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Supplier Selection during the COVID-19 Pandemic Situation by Applying Fuzzy TOPSIS: A Case Study

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Abstract. During the COVID-19 pandemic situation, many factories, companies, and organizations faced difficulties supplying raw materials. Multi-criteria decision-making techniques (MCDM) could be a proper solution that helps managers to make an appropriate and fast decision in supplier selection in such unusual situation. The goal of my research is not only to employ the technique for order of preference by similarity to ideal solution (TOPSIS) in a fuzzy environment but also to use a new criterion, namely "number of employees", for evaluating suppliers during the COVID-19 pandemic situation. Applying fuzzy logic during unstable conditions helps decision makers to make a logical and more precise decision. In this study, five criteria, that is, quality, delivery, price, number of employees, and lead time, are considered to compare and select an appropriate supplier. The results show that "number of employees" is an essential criterion in supplier selection during abnormal conditions like the COVID-19 pandemic situation.

Keywords: multi-criteria decision-making, alternatives, number of employees

JEL Classification: C44, D70

1. Introduction

The COVID-19 have had a significant effect on different sections of international society. Some organizations had to stop working, and some other organizations have fired a great many of their employees. Manufacturing factories have encountered some problems in supplying raw materials, and education has shifted to the online sphere. Economy faced stagnation, and financial issues were raised for international societies.

Therefore, making an optimized decision in different sections of society, such as businesses, economy, healthcare, and some other parts, would not be easy for the decision makers.

To make a proper and stable decision regarding an issue in an organization during the COVID-19 pandemic situation, applying multi-criteria decision-making (MCDM) techniques may help decision makers. In the current research, a decision-making problem during COVID-19 in a small part of the business section is studied. A MCDM technique was used to solve a problem in an Iranian petrochemical factory.

Within the subject of supplier selection, this study tries firstly to identify different attributes (criteria) for selecting suppliers. Secondly, it attempts to choose the most appropriate supplier by applying a MCDM technique. Finally, this study tries to show the importance of "number of employees as one of the main criteria in selecting suppliers during COVID-19 pandemic situations.

Different MCDM techniques, such as Analytic Hierarchy Process (AHP), ELimination Et Choice Translating Reality (ELECTRE), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), etc., can be employed to find a way of dealing with a decision-making problem. In this study, decision makers decided to apply the TOPSIS technique due to some advantages of TOPSIS such as having negative and positive criteria at the same time, converting qualitative criteria to quantitative ones, and a good mathematical basis (dealing with distances) (Orji and Wei, 2015; Shen et al., 2013; Govindan et al., 2013; Awasthi et al., 2010).

The rest of this study is structured as follows. Literature review is presented in Section 2. Section 3 describes the methodology of the study. The case study is explained in Section 4. Finally, the conclusions and recommendations are presented in Section 5.

2. Literature Review

TOPSIS was firstly initiated by Hwang and Yoon (Hwang and Yoon, 1981). Specifying the ideal and the anti-ideal solution is the principle logic in TOPSIS. The anti-ideal solution minimizes affirmative criteria and maximizes negative criteria, while the ideal solution does it vice versa. In TOPSIS technique, alternatives are ranked according to their similarity to the ideal solution. The more similar an alternative to the ideal solution, the higher its ranking. This technique selects the proper alternative on the basis of the proximity of the selected alternative to the affirmative ideal solution and its distance from the negative ideal solution. Some researchers believe that the TOPSIS should be extended to a fuzzy environment (Chen, 2000; Liang, 1999; Raj and Kumar, 1999).

A remarkable stream of previous studies also attempted to integrate TOPSIS and the fuzzy set theory to augment the accuracy of the ultimate selection made by decision makers.

Chen et al. (2006) applied fuzzy TOPSIS in evaluating and selecting the supplier. The supplier's profitability, relationship closeness, capability in technology, quality of conformity, and conflict resolution are considered as the criteria for evaluating suppliers.

Javad et al. (2020) used fuzzy TOPSIS to prioritize various suppliers according to weighted green criteria, such as collaborations, economic advantages, capabilities, resources, etc., for selecting the most effective supplier.

A study in Sweden was conducted to compare fuzzy TOPSIS and fuzzy DEA in selecting sustainable suppliers. Six criteria – cost, energy and resource consumption, quality, management of environment systems, health of staff and safety of work, and social responsibility – are considered in evaluating suppliers (Rashidi and Cullinane, 2019).

