Supplier Selection for A Textile Company Using The Fuzzy TOPSIS Method

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ABSTRACT

The rapid changes that occur nowadays increase the uncertainties around companies and make the decision process harder. The problems encountered in real life predominantly have complex structures and depend on multiple criteria and alternatives. For that reason, fuzzy and multiple-criteria decision making methods are gaining importance. The aim of this study is to help a textile company, which produces shirt-making fabric, choose the most suitable yarn supplier from a number of alternatives. To solve the company's problem in choosing the right supplier, the fuzzy TOPSIS method was proposed in order to handle the linguistic variables used by the decision makers. In the study, the criteria determined by the decision makers were taken into consideration and three suppliers were evaluated to identify the most suitable one.

Key Words: *Fuzzy Sets, Fuzzy TOPSIS, Selecting Supplier in Fuzzy Environment, Textile*

JEL Classification: *C44, D81, L67*

Bir Tekstil Firmasında Bulanık TOPSIS Yöntemiyle Tedarikçi Seçimi

ÖZ

Günümüzde yaşanan hızlı değişim, işletmelerin çevresindeki belirsizlikleri arttırmış, karar verme işlemini de zorlaştırmıştır. Gerçek hayatta karşılaşılan problemlerin yapısı çoğunlukla karmaşık aynı zamanda birden çok kriter ve alternatifi içermektedir. Bu nedenle bulanık çok kriterli karar verme yöntemlerinin kullanılması önem kazanmıştır. Çalışmamızın amacı gömleklik kumaş üretimi yapan bir tekstil işletmesinin kullanacağı ipliğin alternatif tedarikçileri arasından en uygun olanının seçimine yardımcı olmaktır. İşletmenin tedarikçi seçim problemine karar vericilerin sözel değerlendirmelerinde yer alan belirsizliği ele alabilmek için bulanık TOPSIS yöntemi önerilmiştir. Çalışmada, karar vericiler tarafından belirlenen kriterler göz önüne alınarak üç tedarikçi firma arasından işletme için en uygun tedarikçi firma belirlenmeye çalışılmıştır.

Anahtar Kelimeler: *Bulanık Kümeler, Bulanık TOPSIS, Bulanık Ortamda Tedarikçi Seçimi, Tekstil*

JEL Sınıflandırması: *C44, D81, L67*

INTRODUCTION

In today's competitive conditions, managers should make the right decisions in order to keep the business enterprise stable, and gain and sustain any competitive advantage. Most business enterprises acknowledge the importance of links between companies to maintain a competitive structure and increase their market share. For this reason, businesses started to re-establish their connections with suppliers and customers on the basis of collaboration and of creating shared values. The collaboration developed with suppliers has benefits for both product

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quality improvements and cost reduction, while increasing the flexibility of production.

Choosing a supplier is a decision-making problem that involves taking many different criteria into consideration to deliver a solution. It is not easy to make correct and effective decisions when the complexity of the problem's structure is increasing and the results have greater impact on the business. For that reason, utilizing scientific methods is becoming a requirement.

The aim of this study is to help a textile company, which produces shirt fabric, choose the most suitable yarn supplier from a number of alternatives. Therefore, the fuzzy TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method is recommended to companies because it is one of the multiple-criteria fuzzy decision-making methods and is easy to apply. The FTOPSIS method is a multiple-criteria decision- making method that helps makes group decisions by interpreting uncertainties based on the linguistic assesment of the employees.

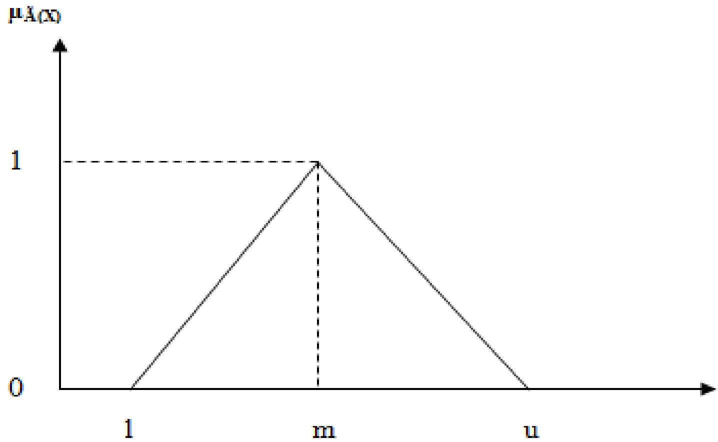
To interpret and understand the FTOPSIS model clearly, fuzzy sets and fuzzy numbers are explained first in the Fuzzy Sets Theory section. Then the fuzzy TOPSIS method is explained. In the application section, the most suitable yarn supplier for a textile company producing shirt fabric is then determined using the FTOPSIS method.

