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Supplier Selection with Fuzzy TOPSIS and VIKOR Method in a Trailer Manufacturing Company

[1]Seher Arslankaya
[1]Faculty of Engineering, Department of Industrial Engineering Sakarya University, Turkey

Abstract

The supplier decision has become a strategic decision for companies to achieve competitive advantage due to growth and increased competition, technology and reduced profit margins. The right choice of the supplier is one of the most important elements that will ensure the production and distribution of the products with the desired quality, flexibility, lower cost and high speed. There may be complexity and uncertainty in supplier selection decision as it includes many factors and multiple decision makers. For this purpose, the right supplier to be cooperated has been decided by using fuzzy TOPSIS and VIKOR methods in Microsoft Visual Basic by evaluating existing suppliers in a trailer factory operating in Turkey.

Key words: Supplier selection, fuzzy TOPSIS, VIKOR, Microsoft Visual Basic

1. Introduction

Nowadays, competition conditions are becoming more and more difficult, which requires companies to be in cooperation with their suppliers. In order to increase operational performance, working with the right supplier is becoming more and more important. Therefore, the decision of supplier selection for enterprises is a strategically important decision that can affect the supply chain. Companies have various expectations from suppliers such as flexibility, appropriate quality, price availability and timely delivery. In supply chain management, carrying out the process of delivering the material from the supplier to the customer successfully depends on the operation of the enterprises with the appropriate suppliers.

In determining the appropriate supplier, there are many criteria to be examined, by taking the supplier's strengths and weaknesses into account. Dickson (1966) has created a ranking list of 23 criteria for supplier selection. Ho et al.(1966) reviewed relevant articles in international journals from 2000 to 2008 and found that the most commonly used criteria are quality, delivery and cost. Wang (2010) added the supplier's after-sales service to these criteria. It can be seen in studies that price, quality and delivery criteria are used primarily.

Different approaches have been proposed in the literature to solve the supplier selection problem. Öztürk et al. [5] used the analytic hierarchy process (AHP) to solve this problem of a textile company. In his study, Chen (2011) proposed a structured methodology for supplier selection and evaluation in the textile sector. In their study, Ayık and Kılavuz (2013) made a suggestion by using the AHP and TOPSIS method in the selection of suppliers who provide software used by the universities in their student affairs. For the supplier selection problem of a company producing corrugated cardboard boxes, Supçiller and Çapraz (2011) used the AHP method to determine the importance of the evaluation criteria and the TOPSIS method to rank the suppliers.

*Seher Arslankaya: Address: Faculty of Engineering, Department of Industrial Engineering Sakarya University, 54187, Sakarya TURKEY. E-mail address: aseherr@sakarya.edu.tr, Phone: +902642955686

The decision processes involve uncertainty due to subjective evaluations of different decision makers. In the multi-criteria decision-making process, it is appropriate to use the fuzzy propositional logic developed by Zadeh (1965). Fuzzy logic is an artificial intelligence technology that allows decision-makers to express their preferences with linguistic variables to measure each criterion associated with each supplier. In his study, Kılıç (2013) proposed an integrated approach including fuzzy TOPSIS and a mixed integer linear programming model that could be used in the selection of the best supplier in the air filter sector. Supçiller and Deligöz (2018) used AHP, TOPSIS, VIKOR, Simple Additive Weighting, Electre II and M-TOPSIS methods to select suppliers for a textile company in Denizli. Şalvarcı Türeli and Manap Davraz (2016) used AHP and VİKOR method to select the staff who could meet the expectations. Fuzzy decision making techniques for supplier selection have recently been used by many researchers. Akyüz (2012), dealt with the choice of the packaging supplier problem of a company producing furniture parts by Fuzzy VIKOR method and concluded that the two alternatives are conciliatory solutions. In the process of recruiting research assistants in a public university, Akın (2016) decided which candidates would be invited to the entrance examination by means of fuzzy TOPSIS method; Yavuz and Deveci (2014) used the Fuzzy TOPSIS and the Fuzzy VIKOR techniques to choose the store plant location for Erzincan.

In the second part of the article, information is given about the techniques used in the study and in the third part, the application of the Fuzzy TOPSIS and VIKOR methods for the supplier selection problem of the company operating in the trailer sector is explained. In the conclusion section, the study is evaluated.