To select a proper supplier providing raw material for a small-scale steel industry company in India, fuzzy TOPSIS was used by Kumar et al. (2018). Suppliers are assessed based on four criteria: cost, delivery capabilities, quality of product, performance, and reputation (Kumar et al., 2018).

Gupta and Barua (2017) applied fuzzy TOPSIS to choose a supplier based on green innovation ability in small and medium-sized enterprises. Weights of criteria are computed by using the best worst method.

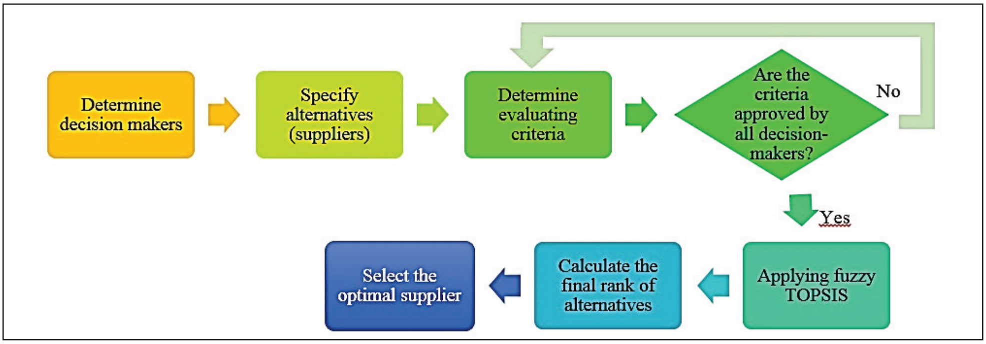
In some previous studies, research focused on important criteria, such as cost, quality, lead time, and delivery, for selecting suppliers (Amindoust et al., 2012a–b; Azadi et al., 2015; Azadnia, et al., 2015; Tavana et al., 2016; Girubha et al., 2016).

A review of previous literature has shown there is extensive research on supplier selection, some of the studies being either theoretical or practical and some others case studies. Although the earlier studies used different criteria in selecting suppliers, none of them considered the number of employees as one of the main criteria. In Iran, this criterion is not considered in selecting a supplier selection.

3. Methodology

A methodology is proposed in *Figure 1* to select an efficient supplier in this study. The first step is identifying decision makers who can help in making decisions for supplier selection. In the second step, suppliers that can supply the required material would be determined. Then, the criteria for supplier selection are determined by studying the literature. The criteria are sent for advisement to senior managers to remove or add on any criteria. If the decision makers approve all selected criteria, the process may continue. Otherwise, the evaluating criteria should be revised. After the approval of all criteria by decision makers, fuzzy

TOPSIS is employed to calculate the final suppliers' rank. Finally, an efficient supplier will be revealed.



Source: author's compilation

Figure 1. *Methodology diagram*

3.1. Fuzzy TOPSIS

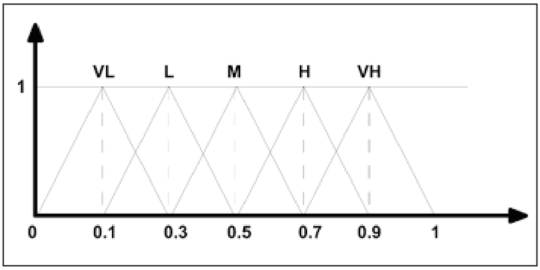
The TOPSIS technique was first introduced in 1981 by Hwang and Yoon. In this method, the best alternative in the company among all the other alternatives would be the one with the shortest interval from the affirmative ideal solution and the outmost interval from the negative ideal solution (Ajripour et al., 2019).

TOPSIS is a helpful technique for prioritizing alternatives, but it utilizes firm values for choosing the alternatives. In some cases, such as pairwise comparisons and superiority ratings, human judgment cannot be accurate because of the firm value rating of alternatives (Chang et al., 2008). To dominate this constraint in my study, fuzzy TOPSIS is utilized by applying linguistic variables.

The Fuzzy TOPSIS steps applied in this paper are as follows:

Before introducing the fuzzy TOPSIS steps, let us assume there are i alternatives named $S = \{S_1, S_2, S_3, \dots, S_i\}$ and j criteria named $C = \{C_1, C_2, C3, \dots, C_j\}$.

