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Araştırma Makalesi

AN APPLICATION ON THE MOST SUITABLE SUPPLIER SELECTION WITH FUZZY TOPSIS AND FUZZY VIKOR METHODS

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Abstract

In today's increasing competitive situations companies need dynamic strategies to survive. Strategic relations with suppliers are undoubtedly at the top of these strategies. Any problems that may occur with the suppliers will cause serious difficulties during the production process of the company. Therefore, companies should determine their suppliers in the best way and establish long-term relationships. In this study, an application was conducted on supplier selection in a food company considering multiple criteria decision-making methodology. To achieve this aim, five different suppliers were determined by the purchasing department managers and they were evaluated concerning five different criteria. Fuzzy TOPSIS methodology was proposed to decide the best supplier. The problem is solved by fuzzy TOPSIS methodology. Finally, the same problem is also solved by using fuzzy VIKOR methodology to compare results.

Keywords: *Multi Criteria Decision-Making, Fuzzy VIKOR, Supplier Selection, Fuzzy TOPSIS*

BULANIK TOPSIS VE BULANIK VIKOR YÖNTEMLERİ İLE EN UYGUN TEDARİKÇİ SEÇİMİ ÜZERİNE BİR UYGULAMA

Öz

Günümüzün her geçen gün artmaya devam eden rekabet durumunda işletmelerin sürdürülebilir bir şekilde faaliyetlerine devam edebilmeleri için belirli stratejilere sahip olmalıdır. Bu stratejilerin başında da hiç kuşkusuz tedarikçiler ile olan stratejik ilişkiler yer almaktadır. Tedarikçiler ile yaşanabilecek herhangi bir problem işletmenin üretiminde ciddi zorluklara sebep olacaktır. Dolayısıyla işletmeler çalıştıkları tedarikçilerini en iyi şekilde belirlemeli ve uzun vadeli tedarikçi ilişkileri kurmalıdır. Bu çalışmada da gıda sektöründe faaliyet gösteren bir firmada tedarikçi seçimi üzerine bir çalışma yapılmıştır. Çalışmada satın alma departmanı personellerinin belirlediği beş farklı tedarikçi beş farklı kriter üzerinden değerlendirilmiştir. Değerlendirme için karar vericilerin daha esnek karar

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vermelerine imkan tanıyan bulanık TOPSIS yöntemi kullanılmıştır. Çok kriterli karar verme metotlarında bulanık TOPSIS metodu ile çözülen problemin sonuçları kıyaslama açısından bulanık VIKOR ile de çözülmüş ve sonuçlar kıyaslanmıştır.

Anahtar kelimeler: *Çok Kriterli Karar Verme, Tedarikçi Seçimi, Bulanık VIKOR, Bulanık TOPSIS*

INTRODUCTION

In today's world competition is felt more and more intensely, the adoption of a competitive purchasing strategy in companies enables the market shares of companies to increase more. Having an effective procurement system should not only focus on minimizing costs, but also aim to cooperate with suppliers that are compatible with the strategic goals of the company. Companies that want to continue their existence in the future must be in good relations with their suppliers to meet customer requests on time. For this reason, when choosing their suppliers, companies should choose suppliers that are suitable for their company strategies and are willing to cooperate.

Choosing the right supplier and evaluating supplier relations objectively has emerged as the main argument. First of all, it is the determination of the criteria to be used in the performance evaluation and the supplier selection with an appropriate method. With its increasing importance in recent years, this subject is included in the literature.

If we look at the supplier selection literature, more than one parameter was used in 47 of the 74 studies available (Weber, 1991, p. 2). The criteria to be considered for supplier selection in different studies were grouped under three groups as the financial, technical, and operational success (Tam & Tummala, 2001, p. 171). The supplier sorting algorithm is also proposed (Demir et al., 2018, p. 479; Araz & Ozkarahan, 2007, p. 585; Xu et a., 2019, p. 273; Akpinar, 2016, p. 54). Hybrid algorithm (Kannan et al., 2020, p. 1), evaluation of suppliers under risk criteria (Alikhani et al., 2019, p. 69), machine learning system (Cavalcante et al., 2019, p. 98) are also proposed in the literature. Companies aim to establish better relationships with their suppliers, depending on the increase in dependency on their suppliers. One of the first studies on the criteria used in supplier selection was carried out by Dickson in 1966 with a study he conducted with 273 purchasing managers in America and Canada. In the study, 23 criteria were used to select the best supplier (Dickson, 1966, p. 5).