2. Materials and Method

In this study, supplier selection decision of a trailer factory operating in Turkey is made by fuzzy TOPSIS and VIKOR methods. In this section, fuzzy TOPSIS and VIKOR, the multi criteria decision making methods, will be mentioned.

2.1. Fuzzy TOPSIS Method

Step 1: Determining the Model: A decision-maker (D) group is formed from the experts of the subject. Criteria (C) = {C, C2, ..., Cn} and alternatives T = {T1, T2, ..., Tm} are determined. Linguistic expressions are used to determine the significance of the criteria and to evaluate the alternatives for each criterion. Decision makers also evaluate alternatives and criteria in linguistic terms. Linguistic expressions are as in table 1 with positive triangular fuzzy numbers.

Table 1. The linguistic expressions used in the evaluation of decision criteria (A) and alternatives (B) and their triangular fuzzy numbers

(A)	Triangular fuzzy numbers	(B)	Triangular fuzzy numbers
Very low (ÇD)	(0.0,0.0,0.1)	Very Bad (ÇK)	(0.0.1)
Low (D)	(0.0,0.1,0.3)	Bad (K)	(0,1,3)
Medium Low (OD)	(0.1,0.3,0.5)	Medium Bad (OK)	(1,3,5)
Medium (O)	(0.3,0.5,0.7)	Medium (O)	(3,5,7)
High (Y)	(0.7,0.9,1)	Medium Good (Oİ)	(5,7,9)
Very High (ÇY)	(0.9,1.0,1.0)	Good (İ)	(7,9,10)
		Very Good (Çİ)	(9,10,10)

Step 2: Evaluation of linguistic variables: The evaluations of decision makers with linguistic expressions are transformed to triangular fuzzy numbers as in Table 1. In the group of D decision-makers, the importance of the criteria ($\tilde{W}j$) and the evaluation of each alternative in relation to each criterion ($\tilde{X}ij$) are as in the following equation.

$$\tilde{W}_j=1/[\tilde{W}_1+\tilde{W}_2+\tilde{W}_3+\ldots+\tilde{W}_j] \quad (1)$$
$$\tilde{X}_{ij}=1/K\,[\tilde{X}_1+\tilde{X}_2+\tilde{X}_3+\ldots\ldots+\tilde{X}_{ij}] \quad (2)$$

Step 3: Determination of Importance Weights: A fuzzy multi criteria decision making matrix of all alternatives and criteria ($\tilde{D}$) is as follows..

$$\tilde{D}= \begin{pmatrix} \tilde{X}12 & \tilde{X}12 & \ldots & \tilde{X}1n \\ \tilde{X}12 & \tilde{X}22 & \ldots & \tilde{X}2n \\ \vdots & \vdots & & \vdots \\ \tilde{X}m1 & \tilde{X}m2 & & \tilde{X}mn \end{pmatrix} \quad (3)$$

$\tilde{X}ij$ and $\tilde{W}j$ linguistic expressions are defined as $\tilde{X}ij$=(mij, nij, uij) and $\tilde{W}ij$=(w1, w2, w3) with triangular fuzzy numbers.

Step 4: Creation of normalized fuzzy decision matrix: The fuzzy decision matrix is normalized. $\tilde{R}$ is expressed as follows.

$$\tilde{R} = [\check{r}_{ij}]_{mxn} \qquad \check{r}\,ij= (mij / uij), (nij / uij), (uij / uij), \quad j \in B \text{ ise } uij= \max_i uij \quad (4)$$
$$\check{r}ij = (mj / uij), (mj / uij), (mj / uij), \quad j \in C \text{ ise } mij= \min_i mij \quad (5)$$

Step 5: Formation of the weighted normalized fuzzy decision matrix: The weighted normalized fuzzy decision matrix is formed as follows.

$$\tilde{V} = [\tilde{v}_{ij}]mxn \qquad i = 1,2,3, \ldots, m \qquad j = 1,2,3, \ldots, n \qquad \tilde{v}_{ij} = \check{r}_{ij}\,(x)\;\tilde{w}_j \quad (6)$$

Step 6: Determination of fuzzy positive and negative ideal solutions: Fuzzy positive ideal solution (FPIS, A*) and fuzzy negative ideal solution (FNIS, A-) are as follows. Here, vij = (1,1,1) and vj = (0,0,0) is considered.