I. FUZZY SETS THEORY

Fuzzy sets were interpreted for the first time in the article titled "Fuzzy Sets" by Lotfi A. Zadeh in 1965 (Zadeh, 1965:338). In this study, Zadeh noted that human thinking is mostly fuzzy, not definitive. Therefore, he expressed a two-valued logic system using 0 and 1 fails to define that thinking (Elmas, 2011:186). Fuzzy logic principles provide the ability to interpret those uncertainties. A fuzzy set is defined with a membership function where each element has degrees of membership that vary between 0 and 1 (Zadeh, 1965:338). Membership degrees are continuous for a fuzzy set. A fuzzy set is shown with a tilde symbol over a letter ($\tilde{A}$). For the fuzzy set $\tilde{A}$, the membership function is defined as $\mu_{\tilde{A}} : E \rightarrow [0,1]$ (Hohle and Rodahaugh, 1999: 63).

Different fuzzy numbers can be used for different types of studies. In general, triangular or trapezoidal fuzzy numbers are used for practical applications. In this study, triangular fuzzy numbers have been used. A triangular fuzzy number is shown below in Figure 1. A triangular fuzzy number is shown as (l/m, m/u) or (l,m,u). The symbols l,m,u represent the minimum possible value, the possible value and the maximum possible value respectively (Mahmoodzadeh et al., 2007:303).

Figure1. Triangular Membership Function



A triangular membership function and its elements are represented as follows:

$$\mu_{\tilde{A}} = \begin{cases} 0 & ,x < l \\ (x-l)/(m-l) & ,l \le x \le m \\ (u-x)/(u-m) & ,m \le x \le u \\ 0 & ,x > u \end{cases} \qquad (1)$$

The distance between two triangular Fuzzy numbers can be calculated by vertex method $\tilde{m} = (m_1, m_2, m_3)$ and $\tilde{n} = (n_1, n_2, n_3)$ represent two fuzzy numbers and the calculation of the difference between $\tilde{m}$ and $\tilde{n}$ with the vertex method is shown in Equation 2 below(Chen,2000:3).

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]} \qquad (2)$$

II. FUZZY TOPSIS METHOD

The TOPSIS method was developed by Hwang and Yoon in 1981 and is one of the multiple-criteria, decision-making (MCDM) methods. In general the TOPSIS method is based on the chosen alternative being closest to the positive ideal solution and furthest from the negative ideal solution. In the TOPSIS method, crisp numbers are used in performance analysis and for the weight of importance of criteria. However, human thinking in decision making is uncertain in general, and preferences can not be estimated with crisp values. Therefore, in measuring human decisions, new methods using TOPSIS with fuzzy numbers were developed when numerical values failed. The fuzzy TOPSIS method was developed to eliminate the uncertainty in human decision making and is also one of the multiple-criteria, decision-making methods that are used in solving problems with linguistic uncertainty and which require a group decision (Chen, 2000:1–9).

The first studies on the fuzzy TOPSIS method are summarized below. The first application of the fuzzy TOPSIS method was made by Chen (2000) in a system analysis engineer's selection problem. After that, Shih, Yuan and Lee (2001) used this method for a company's vehicle selection problem, Chu (2002) used in an incorporation site selection problem, Tiryaki and Ahlatçıoğlu (2005) used in portfolio selection problem, Jahanshahloo, Hosseinzadeh and Izadikhah (2006) used in the ordering of fifteen Iranian banks using their financial ratios, Chen et al. (2006) used in a supplier choice problem, Wang and Chang (2007) used in the evaluation of trainer planes in a fuzzy environment, Benitez et al. (2007) used in evaluating the service quality of three hotels, Wang (2008) used in measuring the financial performance of three regional airway enterprises in Taiwan, Kelemenis and Askounis (2010) used in employee selection problem, Matin et al. (2011) used in employee selection problem of an Iranian company and Ashrafzadeh et al. (2012) used in deciding on warehouse locations, by utilizing triangular fuzzy numbers; and they showed that the fuzzy TOPSIS algorithm is highly applicable.The application steps of the fuzzy TOPSIS algorithm are summarized below(Chen,2000:6).

