cr3	(0.22, 0.38, 0.58)
Cr4	(0.5, 0.7, 0.86)

2.7. Generating a Normalized Fuzzy Decision Matrix

The normalized fuzzy decision matrix is obtained using equation (4,5,6). This matrix is denoted R.

$$R = \left[r_{ij}\right]_{mxn} \tag{4}$$

B and C being cost and benefit criteria.

$$r_{ij} = \left(\frac{a_{ij}}{c_j}, \frac{b_{ij}}{c_j}, \frac{c_{ij}}{c_j}\right), \qquad J \in B \ ise \ c^*{}_{ij} = \max c_{ij} \tag{5}$$

or

$$r_{ij} = \left(\frac{a_j}{c_{ij}}, \frac{a_j}{b_{ij}}, \frac{a_j}{a_{ij}}\right), \qquad J \in C \ ise \ a_{ij} = \min a_{ij} \tag{6}$$

The utility criterion is obtained by dividing the components in each column using the largest value of the 3th component of the elements (Doğanalp, 2016). When calculating according to the cost criterion, the minimum value of the first element in each column should be taken into account (Öztürk et al.,2020). It is necessary to perform normalization in order to bring the triangular fuzzy numbers to the range (0, 1).

Table 9. Normalized fuzzy decision matrix

	Cr1	**Cr2**	**Cr3**	**Cr4**
S1	(0.58,0.76,0.9)	(0.86,0.98,1)	(0.74,0.9,0.98)	(0.74,0.9,0.98)
S2	(0.58,0.76,0.88)	(0.66,0.84,0.94)	(0.32,0.5,0.68)	(0.82,0.96,1)
S3	(0.12,0.22,0.38)	(0.74,0.9,0.98)	(0.78,0.92,0.98)	(0.66,0.84,0.94)
S4	(0.36,0.54,0.72)	(0.36,0.54,0.72)	(0.48,0.66,0.8)	(0.38,0.5,0.62)
S5	(0.74,0.9,0.98)	(0.62,0.8,0.92)	(0.4,0.58,0.74)	(0.74,0.9,0.98)
S6	(0.86,0.98,1)	(0.54,0.74,0.9)	(0.2,0.32,0.48)	(0.82,0.96.1)

2.8. Generating a Weighted Normalized Fuzzy Decision Matrix

The weighted and normalized fuzzy decision matrix is obtained by multiplying the criteria by their importance weights. (V) matrix is found by multiplying the elements of the normalized fuzzy decision matrix by the weight coefficient Wj (Chen et al., 2006). The normalization process ensures that all criteria have equal importance in the process. Calculation is usually made using the weighted average method. The weights are determined in line with the opinions of expert decision makers, reflecting the importance of the relevant criteria. The fuzzy decision matrix, which includes weighted and normalized fuzzy evaluations, shows the relationships between alternatives and criteria. The distance between each alternative must be calculated with using the matrix and the FPIS and the FNIS, which are used to rank the supplier alternatives.

$$V = [v_{ij}]_{mxn} \tag{7}$$

$$V_{ij} = r_{ij}(x).Wj \tag{8}$$

The Fuzzy decision matrix is created with the coefficient *i*=1,2,3,..m and *j*=1,2,3,..n .

Table 10. Fuzzy decision matrix, normalized by weighting

	Cr_1	Cr_2	Cr_3	Cr_4
S_1	(0.45,0.70,0.88)	(0.12,0.29,0,50)	(0.16,0.34,0.57)	(0.37,0.63,0.84)
S_2	(0.45,0.70,0.86)	(0.09,0.25,0.47)	(0.07,0.19,0.39)	(0.41,0.67,0.86)
S_3	(0.09,0.20,0.37)	(0.1,0.27,0.49)	(0.17,0.35,0.57)	(0.33,0.59,0.81)
S_4	(0.28,0.50,0.71)	(0.05,0.16,0.36)	(0.11,0.25,0.46)	(0.19,0.35,0.53)
S_5	(0.58,0.83,0.96)	(0.09,0.24,0.46)	(0.09,0.22,0.43)	(0.37,0.63,0.84)
S_6	(0.67,0.90,0,98)	(0.08,0.22,0.45)	(0.04,0.12,0.28)	(0.41,0.67.0.86)