Step 1: The first step of the fuzzy TOPSIS determines the criteria weights ($\widetilde{W}_j$), where j = 1,2,…, m. All decision makers should use linguistic variables to evaluate the importance of each criterion. Triangular fuzzy numbers were applied in this study. It would often be suitable to get on with triangular fuzzy numbers because of the simplicity in computational processes. A triangular fuzzy number is characterized as $M = (l,m,u)$, where "l" shows the lowest likely number, "m" represents the most propitious number, and "u" the greatest likely number for expressing a fuzzy occasion (Deng, 1999). Triangular fuzzy numbers are depicted in *Figure 2*.



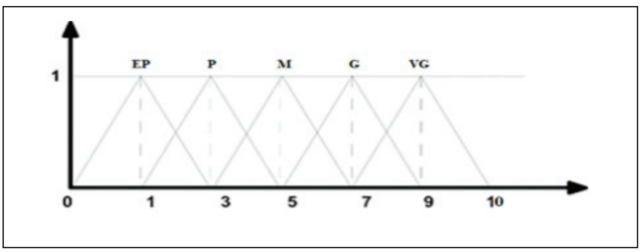
Source: Chen et al., 2006

Figure 2. *Triangular fuzzy numbers (TFNs)*

Step 2: Make fuzzy decision matrix ($\widetilde{D_{ij}}$) including n alternatives and m criteria. Then, by applying fuzzy triangular linguistic variables in *Figure 3*, decision makers should define the value of each alternative based on each criterion.

$$\widetilde{D_{ij}} = \begin{bmatrix} \tilde{X}_{11} & \cdots & \tilde{X}_{1j} \\ \vdots & \ddots & \vdots \\ \tilde{X}_{i1} & \cdots & \tilde{X}_{ij} \end{bmatrix} \qquad \begin{matrix} i = 1,2,\ldots, n \\ j = 1,2,\ldots, m, \end{matrix}$$

where $\tilde{X}_{ij}$ is the value of alternative i based on criterion j.



Source: Chen et al., 2006

Figure 3. *Triangular fuzzy numbers*

Step 3: If the number of decision makers is more than one, the aggregated fuzzy value for $\widetilde{W_j}$ and $\widetilde{D_{ij}}$ should be calculated using equations (1) and (2) respectively.

$$w_{j1} = \min_k \{w_{j1}^k\}, \; w_{j2} = \frac{1}{K}\sum_{k=1}^{k} w_{j2}^k, \; w_{j3} = \max_k \{w_{j3}^k\}$$

$$a_{ij} = \min_k \{w_{ij}^k\}, \; b_{ij} = \frac{1}{K}\sum_{k=1}^{k} b_{ij}^k, \; c_{ij} = \max_k \{c_{ij}^k\},$$

where $W_j^k = (w_{j1}^k, w_{j2}^k, w_{j3}^k)$, and $X_{ij}^k = (a_{ij}^k, b_{ij}^k, c_{ij}^k)$.

$$\widetilde{W}_j = \frac{1}{K}\left[\widetilde{W}_j^1 + \widetilde{W}_j^2 + \cdots + \widetilde{W}_j^k\right] = \frac{1}{K}\sum_{k=1}^{k}\widetilde{W}_j^k \quad (1)$$

$$\widetilde{D_{ij}} = \begin{bmatrix} \frac{1}{K}[\tilde{X}_{11}^1 + \tilde{X}_{11}^2 + \cdots + \tilde{X}_{11}^k] & \cdots & \frac{1}{K}[\tilde{X}_{1j}^1 + \tilde{X}_{1j}^2 + \cdots + \tilde{X}_{1j}^k] \\ \vdots & \ddots & \vdots \\ \frac{1}{K}[\tilde{X}_{i1}^1 + \tilde{X}_{i1}^2 + \cdots + \tilde{X}_{i1}^k] & \cdots & \frac{1}{K}[\tilde{X}_{ij}^1 + \tilde{X}_{ij}^2 + \cdots + \tilde{X}_{ij}^k] \end{bmatrix} = \begin{bmatrix} \frac{1}{K}\sum_{k=1}^{k}\tilde{X}_{11}^k & \cdots & \frac{1}{K}\sum_{k=1}^{k}\tilde{X}_{1j}^k \\ \vdots & \ddots & \vdots \\ \frac{1}{K}\sum_{k=1}^{k}\tilde{X}_{i1}^k & \cdots & \frac{1}{K}\sum_{k=1}^{k}\tilde{X}_{ij}^k \end{bmatrix}, \quad (2)$$

where k is the number of decision makers.