In the study on supplier selection, it was formulated by a linear modeling method that minimizes purchasing and storage costs (Lo et al., 2018, p. 318). In the other study, the best supplier was selected using the integer programming model based on cost, quality, and service criteria, where quality and service are specified in constraints and cost is minimized in the objective function (Hamdan & Cheaitou, 2017, p. 573). Integer programming was used in supplier selection together with Analytical Hierarchy Process (Silalahi et., 2019, p. 124). In the multi-purpose linear programming model established for supplier selection, the relationship between conflicting factors is analyzed (Tirkolaee, 2020, p. 1). In this model, where cost, delivery, and quality are determined as the purpose, items such as the supplier's production capacity, lot sizes, demand fulfillment, purchasing cost are determined as constraints, and factors such as supply quantities and the number of suppliers to work with are added to the model as a separate constraint set.

In the multi-criteria linear goal programming model established, a set of supplier factors such as quality, price, distribution, and a set of factors including specifications such as the material need and safety stock of the company were evaluated (You et al., 2020, p. 302). In another study, he created a multi-purpose programming model, and this model was used in the selection of suppliers for a department of a pharmaceutical company and the determination of the relevant supply amounts (Weber et al, 2000, p. 90).

In the research conducted in the supplier selection problems literature, it was seen that these and similar problems were solved by using too many methods. Especially, the reason for choosing the fuzzy TOPSIS method is that it is based on fuzziness and let flexible decision-making opportunities for the managers. In this way, managers had the opportunity to make decisions by using linguistic expressions within a certain range instead of definite expressions. However, decision-makers were prevented from making wrong decisions due to subjective expressions. In this study, it has been tried to decide which supplier is at the desired level for a food firm.

In the rest of the study, the second section presents fuzzy TOPSIS methodology. Data on the real-life application were shared, the problem was solved and the results were compared in the third section. General comments about the results and possible future studies are detailed in the last section.

FUZZY TOPSIS METHODOLOGY

TOPSIS methodology is a well-known methodology in Multiple Criteria Decision Making (MCDM) problems and this methodology was firstly applied in 1981 (Hwang & Yoon, 1981, p. 16). The most crucial function of this method is that TOPSIS is a linear weighting technique and the determination of the most appropriate solution that is the farthest to the negative ideal solution (NIS) and nearest to the positive ideal solution (PIS). Numerical values may be insufficient when making evaluations in many situations in real life because human thoughts and judgments, especially preferences, often contain uncertainty (Jahanshahloo et al., 2006, p. 1545).

In the TOPSIS methodology fuzzy values are started to use in 1992 with referred to the classical TOPSIS methodology (Chen & Hwang, 1992, p. 289). After that, this method has been used to get a solution to many MCDM problems. In the fuzzy TOPSIS methodology proposed by (Chen, 2000, p. 1), determination of criterion weights and evaluation of candidates are made with verbal parameters expressed with Triangular Fuzzy Numbers (TFN). The methodology used in the evaluation of the quality of service operating in the air sector by (Tsaur & Chang, 2002, p. 107; Chu & Lin, 2003, p. 284), sustainable supplier selection (Rashini & Cullinana, 2019, p. 266, Memari et al., 2019, p. 9; Lei et al., 2020, p. 1), in robot Selection (Deli, 2020, p. 779) proposed the fuzzy TOPSIS method to handle multi-purpose large-scale nonlinear programming problems. It is also used to decide suitable logistics service providers (Singh et al., 2018, p. 531) and nonlinear programming (Zeng et al., 2020, p. 424).

The fuzzy TOPSIS algorithm enables decision-makers, which can be also as a group, to transform the weights of importance they have determined for criteria and their evaluations for alternatives into a group evaluation (Zimmermann, 1987, p. 19). The steps in the implementation of the fuzzy TOPSIS methodology can be detailed as follow subsections (Chen, 2000, p. 9).