Step 1: A committee of decision makers is formed. Alternatives are determined for the committee and the criteria used for their evaluation.

Step 2: Linguistic variables used to evaluate the alternatives and to calculate importance weights of the criteria are determined.

Step 3: Linguistic variables are converted to fuzzy numbers to use in the importance weights of decision makers and for evaluating alternatives.

Step 4: A fuzzy decision matrix and normalized fuzzy decision matrix are formed.

Step 5: A weighted, normalized decision matrix is obtained.

Step 6: Fuzzy positive and negative ideal solutions are determined.

Step 7: Distances of each alternative to the fuzzy positive and fuzzy negative ideal solutions are calculated.

Step 8: Closeness coefficients are obtained for each alternative.

Step 9: According to the closeness coefficients, the ranking of the alternatives can be determined.

The most distinctive property of the FTOPSIS method, is that decision criteria can have different importance weights. Decision makers use suitable linguistic variables to determine the importance weights of decision criteria and to evaluate alternatives according to those criteria. The linguistic variables are shown as triangular fuzzy numbers in Table 1 and Table 2 (Chen, 2000: 6).

Table 1. Linguistic Variables for The Importance Weight of Each Criterion

Linguistic Variables	**Triangular Fuzzy Numbers**
Very Low (VL)	(0,0,0.1)
Low (L)	(0,0.1,0.3)
Medium Low (ML)	(0.1,0.3,0.5)
Medium (M)	(0.3,0.5,0.7)
Medium High (MH)	(0.5,0.7,0.9)
High (H)	(0.7,0.9,1.0)
Very High (VH)	(0.9,1.0,1.0)

Table 2. Linguistic Variables for The Ratings

Linguistic Variables	**Triangular Fuzzy Numbers**
Very Poor (VP)	(0,0,1)
Poor (P)	(0,1,3)
Medium Poor (MP)	(1,3,5)
Fair (F)	(3,5,7)
Medium Good (MG)	(5,7,9)
Good (G)	(7,9,10)
Very Good (VG)	(9,10,10)

In this study, the fuzzy TOPSIS method used is based on the model that Chen developed. The mathematical definition of the fuzzy TOPSIS method is given below (Chen, 2000:1–9).

The importance weights of the criteria and the criteria values of alternatives are calculated by using Equation (3) and Equation (4), where K decision makers exist and $\tilde{w}_j^{\,K}$ indicates the importance weight of the Kth decision maker, and $\tilde{x}_{ij}^{K}$ indicates the criteria values of the ith alternative.

$$\tilde{x}_{ij} = \frac{1}{K}\left[\tilde{x}_{ij}^{1}(+)\tilde{x}_{ij}^{2}(+)........(+)\tilde{x}_{ij}^{K}\right] \tag{3}$$

$$\tilde{w}_{j} = \frac{1}{K}\left[\tilde{w}_{j}^{1}(+)\tilde{w}_{j}^{2}(+).......(+)\tilde{w}_{j}^{K}\right] \tag{4}$$

A fuzzy multiple-criteria decision problem matrix and the criteria weight vector with n criteria and m alternatives is given below.

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \ldots\ldots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \ldots\ldots & \tilde{x}_{2n} \\ . & . & \ldots\ldots & . \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \ldots\ldots & \tilde{x}_{mn} \end{bmatrix}, \ \tilde{W} = [\tilde{w}_1, \tilde{w}_2, \ldots\ldots\ldots, \tilde{w}_n] \qquad (5)$$

Here, $\forall$ i,j $\tilde{x}_{ij}$ and for j=1,2….n $\tilde{w}_j$ are linguistic variables, and those linguistic variables are expressed with the triangular fuzzy numbers as $\tilde{x}_{ij}(a_{ij}, b_{ij}, c_{ij})$, and $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$. $\tilde{D}$ and $\tilde{w}$ represent the fuzzy decision matrix and the importance weights of the decision criteria respectively. The next step, after forming the fuzzy decision matrix, is to normalize the decision matrix. The normalized fuzzy decision matrix is shown as $\tilde{R}$ and is represented by Equation (6) given below.

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn} \quad \text{i=1,2…m ; j=1,2…n} \qquad (6)$$

The normalized fuzzy decision matrix is calculated with the equations given below, where B and C represent the benefit criteria set, and cost criteria set, respectively.