Since fuzzy triangular numbers are used in this study, the two important operations for these numbers are as follows:

Let us suppose $K_1 = (l_1, m_1, u_1)$ and $K_2 = (l_2, m_2, u_2)$ are the two affirmative triangular fuzzy numbers; thus, the two primary functions of TFNs are denoted as below (Kaufmann and Gupta, 1991):

$$K_1 \oplus K_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$

$$K_1 \otimes K_2 = (l_1.l_2, m_1.m_2, u_1.u_2)$$

The distance between two triangulate fuzzy numbers could be calculated as follows:

$$d(K_1, K_2) = \sqrt{\frac{1}{3}\left[(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2\right]}$$

Step 4: Fuzzy decision matrix $\widetilde{D_{ij}}$ normalization:

Fuzzy decision matrix normalization would be calculated as shown below:

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{m.n} \qquad i = 1, 2, \ldots, n \text{ and } j = 1, 2, \ldots, m, \quad (3)$$

where

$$\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^*}, \frac{m_{ij}}{u_j^*}, \frac{u_{ij}}{u_j^*}\right), u_j^* = max\, u_{ij} \qquad \textit{If criterion is positive (benefit criterion)} \quad (4)$$

$$\tilde{r}_{ij} = \left(\frac{l_j^-}{l_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{u_{ij}}\right)\ l_j^- = min\, l_{ij} \qquad \textit{If criterion is negative (negative criterion)} \quad (5)$$

Step 5: Using Equation (6), the weighted normalized fuzzy decision matrix $(\widetilde{V})$ would be computed by multiplying the normalized fuzzy decision matrix $(\tilde{r}_{ij})$ by the criteria weights $(\widetilde{W_j})$.

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{m.n} \quad i = 1,2,\ldots, n \quad \text{and} \quad j = 1,2,\ldots, m, \text{ where } \tilde{v}_{ij} = \tilde{r}_{ij}.\widetilde{W}_j \tag{6}$$

Step 6: Determining alternatives' positive and negative ideal solution.

$$S^* = \{\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*\} \text{ where } \tilde{v}_j^* = \{1,1,1\} \quad j = 1,2, \ldots, n \tag{7}$$

$$S^- = \{\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-\} \text{ where } \tilde{v}_j^- = \{0,0,0\} \quad j = 1,2, \ldots, n \tag{8}$$

Step 7: Computing the distances of all alternatives from the affirmative and negative ideal solution.

$$d_i^* = \sum_{j=1}^{n} d_v\left(\tilde{v}_{ij}, \tilde{v}_j^*\right), \quad i = 1, \ldots, n \quad \text{and} \quad j = 1, \ldots, m \tag{9}$$

$$d_i^- = \sum_{j=1}^{n} d_v\left(\tilde{v}_{ij}, \tilde{v}_j^*\right), \quad i = 1, \ldots, n \quad \text{and} \quad j = 1, \ldots, m, \tag{10}$$

where $d_v(.,.)$ is the distance measurement between two fuzzy numbers.

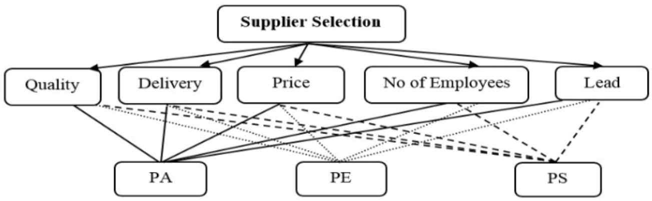
Step 8: Computing the closeness coefficient by applying Equation (11). Considering the value of the closeness coefficient, alternatives would be prioritized. The value of the closeness coefficient varies between zero and one. The ideal alternative is the one with a closeness coefficient close to one.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \tag{11}$$