$$A^*=(\tilde{v}_1^*, \tilde{v}_2^*, \tilde{v}_3^* \ldots \tilde{v}_n^*) \quad (7) \qquad A^-=(\tilde{v}_1^-, \tilde{v}_2^-, \tilde{v}_3^- \ldots \tilde{v}_n^-) \quad (8)$$

Step 7: Calculation of fuzzy positive and negative ideal solutions: Distances of each alternative from A* and A- are calculated as follows..

$$d = \sum d(V, V), \; i= 1,2,\ldots,m \quad (9) \qquad di = \sum \; d(V, V), \; i= 1,2,\ldots,m \quad (10)$$

Step 8: Calculation of the closeness coefficient: To determine the alternatives, the closeness coefficients of each alternative are calculated as follows. According to the calculated proximity coefficient, the order of the alternatives is determined and the most appropriate one is selected.

$$CC_i= (di^- / (di^* + di^-)) \qquad i= 1,2,\ldots,m \qquad (11)$$

2.2 Solution Steps of VIKOR Method

The VIKOR method aims to ensure the maximum group utility of the majority and to minimize the individual regret of the competitors. The calculations are simple and clear (Ju and Wang, 2013). VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje) method was first introduced by Serafim Opricovic (1973) in 1998. This method is known as a method that focuses on making a choice between alternatives and ranking these alternatives if there are contradictory criteria. It is the introduction of "closeness" based "ideal solution" according to many criteria. The compromise ranking is done by comparing the measure of closeness to the ideal alternative. The compromise ranking algorithm steps of VIKOR algorithm are as follows (Opricovic and Tzeng, 2004).

Step 1: Finding the Best (fi*) and Worst (fi-) Values: The best (fi*) and worst (fi-) values are determined as the first step of the Vikor method. i Comparative criteria (i = 1,2,3,4 …… .., n) and j alternatives (j = 1,2,3,4 …… .m) are shown in the formulas below.

$$fi^* = \max_j fij \quad fi^- = \min_j fij \qquad (12)$$

Step 2: Calculation of Sj and Rj Values: After calculating the best (fi *) and worst (fi-) values for each criterion, Sj and Rj values are calculated for each alternative. The Sj value is the average group and Rj represents the worst group value.

$$S = \sum_{i=1}^{n} wi\,(f^* - fij) / (fi^* - fi^-) \qquad (13) \qquad\qquad Rj = \max_{ij}\, wi\,(fi^* - fij) / (fi \;\; - fi\,) \qquad (14)$$

Step 3: Calculation of Qj Values: The Qj values determined by the evaluation criteria for each alternative indicate the maximum group benefit.

$$S^* = \min S_j,\ S- = \max S_j \qquad (15)$$
$$R^* = \min R_j,\quad R- = \min R_j \qquad (16)$$
$$Q_j = (S_j - S^*)/(S- - S^*) + (1-v)\,(R_j - R^*)/(R- - R^*) \qquad (17)$$

The value of v in the formula represents the weight value for the strategy that will yield the maximum group utility, but the value of (1-v) refers to the minimum regret of the opposing decision makers. For the maximum group benefit in the Vikor method, $v>0.5$ represents the majority preference, $v=0.5$ represents consensus and $v<0.5$ represents veto and this v value is determined by the group decision (Yaralıoğlu, 2010). In our study, "v=0.5" is accepted by taking the numbness into consideration because v value is generally taken as 0.5 in literature.

Step 4: Ranking Sj, Rj and Qj Values: Sj, Rj and Qj values calculated for each alternative are sorted from minimum to maximum. The alternative with the minimum Q value can be chosen as the best alternative.

3. Supplier Selection with Fuzzy TOPSIS and VIKOR Method in a Trailer Manufacturing Company

3.1. Application of the Fuzzy TOPSIS Method to the problem of the supplier selection

A team was organized from the decision-makers of the company to determine the supplier selection criteria before the implementation of the methods. This team consists of five directors from production planning, quality control and purchasing departments. In order to determine the criteria according to the needs of the enterprise, the expert team in the study made a decision by evaluating 23 criteria presented by Dickson (1966).