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right), j \in B;$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right), j \in C; \qquad (7)$$

$$c_j^* = \max imum_i \ \ \mathrm{c_{ij}} \quad \mathrm{j} \in \mathrm{B};$$

$$\mathrm{a_j^-} = \min imum_i \ \ \mathrm{a_{ij}} \quad \mathrm{j} \in \mathrm{C}.$$

The reason for using the normalization method is to ensure the normalized triangular fuzzy numbers are in the [0,1] interval.

After obtaining the normalized fuzzy decision matrix, the weighted normalized fuzzy decision matrix is calculated using Equation (8) below, since each criterion as a different importance weight.

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn} \qquad \text{i=1,2…m} \qquad (8)$$

$$\text{j=1,2…n}$$

The elements of this matrix are calculated using the equation $\tilde{v}_{ij} = \tilde{r}_{ij}(\otimes)\tilde{w}_j$.

In the weighted normalized fuzzy decision matrix, $\forall$ i,j $\tilde{x}_{ij}$ values are normalized positive triangular fuzzy numbers and are in the [0,1] interval.

After that, the fuzzy positive ideal solution (A^*) and the fuzzy negative ideal solution (A^-) should be determined. This is expressed in Equations (9) and (10).

$$A^* = \left(\tilde{v}_1^*, \tilde{v}_2^* ......\tilde{v}_n^*\right) \quad (9)$$

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^- ......\tilde{v}_n^-\right) \quad (10)$$

Here there exists $\tilde{v}_j^*$ = (1,1,1) values, as many as the number of decision criteria in (A^*), where j=1,2…n. Similarly, there exists $\tilde{v}_j^-$ = (0,0,0) values, as many as the number of decision criteria in (A^-).

For each alternative, the calculation of distances to the (A^*) and (A^-) are shown in equations (11) and (12) below.

$$d_i^* = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^*\right), \text{ i=1, 2…m} \quad (11)$$

$$d_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right), \text{ i=1, 2…m} \quad (12)$$

Where $d\left(\tilde{v}_{ij}, \tilde{v}_j^*\right)$ and $d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right)$ are the distances between two fuzzy numbers, these distances are calculated by using the Vertex method.

After calculating the distances to the positive ideal solution and to the negative ideal solution, closeness coefficients (CC_i) are determined for each alternative in order to obtain a ranking. Each closeness coefficient is calculated using the equation given below.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \text{ i=1, 2…m} \quad (13)$$

It is obvious that if $A_i=A^*$, then $CC_i = 1$ and if $A_i= A^-$, then $CC_i = 0$. In another words, as the value CC_i gets closer to 1, the alternative A_i will be closer to the positive ideal solution and further from the negative ideal solution. Through graded ranking of CC_i, the ranking of all alternatives can be obtained, and the best possible alternative can be chosen. Evaluation results for the alternatives can be defined according to their closeness coefficients. In order to determine the evaluation results, the [0,1] interval was divided into five sub-intervals and linguistic variables were set for each sub-interval. The acceptance criteria of these five classes are shown in Table 3.

Table 3. Acceptance Criteria

Closeness Coefficient (CC_i)	**Evaluation**
$CC_i \in [0,0.2)$	Not recommended
$CC_i \in [0.2,0.4)$	Recommended with high risk
$CC_i \in [0.4,0.6)$	Recommended with low risk
$CC_i \in [0.6,0.8)$	Acceptable
$CC_i \in [0.8,1.0)$	Accepted and preferred