4. Case Study

The primary goal of this research is selecting an efficient supplier to supply the required raw material for a petrochemical factory in Iran during the COVID-19 situation. The name of the petrochemical factory and the names of suppliers are not disclosed because of the privacy policy of the concerned petrochemical factory and the suppliers. Five senior managers involved in supply chain management in the petrochemical factory are appointed as the main decision makers. The team of decision makers selected three potential suppliers for supplying the required raw material in the petrochemical factory. To assess and choose an efficient supplier based on the literature review, four criteria, i.e. quality, delivery, price, and lead time, were considered by the decision makers. In addition to the four criteria, senior managers decided to take into account the number of the suppliers' employees. Due to the COVID-19 pandemic situation, some factories have encountered financial problems. To overcome such a problem, some of the factories downsize human resources. Decision-makers believed that a decrease in employees' number affects the output of suppliers' production. After initial consensuses regarding the criteria and the alternatives, the fuzzy TOPSIS was applied. Finally, the rank of suppliers will be calculated, and the efficient supplier will be revealed. This study will help the managers of the petrochemical factory to select an appropriate raw material supplier during the COVID-19 pandemic situation.

To solve a multi-criteria decision-making problem, one can first make a hierarchal decision-making tree. In the first level, a goal should be determined. In our study, the goal is supplier selection. Then, the criteria should be placed on the next level and, finally, alternatives on the last level. If there are some sub-criteria, those should be placed on the third level and the alternatives on the fourth level (see *Figure 4*).



Source: author's compilation

Figure 4. *Decision-making tree*

In order to solve a decision-making problem by applying fuzzy TOPSIS, one should first determine the importance of the criteria using linguistic variables (*Table 1*). If there is more than one decision maker, all decision makers should determine the value of each criterion based on linguistic variables. Fuzzy triangular numbers are utilized to convert linguistic variables (*Table 2*).

Table 1. *Criteria weights based on decision makers' ideas*

Criterion	D1	D2	D3	D4	D5
Quality	VH	VH	VH	VH	VH
Geographical Distance	H	M	M	M	L
Price	M	H	VH	M	M
Number of Employees	VH	H	VH	H	VH
Lead Time	H	M	M	H	H

Source: author's work based on decision makers' opinions

Table 2. *Linguistic variables for pairwise comparison of criteria*

Linguistic Variables	Fuzzy Numbers
Totally Low (TL)	(0,0,0.1)
Very Low (VL)	(0,0.1,0.3)
Low (L)	(0.1,0.3,0.5)
Medium (M)	(0.3,0.5,0.7)
High (H)	(0.5,0.7,0.9)
Very High (VH)	(0.7,0.9, 1)
Totally High (TH)	(0.9,1,1)

Source: Chen et al., 2006

The next step is calculating the aggregated fuzzy values of the criteria by applying Equation (1). The criteria's fuzzy weights are represented in *Table 3*.

Table 3. *Criteria fuzzy weights*

Quality	**0.7**	**0.9**	**1.0**
Geographical Distance	0.3	0.5	0.7
Price	0.5	0.7	0.57
Number of Employees	0.6	0.8	0.95
Lead Time	0.4	0.6	0.8

Source: author's calculation

After determining the criteria weights, a decision-making matrix should be formed. Using linguistic variables, all decision makers compared the alternatives according to each criterion (*Table 4*).

Table 4. *Decision matrix*

Criteria	**Alternatives**	**D1**	**D2**	**D3**	**D4**	**D5**
Quality (The quality of raw material)	PA	VG	G	VG	G	G
	PE	G	VG	VG	G	G
	PS	G	G	VG	G	VG
Geographical Distance (The geographical distance of suppliers from the factories)	PA	P	EP	P	M	EP
	PE	VG	G	VG	VG	VG
	PS	G	M	M	G	M
Price (The price of raw material provided by suppliers)	PA	M	P	EP	P	M
	PE	VG	G	M	VG	VG
	PS	M	P	P	P	M
Number of Employees (The number of staff working at the supplier companies)	PA	VG	G	G	G	VG
	PE	G	M	G	M	M
	PS	P	P	M	P	EP
Lead Time (The time between order and the receipt of raw material)	PA	G	VG	M	VG	G
	PE	P	P	EP	G	P
	PS	M	M	P	P	EP

Source: author's calculation

Applying fuzzy linguistics (*Table 5*) to convert linguistic variables, one should then normalize the decision-making matrix using equations (4) and (5). If a criterion is a positive one, Equation (4) should be used at first. If a criterion is a negative one, Equation (5) should be employed. A positive criterion is the one that has an advantage for the petrochemical factory; for example, quality and number of employees are the positive criteria. A negative criterion is the one that does not have an advantage for the factory such as price, delivery, and lead time.