Step 1: According to the evaluation results, the expert team approved five suppliers to be evaluated according to five decision criteria. The hierarchical structure of the supplier selection problem is shown in Figure 2. In the study, alternative suppliers of the company are expressed as T1, T2, T3, T4, T5. These decision criteria are described below:

1) Technology (C1): It concerns whether the supplier's production facility can meet the demands.
2) Cost (C2): It refers to the purchasing and logistics costs of raw materials from suppliers.
3) Quality (C3): It is related to low error rate and high quality level.
4) Performance (C4): Requests the supplier to meet the specifications required by the company.
5) Delivery (C5): It is the ability of the firm to deliver the purchase orders given to the supplier at the desired time.

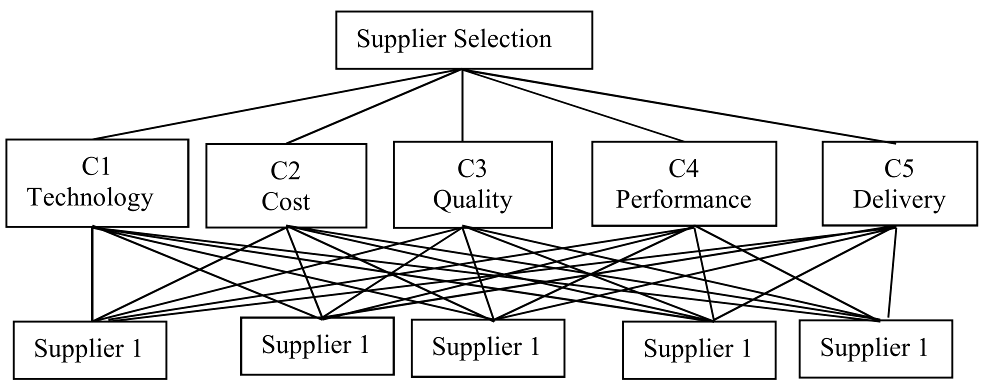

Figure 2 Hierarchical structure of supplier selection decision problem

Step 2: Following the evaluation of the criteria, the decision makers evaluated the criteria according to their severity by using the linguistic expressions in Table 1. The evaluations of decision makers according to linguistic expressions are given in table 2.

Table 2. Triangular fuzzy numbers of criterion weights

Criterias	**Decision makers**				
	KV1	**KV2**	**KV3**	**KV4**	**KV5**
C1	Y	ÇY	O	OY	OD
C2	ÇY	ÇY	OY	Y	ÇY
C3	ÇY	ÇY	Y	Y	ÇY
C4	OY	Y	ÇY	Y	Y
C5	ÇY	ÇY	Y	ÇY	OY

KVi: i. decider; Ci: i. decision criteria, ÇY: Very High; A: High; OY: Medium High; O: Medium, OD: Medium Low

Step 3: transformation of linguistic assessments in Table 2 into triangular fuzzy numbers is shown in Table 3. The criterion weights evaluated by decision makers were calculated by the equation (1). C2 criterion was computed as follows, by taking into account fuzzy numbers of the five decision-makers shown on Table 2.

(0.9+0.9+0.5+0.7+0.9/)5, (1.0+1.0+0.7+0.9+1.0/5), (1.0+1.0+0.9+1.0+1.0/5)=(0.78, 0.92, 0.98)

Table 3. Triangular fuzzy numbers of criterion weights

Criteria	KV1	KV2	KV3	KV4	KV5	Weights
C1	(0.7,0.9,1.0)	(0.9,1.0,1.0)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.1,0.3,0.5)	(0.5,0.68,0.82)
C2	(0.9,1.0,1.0)	(0.9,1.0,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.9,1.0,1.0)	(0.78,0.92,0.98)
C3	(0.9,1.0,1.0)	(0.9,1.0,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.9,1.0,1.0)	(0.82,0.96,1)
C4	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.9,1.0,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.7,0.88,0.98)
C5	(0.9,1.0,1.0)	(0.9,1.0,1.0)	(0.7,0.9,1.0)	(0.9,1.0,1.0)	(0.5,0.7,0.9)	(0.78,0.92,0.98)