Creating Linguistic Variables (LVs) and Evaluating Criteria Weights and Alternatives According to These LVs

Weights importance and criterion values of the decision criterion, which are considered to be included in the alternatives to be selected, are evaluated by decision-makers using linguistic expressions. Positive triangle or trapezoidal fuzzy numbers can be used to use the evaluations made with linguistic expressions in calculations. Since positive triangle fuzzy numbers were used in the study, linguistic expressions used by managers while evaluating the decision criteria and candidates and their positive TFN equivalents are as in Table 1. Table 2 presents the evaluation of TFN.

Table 1: LVs Used in Weighting Criteria and Their Equivalents as TFN (Chen, 2000, p. 4)

Linguistic Variables	Short form	TFN
Very High	VH	(0.90, 1.0, 1.0)
High	H	(0.70, 0.90, 1.0)
Moderate High	MH	(0.50, 0.70, 0.90)
Moderate	M	(0.30, 0.50, 0.70)
Moderate Low	ML	(0.10, 0.3, 0.50)
Low	L	(0.0, 0.10, 0.30)
Very Low	V	(0.0, 0.0, 0.10)

Creating the Fuzzy Decision Matrix (FDM)

Matrix A shows the initial matrix created by manager/s. The following parameters are needed for the selection of candidates for the evaluation committee (Chen et al, 2006, p. 289).

- Decision-makers ($DM_1, DM_2, \ldots, DM_k$),
- Candidates or Alternatives ($A_1, A_2, \ldots., A_k$)
- The set of decision criteria by which candidates are evaluated ($C_1, C_2, \ldots., C_k$),
- The set of criteria values by which candidates are assessed to a predefined criterion

Table 2: LVs Used in the Evaluation of Alternatives and Their Corresponds as TFN (Chen, 2000, p. 5)

Linguistic Variables	Short form	TFN
Very Good	VG	(9.0, 10.0, 10.0)
Good	G	(7.0, 9.0, 10.0)
Moderate Good	MG	(5.0, 7.0, 9.0)
Fair	F	(3.0, 5.0, 7.0)
Moderate Poor	MP	(1.0, 3.0, 5.0)
Poor	P	(0.0, 1.0, 3.0)
Very Poor	VP	(0.0, 0.0, 1.0)

Let the assessment of *k DMs* on the candidates or alternatives based on the importance weights and decision criterion of the criteria be $\tilde{w} = (w_{ij1}, w_{ij2}, w_{ij3})$ and $\tilde{x} = (a_{ijk}, b_{ijk}, c_{ijk})$ respectively. Fuzzy criteria values obtained by evaluating candidates according to the criteria of *DMs* are shown as $\tilde{x} = (a_{ij}, b_{ij}, c_{ij})$ and these values are calculated with the help of Equation (1).

$$a_{ij} = \min_k (a_{ijk}), b_{ij} = \frac{1}{k}\sum_{k=1}^{K} b_{ijk}, c_{ij} = \max_k (c_{ijk}) \tag{1}$$

Importance weights of the criterion presented as $\tilde{w}(w_1, w_2, w_3)$ and calculated with the help of Equation (2).

$$w_{j1} = \min_k (w_{jk1}), w_{j2} = \frac{1}{k}\sum_{k=1}^{K} w_{jk2}, w_{j3} = \max_k (w_{jk3}) \tag{2}$$

The representation of the matrix is as follows:

$$\tilde{A}=\begin{bmatrix} B_{11} & B_{12} & \dots & B_{1n} \\ B_{21} & B_{22} & \dots & B_{2n} \\ \dots & \dots & \dots & \dots \\ B_{m1} & B_{m2} & \dots & B_{mn} \end{bmatrix} \text{ and } \tilde{W}=\left[\tilde{w}_1,\tilde{w}_2,\dots,\tilde{w}_n\right]$$

In the decision matrix, $\tilde{x}=(a_{ij},b_{ij},c_{ij})$ and $\tilde{w}(w_1,w_2,w_3)$ are TFN, FDM is $\tilde{A}$ while Fuzzy Weights Matrix (FWM) is $\tilde{W}$.