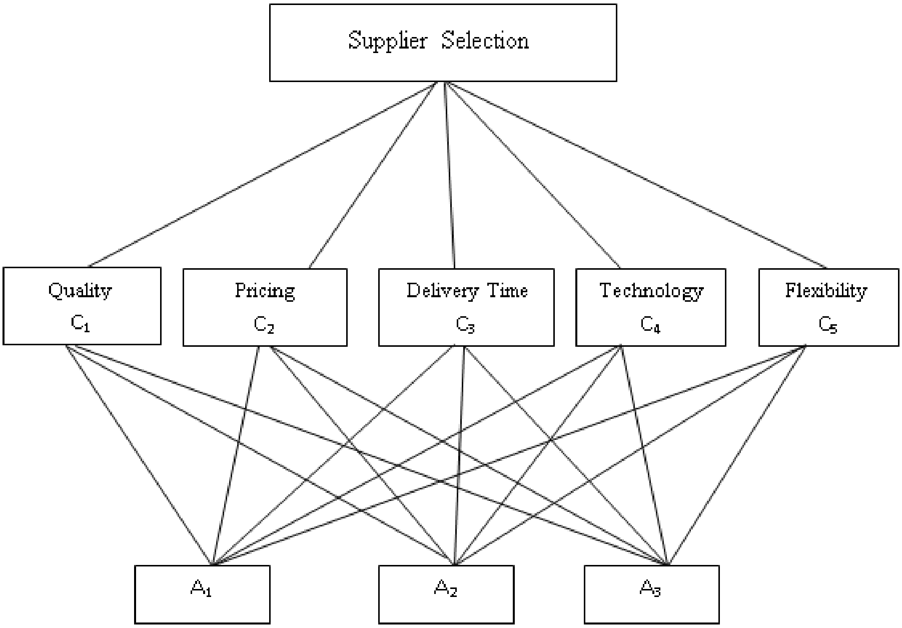
III. APPLICATION

The company that was chosen for the application is a textile company located in the Bursa textile industrial area, producing fabric used for making shirts. For the company, customer satisfaction is very important. However, other factors like quality or pricing are also important. For that reason, choosing the supplier is strategically important. There are many conflicting criteria with this problem. In conventional methods, some of the criteria are not taken into consideration, since they cannot be represented with crisp values. In addition to this, these methods cannot handle the uncertainties that the decision makers encounter during the process(Öztürk, Ertuğrul ve Karakaşoğlu,2008:798). For that reason, the fuzzy TOPSIS method, which is one of the multiple-criteria decision methods, had been proposed to the company for solving the supplier selection problem.

The criteria used in supplier selection were determined with a meeting we made with production, purchasing and quality managers. Three suppliers would be evaluated using five main criteria. The main criteria for our model were: quality, pricing, delivery time, technology and flexibility.

The hierarchical structure of the criteria, and alternatives used in supplier selection can be seen in Figure 2. With the five criteria determined, the three supplier alternatives were evaluated with the fuzzy TOPSIS method, and the best possible selection for the company was made. Alternative suppliers were represented as A_i= (A_1, A_2, A_3) and the decision criteria used for evaluating those alternatives were represented as C_i =(C_1, C_2, C_3, C_4, C_5).

Figure2. Hierarchical Structure of the Supplier Selection Problem



Decision makers determine the importance weights of the criteria by using the linguistic variables shown in Table 1. Table 4 shows the result of the decision-makers evaluations of the decision criteria by using the linguistic variables.

Table 4. Evaluations of Decision Makers for Decision Criteria Using The Linguistic Variables

	C1	**C2**	**C3**	**C4**	**C5**
D1	VH	H	VH	MH	MH
D2	H	MH	H	MH	MH
D3	VH	H	H	H	MH

D i : i. Decision Maker, C i : i. Decision Criteri

Evaluation results as triangular fuzzy numbers are shown in Table 5.

Table5. Evaluation Results of the Decision Criteria as Triangular Fuzzy Numbers

	C1	**C2**	**C3**	**C4**	**C5**
D1	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)
D2	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)
D3	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.5,0.7,0.9)

Decision makers evaluated the supplier alternatives for each criterion, by using the linguistic variables shown in Table 2. Table 6 shows the alternative supplier evaluation results of the decision makers for each criterion, by using the linguistic variables.

Table 6. Alternative Supplier Evaluations of Decision Makers by Using the Linguistic Variables

		Suppliers		
Decision Makers	**Criteria**	**A1**	**A2**	**A3**
D1	C1	VG	MG	MG
	C2	G	F	MG
	C3	VG	MG	F
	C4	G	F	G
	C5	G	MG	MP
D2	C1	VG	MG	G
	C2	G	MG	F
	C3	G	F	G
	C4	G	MG	MG
	C5	G	F	M
D3	C1	G	G	VG
	C2	VG	F	MG
	C3	G	F	F
	C4	G	F	MG
	C5	G	MG	MP

The evaluation results were converted to the fuzzy triangular numbers by utilizing Table 2, in order to form the fuzzy decision matrix calculations. Evaluation results as triangular fuzzy numbers are shown in Table 7.