Table 4. The rating of all suppliers by decison makers under all criteria

		KV1	**KV2**	**KV3**	**KV4**	**KV5**	**KV1**	**KV2**	**KV3**	**KV4**	**KV5**
C1	T1	İ	İ	E	Bİ	Çİ	(7,9,10)	(7,9,10)	(3,5,7)	(5,7,9)	(9,10,10)
	T2	E	E	Bİ	İ	Çİ	(3,5,7)	(3,5,7)	(5,7,9)	(7,9,10)	(9,10,10)
	T3	Bİ	İ	İ	Bİ	Çİ	(5,7,9)	(7,9,10)	(7,9,10)	(5,7,9)	(9,10,10)
	T4	İ	Çİ	İ	K	İ	(7,9,10)	(9,10,10)	(7,9,10)	(0,1,3)	(7,9,10)
	T5	Bİ	Çİ	İ	Bİ	Çİ	(5,7,9)	(9,10,10)	(7,9,10)	(5,7,9)	(9,10,10)
C2	T1	İ	E	E	BK	Çİ	(7,9,10)	(3,5,7)	(3,5,7)	(1,3,5)	(9,10,10)
	T2	E	Bİ	İ	Bİ	İ	(3,5,7)	(5,7,9)	(7,9,10)	(5,7,9)	(7,9,10)
	T3	Çİ	İ	İ	İ	Çİ	(9,10,10)	(7,9,10)	(7,9,10)	(7,9,10)	(9,10,10)
	T4	İ	E	İ	İ	İ	(7,9,10)	(3,5,7)	(7,9,10)	(7,9,10)	(7,9,10)
	T5	Çİ	İ	Bİ	K	Çİ	(9,10,10)	(7,9,10)	(5,7,9)	(0,1,3)	(9,10,10)
C3	T1	E	K	İ	E	BK	(3,5,7)	(0,1,3)	(7,9,10)	(3,5,7)	(1,3,5)
	T2	K	BK	İ	İ	K	(0,0,1)	(1,3,5)	(7,9,10)	(7,9,10)	(0,1,3)
	T3	E	Bİ	İ	Çİ	Bİ	(3,5,7)	(5,7,9)	(7,9,10)	(9,10,10)	(5,7,9)
	T4	İ	E	İ	Çİ	E	(7,9,10)	(3,5,7)	(7,9,10)	(0,1,3)	(3,5,7)
	T5	İ	Bİ	İ	Çİ	Bİ	(7,9,10)	(5,7,9)	(7,9,10)	(9,10,10)	(5,7,9)
C4	T1	Bİ	İ	Bİ	BK	Bİ	(5,7,9)	(7,9,10)	(5,7,9)	(1,3,5)	(5,7,9)
	T2	E	İ	İ	Bİ	İ	(3,5,7)	(7,9,10)	(7,9,10)	(5,7,9)	(7,9,10)
	T3	BK	Bİ	Bİ	İ	Çİ	(1,3,5)	(5,7,9)	(5,7,9)	(7,9,10)	(9,10,10)
	T4	Çİ	Bİ	Çİ	Çİ	İ	(9,10,10)	(5,7,9)	(9,10,10)	(9,10,10)	(7,9,10)
	T5	Bİ	İ	Çİ	Bİ	Çİ	(5,7,9)	(7,9,10)	(9,10,10)	(5,7,9)	(9,10,10)
C5	T1	E	Bİ	İ	Bİ	İ	(3,5,7)	(5,7,9)	(7,9,10)	(5,7,9)	(7,9,10)
	T2	E	İ	ÇK	Bİ	K	(3,5,7)	(7,9,10)	(0,0,1)	(5,7,9)	(0,1,3)
	T3	Bİ	Bİ	İ	Çİ	İ	(5,7,9)	(5,7,9)	(7,9,10)	(9,10,10)	(7,9,10)
	T4	E	Bİ	Çİ	Çİ	Çİ	(3,5,7)	(5,7,9)	(9,10,10)	(9,10,10)	(9,10,10)
	T5	İ	K	BK	Bİ	Bİ	(7,9,10)	(0,1,3)	(1,3,5)	(5,7,9)	(5,7,9)

(E = Equal, BI = Slightly Good, Çİ = Very Good, BK = Slightly Bad, I = Good)

Table 4 shows the evaluation of suppliers by decision makers according to criteria. The criteria of decision makers according to linguistic expressions and the transformation of these linguistic expressions into triangular fuzzy numbers are given in table 3 and table 4. The triangular fuzzy numbers of the supplier evaluations are reduced to a single value. The obtained fuzzy decision matrix is shown in table 5. In the next step, the decision makers evaluated each supplier separately according to each criterion.