Creation of Normalized FDM

$$\tilde{R}=\left[\tilde{r}_{ij}\right]_{mxn} \tag{3}$$

where, $\tilde{R}$ is the utility criterion, $\tilde{r}$ is the cost criterion can be found as follows;

$$\tilde{r}_{\hat{i}j}=(\frac{a_{ij}}{d_j^*},\frac{b_{ij}}{d_j^*},\frac{c_{ij}}{d_j^*}),c_j^*={}^{\max}{}_i c_{ij},\ j\in B \tag{4}$$

$$\tilde{r}_{\hat{i}j}=(\frac{a_j^-}{c_{ij}},\frac{a_j^-}{b_{ij}},\frac{a_j^-}{c_{ij}}),a_j^-={}^{\min}{}_i a_{ij},\ j\in B \tag{5}$$

Creation of the Weighted Normalized FDM

$$\tilde{V}=\left[\tilde{v}_{ij}\right]_{mxn} \qquad i=1,2,\dots,m;\ j=1,2,\dots,n \tag{6}$$

and each of elements can be created:

$$\tilde{v}_{ij}=\tilde{r}_{\hat{i}j}\odot\tilde{w}_j \tag{7}$$

Calculation of Fuzzy (F-PIS) and Fuzzy (F-NIS)

Determining the weighted normalized FDM then the FPIS and FNIS points are as follows:

$$A^*=(\tilde{v}_1^*,\tilde{v}_2^*,\dots,\tilde{v}_n^*)\ ,\ A^-=(\tilde{v}_1^-,\tilde{v}_2^-,\dots,\tilde{v}_n^-)$$

$$v_j^*={}^{\max}{}_i(v_{ij3}) \text{ and } v_j^-={}^{\min}{}_i(v_{ij1})\ \ i=1,2,\dots,m;\ j=1,2,\dots,n$$

Calculation of Distances from FNIS and FPIS Points

d_v represents the distances of each alternative from FNIS to FPIS and these points are found as follows:

$$d_v^* = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, v_j^*), i = 1, 2, ..., m \tag{8}$$

$$d_v^- = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, v_j^-), i = 1, 2, ..., m \tag{9}$$

Calculation of Proximity Coefficients

After determining the candidates' distances to FPIS and FNIS points, the proximity coefficients are calculated to determine the rank of the candidates. The proximity coefficient calculates as follows:

$$CC_i = \frac{d_i^*}{(d_i^- + d_i^*)}, i = 1, 2, ..., m \tag{10}$$

Sorting and Evaluating Alternatives

According to the calculated proximity coefficients, alternatives are sorted to values from high to low.

SUPPLIER SELECTION USING FUZZY TOPSIS

In this part of the study, information is given about the application of supplier selection based on the fuzzy TOPSIS method. The study includes a real-life application and it has been applied in a company operating in the food sector in İzmir Sarnıç Organized Industrial Zone. The company has many suppliers that supply the products it consumes daily during the purchasing phase. Although many of these suppliers have the same products, the company manager has understood that he is meeting with too many suppliers when purchasing. This causes unnecessary waste of time for the decision-maker. Based on this problem, it was decided to choose the supplier that satisfies the criteria at the best level.

Step 1: Managers are determined the criteria.

Mangers consist of three personnel working in the purchasing department (DM_1, DM_2, DM_3). There are five suppliers to be evaluated (S_1, S_2, S_3, S_4, S_5). Criterion decided by the managers as presented in Table 3.

Table 3: Fuzzy TOPSIS Case Criterion

CRITERION	
Criteria 1 (C_1)	Price
Criteria 2 (C_2)	Delivery Time
Criteria 3 (C_3)	Payment Options
Criteria 4 (C_4)	Quality
Criteria 5 (C_5)	Accessibility

Step 2: Suitable verbal variables are selected for the weights of the significance of each criterion by considering verbal variables.

At this stage, managers used the Table 1 parameter to decide the criteria importance and evaluating the suppliers. The data obtained are presented in Tables 4 and 5.