2.9. Defining FPIS and FNIS

To evaluate supplier alternatives with their distances to 0 and 1, which is the basic rule of fuzzy TOPSIS, must be known. (A*) is the FPIS and (A-) is FNIS which are defined in equations (9) and (10), respectively.

$$A^{*} = ({v_1}^{*}, {v_2}^{*}, {v_3}^{*}, \dots, {v_n}^{*}) \tag{9}$$

$$A^{-} = ({v_1}^{-}, {v_2}^{-}, {v_3}^{-}, \dots, {v_n}^{-}) \tag{10}$$

There are as many decision criteria as (1,1,1) and (0,0,0).

2.10. Length Between Vertex Method and Positive Trapezoid Fuzzy Numbers

In the study, the vertex method given in equation (11) benefited from to calculate distance among them two positive fuzzy numbers. Vertex method is simple and effective for calculating the distance among them fuzzy numbers (Chen et al., 2006).

$$d_v(\breve{m},\breve{n}) = \sqrt{\frac{1}{3}\,[(m_1-n_1)^2+(m_2-n_2)^2+(m_3-n_3)^2]} \tag{11}$$

Using equations (12) and (13), alternatives distances are calculated.

$$d_i^* = \sum_{i=1}^{n} d(V_j\,,V_j{}^*) \tag{12}$$

$$d_i^- = \sum_{i=1}^{n} d(V_j\,,V_j{}^-) \tag{13}$$

Table 11. Distances and proximity coefficients according to FPIS and FNIS

Supplier	*d**	*d-*
S_1	3,54	3,39
S_2	3,80	3,13
S_3	4,42	2,51
S_4	4,65	2,28
S_5	3,62	3,31
S_6	3,65	3,28

2.11. Calculation of Proximity Coefficients

The closeness coefficient is calculated to grade suppliers. The coefficient CC_i takes a value between 0 and 1 as shown in equation (14). CC_i being 1 shows that alternative is completely nearest to the positive solution, and CCi being 0 shows that alternative is completely nearest to the negative solution (Orçun, 2017),(Özen et al., 2015).

i=1,2,3…m

$$\mathrm{cc}_i = \frac{d_i^-}{d_i^*+d_i^-} \tag{14}$$

2.12. Determining the Ranking of Alternatives

The degree to which an alternative is close to the ideal solution and how far it is from a negative solution must be determined. Table 12 shows the order of the alternatives according to the calculations made.

Table 12. Closeness Coefficients and Rankings of Alternatives

Supplier	Closeness Coefficient	Ranking
S_1	**0,489**	1
S_2	0,452	4
S_3	0,362	5
S_4	0,329	6
S_5	**0,478**	2
S_6	**0,474**	3

3. Findings and Discussion

When the results in Table 12 are examined, the best closeness coefficient value is S1 alternative with 0.489. S5 alternative ranks second with 0.478, and S6 alternative ranks third with 0.474. Alternatives S2, S3 and S4 have values of 0.452, 0.362 and 0.329, respectively. While the best supplier with the closeness coefficient was determined as S1, the supplier with the worst closeness coefficient was S4.

4. Conclusions and Recommendations

Electric motors are the most critical component of the hood industry. Any interruption in its supply can directly affect production. In the study, 6 suppliers were evaluated for the selection process and five experts working in the company were determined as decision makers. Four main criteria were evaluated: quality, system capacity, finance and delivery performance. As a result of the evaluations, the Fuzzy TOPSIS method was used to determine the best supplier. According to the results, supplier S1 was determined to be the best supplier in the 1-phase asynchronous motor supplier list, having the best closeness coefficient with 0.489 points. The second-ranked supplier S5 can be recommended as the best alternative to supplier S1. According to the results, supplier S4 is the worst supplier with the lowest closeness coefficient. An important contribution has been made to the literature thanks to the study in which this method is applied for the first time for single-phase asynchronous motor supplier selection. In addition, a solution regarding supplier selection was offered to the built-in company operating in our region, with the aim of contributing to university-industry cooperation.

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Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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