Step 4: The fuzzy decision matrix in table 5 is created by taking the fuzzy numbers of the decision makers in Table 4 into account. For example, C1 criteria is calculated as (7+7+3+5+9)/5), (9+9+5+7+10)/5), (10+10+7+9+10)/5)=(6.2,8,9.2).

Table 5. Fuzzy Decision Matrix

	C1	C2	C3	C4	C5
T1	(6.2,8,9.2)	(4.6,6.4,7.8)	(2.8,4.6,6.4)	(4.6,6.6,8.4)	(5.4,7.4,9)
T2	(5.4,7.2,9)	(5.4,7.4,9)	(3,4.4,5.8)	(5.8,7.8,9.2)	(3,4.4,6)
T3	(6.6,8.4,9.6)	(7.8,8.2,9.4)	(5.8,7.6,9)	(5.4,7.2,8.6)	(6.6,8.4,9.6)
T4	(6,7.6,8.6)	(6.2,8.2,9.4)	(4,5.8,7.4)	(7.8,9.2,9.8)	(7,8.6,9.6)
T5	(7,8.6,9.6)	(6,7.4,8.4)	(6.6,8.4,9.6)	(6.8,8.6,9.6)	(3.6, 5.4,7.2)

Step 5: Fuzzy decision matrix is normalized using equation (4) and shown in table 6. In the fuzzy decision matrix given in Table 5, the largest of the u factor in each row is chosen and divided into all numbers in that row. For example, the largest u value in row 1 is 9.2. So it was calculated as ((6.2 / 9.2), (8 / 9.2), (9.2 / 9.2) and in table 6, T1 supplier of the C1 criteria was obtained as (0.67, 0.87, 1).

Table 6. Normalized Fuzzy Decision Matrix

	C1	C2	C3	C4	C5
T1	(0.67,087,1)	(0.5,0.7,0.85)	(0.3,0.5,0.7)	(0.5,0.72,0.91)	(0.59,0.80,0.53)
T2	(0.59,0.78,0.98)	(0.59,0.80,0.53)	(0.3,0.48,0.63)	(0.63,0.85,1)	(0.33,0.48,0.65)
T3	(0.69,0.88,1)	(0.81,0.85,0.98)	(0.6,0.79,0.94)	(0.56,0.75,0.9)	(0.69,0.88,1)
T4	(0.61,0.78,0.88)	(0.62,0.84,0.96)	(0.4,0.59,0.76)	(0.8,0.94,1)	(0.71,0.88,0.98
T5	(0.72,0.9,1)	(0.63,0.77,0.88)	(069,0.88,1)	(0.71,0.9,1)	(0.38,0.56,0.75)

Step 6: Each of the values shown in table 6 was multiplied by the weight of the criteria specified in Table 1 to obtain a weighted normalized fuzzy decision matrix (table 7).

Table 7. Weighted Normalized Fuzzy Decision Matrix

	C1	C2	C3	C4	C5
T1	(0.34,0.6,0,82)	(0.39,0.64,0.83)	(0.25,0.48,0.7)	(0.35,0.63,0.89)	(0.46,0.74,0.52)
T2	(0.3, 0.53,0.8)	(0.46,0.74,0.52)	(025,0.46,0.63)	(0.44,0.75,0.98)	(0.26,0.44,0.64)
T3	(0.35,0.34,0.82)	(0.63,0.78,0.96)	(0.49,0.76,0.94)	(0.39,0.66,0.88)	(0.54,0.81,0.98
T4	(0.31,0.57,0.79)	(0.48,0.77,0.94)	(0.33,0.57,0.76)	(0.56,0.83,0.98)	(0.55,0.81,0.96
T5	(0.36,0.61,0.98	(0.49,0.71,0.86)	(0.57,0.84,1)	(0.5,0.79,0.98)	(0.3,0.52,0.74)

Step 7: After the weighted normalized fuzzy decision matrix seen in table 7 is formed, the fuzzy positive ideal solution (FPIS,A*) values and the negative ideal solution (FNIS,A-) values are calculated.