Table 4: Weights of Importance of the Criterion

	C_1	C_2	C_3	C_4	C_5
DM_1	H	H	H	VH	VH
DM_2	H	VY	VH	VH	H
DM_3	H	VY	H	VH	VH

Table 5: Importance Levels of Suppliers According to the Criteria

Criterion (C)	Suppliers (S)	Decision Makers (DMs)		
		DM_1	DM_2	DM_3
C_1	S_1	G	VG	VG
	S_2	VG	VG	MG
	S_3	VG	MG	F
	S_4	VG	MG	MG
	S_5	VG	G	F
C_2	S_1	MG	F	G
	S_2	G	MG	MG
	S_3	MG	MG	F
	S_4	VG	G	F
	S_5	VG	G	MG
C_3	S_1	G	VG	G
	S_2	G	G	G
	S_3	VG	G	MG
	S_4	VG	MG	MG
	S_5	G	MG	F
C_4	S_1	VG	G	MG
	S_2	G	G	F
	S_3	G	G	MG
	S_4	VG	VG	MG
	S_5	VG	MG	F

C_5	S_1	G	VG	G
	S_2	G	G	VG
	S_3	G	G	G
	S_4	VG	G	MG
	S_5	VG	MG	MG

Step 3: The verbal variables decided by managers for the evaluation of the importance weights and alternatives are turned into TFN. After the converted process, the decision matrix is attained by using Equation (1). This matrix is presented in Table 6. Using Equation (2), the fuzzy weights matrix is obtained. Table 7 illustrates the values obtained from the calculation.

Step 4: FDM and normalized FDM (NFDM) are formed.

FDM is normalized considering Equation (3, 4, 5) and Table 8 presented these calculations.

Table 6: FDM of methodology

	C_1	C_2	C_3	C_4	C_5
S_1	(5, 8.3, 10)	(7, 9, 10)	(7, 9, 10)	(3, 6.3, 9)	(5, 8.3, 10)
S_2	(3, 7, 10)	(5, 8.7, 10)	(5, 8, 10)	(3, 8, 10)	(5, 9, 10)
S_3	(7, 9, 10)	(7, 9.3, 10)	(7, 9.7, 10)	(3, 7, 10)	(7, 9, 10)
S_4	(3, 7, 10)	(5, 8, 10)	(3, 8, 10)	(5, 8.7, 10)	(3, 7.3, 10)
S_5	(7, 9.3, 10)	(7, 9.3, 10)	(7, 9, 10)	(5, 7.7, 10)	(3, 7.7, 10)

Table 7: FWM of the methodology

Criterion	Weights
C_1	(0.7, 0.93, 1)
C_2	(0.9, 1, 1)
C_3	(0.7, 0.9, 1)
C_4	(0.7, 0.97, 1)
C_5	(0.7, 0.97, 1)

Step 5: The weighted NFDM (WNFDM) is obtained.

WNFDM is calculated by considering Equations (6, 7) and the calculations are presented in Table 9.

Table 8: NFDM of the methodology

	C_1	C_2	C_3	C_4	C_5
S_1	(0.1, 0.64, 1)	(0.1, 0.64, 1)	(0.1, 0.5, 1)	(0.1, 0.7, 1)	(0.3, 0.74, 1)
S_2	(0.3, 0.8, 1)	(0.1, 0.72)	(0 1, 0.54, 1)	(0 3, 0.78, 1)	(0.3, 0.74, 1)
S_3	(0.5, 0.92, 1)	(0.7, 0.94, 1)	(0.1, 0.6, 1)	(0.3, 0.84, 1)	(0 3, 0.84, 1)
S_4	(0.7, 0.94, 1)	(0.5, 0.88, 1)	(0.3, 0.82, 1)	(0.7, 0.94, 1)	(0.5, 0.94, 1)
S_5	(0.5, 0.86, 1)	(0.5, 0.86, 1)	(0.1, 0.74, 1)	(0.3, 0.78, 1)	(0.5, 0.86, 1)

Table 9: WNFDM of the methodology

	C_1	C_2	C_3	C_4	C_5
S_1	(0.07,0.61,1)	(0.07,0.60,1)	(0.03,0.38,1)	(0.03,0.52,1)	(0.09,0.55,1)
S_2	(0.21,0.77,1)	(0.07,0.68,1)	(0.03,0.41,1)	(0.09,0.58,1)	(0.09,0.55,1)
S_3	(0.35,0.88,1)	(0.49,0.88,1)	(0.03,0.46,1)	(0.09,0.62,1)	(0.15,0.65,1)
S_4	(0.49,0.90,1)	(0.35,0.83,1)	(0.09,0.62,1)	(0.21,0.70,1)	(0.15,0.70,1)
S_5	(0.35,0.83,1)	(0.35,0.81,1)	(0.03,0.56,1)	(0.09,0.58,1)	(0.15,0.64,1)

Step 6: FPIS and FNIS are determined.