Table 7. Representations of Alternatives Evaluation Results as Triangular Fuzzy Numbers

		Suppliers		
Decision Makers	**Criteria**	**A1**	**A2**	**A3**
D1	C1	(9,10,10)	(5, 7, 9)	(5, 7, 9)
	C2	(7, 9,10)	(3, 5, 7)	(5, 7, 9)
	C3	(9,10,10)	(5, 7, 9)	(3, 5, 7)
	C4	(7, 9,10)	(3, 5, 7)	(7, 9,10)
	C5	(7, 9,10)	(5, 7, 9)	(1, 3, 5)
D2	C1	(9,10,10)	(5, 7, 9)	(7, 9,10)
	C2	(7, 9,10)	(5, 7, 9)	(3, 5, 7)
	C3	(7, 9,10)	(3, 5, 7)	(7, 9,10)
	C4	(7, 9,10)	(5, 7, 9)	(5, 7, 9)
	C5	(7, 9,10)	(3, 5, 7)	(3, 5, 7)
D3	C1	(7, 9,10)	(7, 9,10)	(9,10,10)
	C2	(9,10,10)	(3, 5, 7)	(5, 7, 9)
	C3	(7, 9,10)	(3, 5, 7)	(3, 5, 7)
	C4	(7, 9,10)	(3, 5, 7)	(5, 7, 9)
	C5	(7, 9,10)	(5, 7, 9)	(1, 3, 5)

After the decision makers evaluate the criteria and the alternatives by using the linguistic variables, the importance weights of the criteria are determined by using the evaluation results of criteria, which are obtained from the three decision makers, and with the help of Equation (4). The importance weights of the criteria are given in Table 8.

Table 8. Importance Weights of the Decision Criteria

Criteria	**Weights**
Quality (C1)	(0.83,0.97,1)
Pricing (C2)	(0.63,0.83,0.97)
Delivery Time (C3)	(0.77,0.93,1)
Technology (C4)	(0.57,0.77,0.93)
Flexibility (C5)	(0.50,0.70,0.90)

The Fuzzy decision matrix is formed by using Table 7 and with the help of Equation (3).

The Fuzzy decision matrix is shown in Table 9.

Table 9. Fuzzy Decision Matrix

	C_1	C_2	C_3	C_4	C_5
A_1	(8.33,9.67,10)	(7.67,9.33,10)	(7.67,9.33,10)	(7, 9,10)	(7, 9,10)
A_2	(5.67,7.67,9.33)	(3.67,5.67,7.67)	(3.67,5.67,7.67	(3.67,5.67,7.67	(4.33,6.33,8.33)
A_3	(7,8.67,9.67)	(4.33,6.33,8.33)	(4.33,6.33,8)	(5.67,7.67,9.33)	(1.67,3.67,5.67)

The normalized fuzzy decision matrix is formed by using Equation (7). The normalized fuzzy decision matrix is shown in Table 10.

Table 10. Normalized Fuzzy Decision Matrix

	C_1	C_2	C_3	C_4	C_5
A_1	(0.83,0.97,1)	(0.77,0.93,1)	(0.77,0.93,1)	(0.7,0.9,1)	(0.7,0.9,1)
A_2	(0.57,0.77,0.93)	(0.37,0.57,0.77)	(0.37,0.57,0.77)	(0.37,0.57,0.77)	(0.43,0.63,0.83)
A_3	(0.70,0.87,0.97)	(0.43,0.63,0.83)	(0.43,0.63,0.83)	(0.57,0.77,0.93)	(0.17,0.37,0.57)

After obtaining the normalized fuzzy decision matrix, the weighted normalized fuzzy decision matrix is formed by the multiplication of each element of this matrix and the related criterion weight. This matrix can be seen in Table 11. For instance, the calculation of the weighted normalized fuzzy decision value of alternative A_1, according to the criterion C_4, is shown below.

$$\tilde{v}_{14} = (0.7,0.9,1)(\otimes)(0.57,0.77,0.93) = (0.40,0.69,0.93)$$

Table 11. Weighted Normalized Fuzzy Decision Matrix

	C_1	C_2	C_3	C_4	C_5
A_1	(0.69,0.94,1)	(0.48,0.77,0.97)	(0.59,0.86,1)	(0.40,0.69,0.93)	(0.35,0.63,0.90)
A_2	(0.47,0.75,0.93)	(0.23,0.47,0.75)	(0.28,0.53,0.77)	(0.21,0.44,0.72)	(0.21,0.44,0.75)
A_3	(0.58,0.84,0.97)	(0.27,0.52,0.80)	(0.33,0.58,0.83)	(0.32,0.59,0.86)	(0.08,0.26,0.51)

By using the maximum and minimum values of each criteria column of the weighted normalized fuzzy decision matrix, the fuzzy positive ideal solution ($\tilde{A}^*$) and the fuzzy negative ideal solution ($\tilde{A}^-$) are determined.