A*= [(1,1,1), (1,1,1), (1,1,1), (1,1,1), (1,1,1)]
A- =[(0,0,0), (0,0,0), (0,0,0), (0,0,0), (0,0,0)]

Step 8: The distances of each alternative from the FPIS and FNIS are calculated. The closeness coefficients for each alternative were calculated as the last step after the determination of the distances (Table 8).

Table 8. Distances from FPIS and FNIS and closeness coefficients

	d_i^*	di^-	CCi
T1	2.31	3,03	0,43
T2	2.44	2.85	0,46
T3	1.82	3.57	0,33
T4	1,99	3.52	0,36
T5	1.86	3.54	0,34

When Table 8 is examined, the alternatives are T2> T1> T4> T5> T3 when the closeness coefficients are ordered from large to small. In this case, the best supplier is the number 2. Then 1 and 4 follow it.

3.2 Application of VIKOR Method to Supplier Selection Problem

VIKOR was used as a second method to determine the best among the suppliers. There are 5 suppliers and 5 criteria in this method. Each supplier company is scored for each selection criterion. While evaluations were made, decision matrix was formed from the scoring of the working groups consisting of purchasing and production planning managers (table 9). The decision matrix was examined and the best (fi*) and worst (f -) values were determined for each criterion (table 10).

Table 9. Results of alternative supplier evaluation

	C1	C2	C3	C4	C5
T1	6	4	5	6,5	5
T2	7,5	6	7	7,5	7
T3	7	5,5	9	7	8
T4	7.0	4,5	6	7,5	6
T5	8,5	7,5	9	8	9

Table 10. Decision matrix best and worst values

	C1	C2	C3	C4	C5
fi*	8.5	7.5	9	8	9
fi-	6	4	5	6.5	5

For each decision point, Sj values were calculated with the help of formula (13) and Rj values were calculated with the help of formula (14) and are shown in the table below.

Table 11. S and R values of alternatives and suppliers

	C1	C2	C3	C4	C5	Sj	Rj
T1	0.64	0.64	0.64	0.64	0.56	3.12	0.64
T2	0.34	0.37	0.43	0.43	0.58	1.72	0.58
T3	0.55	0.52	0.23	0.23	0.21	2.12	0.61
T4	0.68	0.72	0.63	0.63	0.00	2.31	0.72
T5	0.00	0.00	0.00	0.00	0.82	1.09	0.82

In the calculation of Sj and Rj values, the highest and lowest S and R values calculated with the formula (13) and (14) are shown in table 12.

Table 12. Highest and Lowest S and R Values

Sj*	1.09
Sj-	3.12
Rj*	0.58
Rj-	0.82

After calculating the Sj and Rj values, Qj values calculated with the formula (15) are shown in table 13.

Table 13. Q Values for Alternative Suppliers

	Qj
T1	0.62
T2	0.15
T3	0.31
T4	0.59
T5	0.50

By sorting the S, R, and Q values obtained from the VIKOR method from small to large, the selection priority ranking of alternative suppliers has emerged. In this case, the best supplier is T2> T3> T5> T4> T1 according to the VIKOR method.

Conclusions

The fact that purchase can be achieved correctly, quickly and at the lowest cost is extremely important in terms of improving the performance of the enterprise and its competitiveness. For this reason, businesses want to find suppliers who can provide the highest quality service, cost advantage and timely delivery. In the supplier selection process, there will be different decision makers who will reflect the nature of the field related to many qualitative and quantitative criteria. Uncertainty is inevitable in such a process where there are many criteria, a large number of decision makers and a large number of alternatives and this leads to linguistic expressions.

In this study, fuzzy TOPSIS method and VIKOR method were used for the selection of suppliers in the framework of fuzzy logic. Here, five experts evaluated five suppliers according to five criteria. Fuzzy TOPSIS method was applied by transforming the linguistic variables assigned by experts into triangular fuzzy numbers and the second supplier was found to be the best supplier. Then, to strengthen the selection, VIKOR method was applied under the same conditions and the second supplier was found to be the most suitable again. In future studies or in the studies of selecting suppliers in the trailer sector, additions and reductions may be done to the criteria determined and evaluated here.

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