FNIS and FPIS points are decided to the WNFDM. FPIS and FNIS parameters are respectively:

A* = [(1.0, 1.0, 1.0),(1.0, 1.0, 1.0),(1.0, 1.0, 1.0),(1.0, 1.0, 1.0),(1.0, 1.0, 1.0),(1.0, 1.0, 1.0),(1.0, 1.0, 1.0)]

A-= [(0.21, 0.21, 0.21), (0.35, 0.35, 0.35), (0.21, 0.21, 0.21), (0.27, 0.27, 0.27), (0.21, 0.21, 0.21)]

Step 7: Suppliers' distance from FNIS and FPIS is figured out.

The distances for suppliers from FPIS and FNIS points were figured out with the help of Equations (8, 9, 10) and presented in Table 10.

Table 10: FNIS and FPIS Point Distances

Suppliers	d_i^*	d_i^-
S_1	4.31	4.59
S_2	4.02	4.72
S_3	3.63	4.98
S_4	3.53	5.03
S_5	3.72	4.91

Step 8: Find the proximity coefficients for each alternative and by looking at the proximity coefficients, all suppliers are listed and the suppliers with the highest proximity coefficient are decided. Table 11 presents these calculations.

According to Table 11, when the proximity coefficients are listed in descending order, the supplier is in the form of $S_4 > S_3 > S_5 > S_2 > S_1$. In other words, the number 4 supplier criteria is the supplier that satisfies the best level. To analyze the superiority or weakness of the supplier selection problem, the same variables are used and the problem was solved using fuzzy VIKOR methodology and the solutions are shown in Table 12.

Table 11: Proximity Coefficients of Suppliers and Ranking

Suppliers	CC_{Si}	Ranking
S_1	0.521	5
S_2	0.553	4
S_3	0.586	2
S_4	0.593	1
S_5	0.578	3

Table 12: Fuzzy VIKOR Results

Suppliers	*Q values*	Ranking
S_1	0.631	5
S_2	0.663	4
S_3	0.801	3
S_4	0.915	1
S_5	0.813	2

As seen in Table 12, S_4 showed the best performance again. S_5 is the second-best supplier while S_3, $S_{2,}$ and S_1 are the other good suppliers respectively. According to this comparison, in both cases, the S_4 supplier is the supplier that can be chosen by the company because it has the best performance that satisfies all the criteria at the best level.

RESULT AND CONCLUSION

In increasing competitive conditions, companies need dynamic strategies to survive. The ability to respond to customer needs and expectations in the fastest way and to catch market opportunities is vital. Throughout history, all companies have researched how to use scarce resources most efficiently and tried to answer how we can achieve this job with the highest efficiency, highest quality, and lowest cost.

The selection process is always laborious for decision-makers and raises concerns about the accuracy of its results. These concerns cause the development of many new selection methods or models today. The supplier selection process is one of the topics that have been widely studied. In recent years, many academic studies have been conducted on systematic approaches to be used in supplier selection decisions. In this context, detailed literature research is available on methods and tools that support supplier selection.

In this study, a real-life application was made for supplier selection. The company is a food production company located in İzmir Sarnıç Organized Industrial Zone. An application has been made on the suppliers of the products supplied by the purchasing department for the products needed. In practice, the purchasing department experts decided on criteria and alternatives. They were acted during the evaluation phase. Fuzzy TOPSIS and fuzzy VIKOR methods were used as methods for selection. First of all, the problem was solved with fuzzy TOPSIS. The problem is also solved with fuzzy VIKOR to compare the results. In both cases, the fourth supplier performed the best. A certain number of criteria were used in the study. Lack of more criteria and decision-makers were the limitations of this study. Besides, the analytical network process or Choquet integral methods that take into account the interactions between criteria can be considered as future studies. In addition, linear physical programming or simulation modeling methods can be used to extend the study.

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