$\tilde{A}^*$ =[(1,1,1), (0.97,0.97,0.97), (1,1,1),(10.93,0.93,0.93),(0.90,0.90,0.90)]

$\tilde{A}^{-}$=[(0.47,0.47,0.47),(0.23,0.23,0.23),(0.28,0.28,0.28),(0.21,0.21,0.21),
(0.08, 0.08, 0.8)]

After that, the distance between each alternative to the positive and negative ideal solutions for each criterion is calculated using the vertex method. For example, for the first criterion, the distance calculation between the first alternative and the positive and negative ideal solutions is given below.

$$d(A_1, A^*) = \sqrt{\frac{1}{3}(1-0.69)^2 + (1-0.94)^2(1-1)^2} = 0.17$$

$$d(A_1, A^-) = \sqrt{\frac{1}{3}(0.47-0.69)^2 + (0.47-0.94)^2(0.47-1)^2} = 0.43$$

For the other five criteria, the calculation results of the distances of the three alternatives to the positive and negative solutions are given in Table 12.

Table 12. Distances to the Positive and Negative Ideal Solutions

	C_1	C_2	C_3	C_4	C_5
$d(A_1,A^*)$	0.17	0.33	0.25	0.32	0.35
$d(A_1,A^*)$	0.34	0.53	0.51	0.49	0.49
$d(A_3,A^*)$	0.26	0.49	0.47	0.38	0.64
$d(A_1,A^-)$	0.43	0.55	0.56	0.51	0.59
$d(A_2,A^-)$	0.31	0.33	0.32	0.32	0.45
$d(A_3,A^-)$	0.37	0.37	0.36	0.44	0.26

After calculating the distances between the alternatives and the fuzzy positive and fuzzy negative ideal solutions, the closeness coefficients are calculated for the three alternatives. The results can be seen in Table 13.

Table 13. Closeness Coefficients and The Ranking of Alternatives

	d_i^*	d_i^-	CC_i	Ranking
A_1	1.41	2.63	0.65	1
A_2	2.36	1.73	0.42	3
A_3	2.24	1.8	0.44	2

Since the closeness coefficients are ranked from the biggest to the smallest, as $CC_1 > CC_3 > CC_2$, the ranking of alternatives is determined as A_1, A_3, A_2. By looking at the acceptance criteria of alternatives in Table 13, the alternative A_1 is determined to be "Acceptable", and the alternatives A_2 and A3 are determined to be “recommended with low risk".

RESULTS

In today's competitive conditions, it is important for companies to obtain their raw materials on time from the right supplier and with low cost to maintain their business. Thus, companies are trying to find the suppliers that can give service with good quality, competitive prices and who can be flexible when orders change.

In the supplier selection problem, linguistic uncertainties occur because the decision makers are individuals. In this study, the fuzzy TOPSIS method, as one of the fuzzy multiple-criteria, decision-making methods, was used for the solution to the problem where a group decision has to be made and linguistic uncertainties exist. The aim of this study is to help a textile company producing shirt-making fabric choose the most suitable yarn supplier from various alternatives. With the fuzzy TOPSIS method, the decision makers can make linguistic assessments of the weights that they give to the criteria and supplier alternatives. Furthermore, since the fuzzy TOPSIS method is effective for group decisions, it makes the decision process simpler by preventing possible conflicts between decision makers.

In this study, five decision criteria were determined, with the help of the literature information and the opinions of the decision makers of the company, to evaluate the supplier alternatives. These were quality, pricing, delivery time, technology and flexibility. With the decision-makers opinions, it was determined that the relative importance weights of the decision criteria, ranked from the highest to the lowest, were quality, delivery time, pricing, technology and flexibility.

When the closeness coefficients of the alternatives in this application were studied, it was seen that alternative A_1 had the highest coefficient value with (0.65) and ranked as first. For that reason, we recommended to the company that A1 was the best alternative. It can be seen that the closeness coefficients of the other alternatives, 0.42 and 0.44, are in the interval that can be recommended with low risk. Thus, we stated to the company that it is not suitable to work with the alternatives A_2 and A_3.

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