Table 5. *Linguistic variables for the pairwise comparison of alternatives based on criteria*

Linguistic Variables	Fuzzy Numbers
Totally Poor (TP)	(0,0,1)
Extremely Poor (EP)	(0,1,3)
Poor (P)	(1,3,5)
Medium (M)	(3,5,7)
Good (G)	(5,7,9)
Very Good (VG)	(7,9,10)
Excellent (E)	(9,10,10)

Source: Chen et al. 2006

Using Equation (2), the final normalized decision matrix is represented in *Table 6*.

Table 6. *Normalized decision matrix*

Criteria	Alternatives	l	m	u
Quality (+)	PA	5.8	7.8	9.4
	PE	5.8	7.8	9.4
	PS	5.8	7.8	9.4
Geographical Distance (-)	PA	1	2.6	4.6
	PE	6.6	8.6	9.8
	PS	4.2	6.2	8.2
Price (-)	PA	1.4	3	5
	PE	5.8	7.8	9.2
	PS	1.8	3.8	5.8
Number of Employees (+)	PA	5.8	7.8	9.4
	PE	3.8	5.8	7.8
	PS	1.2	3	5
Lead Time (-)	PA	5.4	7.4	9
	PE	2	3.4	5.4
	PS	1.6	3.4	5.4

Source: author's calculation

Calculating the weighted normalized fuzzy decision matrix would be the goal. The final results are represented in *Table 7*. After calculating the weighted decision matrix, the fuzzy positive and negative ideal solution is determined.

The Positive Ideal Solution (P.I.S.) in each column is an element with the maximum value among all the others, and the Negative Ideal Solution (N.I.S.) is the component with the minimum value among all the other components in a column.

Table 7. *Weighted decision matrix*

Criteria	Alternatives	l	m	u
Quality	PA	0.43	0.75	1
	PE	0.43	0.75	1
	PS	0.43	0.75	1
	P.I.S	0.43	0.75	1
	N.I.S	0.43	0.75	1
Geographical Distance	PA	0.30	0.19	0.15
	PE	0.05	0.06	0.07
	PS	0.07	0.08	0.09
	P.I.S	0.30	0.19	0.15
	N.I.S	0.05	0.06	0.07
Price	PA	0.500	0.327	0.159
	PE	0.121	0.126	0.086
	PS	0.389	0.258	0.137
	P.I.S	0.500	0.327	0.159
	N.I.S	0.121	0.126	0.086
Number of Employees	PA	0.370	0.664	0.950
	PE	0.243	0.494	0.788
	PS	0.077	0.255	0.505
	P.I.S	0.370	0.664	0.950
	N.I.S	0.077	0.255	0.505
Lead Time	PA	0.119	0.130	0.142
	PE	0.320	0.282	0.237
	PS	0.400	0.282	0.237
	P.I.S	0.400	0.282	0.237
	N.I.S	0.119	0.130	0.142

Source: author's calculation

To find the final ranks of alternatives, firstly, the sum of Euclidean distance for each component from a positive fuzzy ideal solution and fuzzy negative ideal solution is computed by employing equations (9) and (10). Then, using Equation (11), the closeness coefficient of the alternatives is calculated (*Table 8*).

Table 8. *Closeness coefficient*

	d_i^*	d_i^-	CC_i
PA	0.33	0.85	0.72
PE	0.60	0.49	0.45
PS	0.73	0.62	0.46

Source: author's calculation

Applying fuzzy TOPSIS to choose the most proper supplier for supplying the raw material during the COVID-19 situation, supplier "PA" ranked the first and suppliers "PS" and "PE" ranked the second and third ones respectively (PA ≻ PS ≻ PE).

5. Conclusions and Recommendations

Due to the unexpected and unstable situation created by the COVID-19, most businesses, companies, and factories have encountered different kinds of problems. One of the most important issues that many factories have faced during the COVID-19 pandemic situation was selecting the most appropriate supplier. To select an applicable supplier for the Iranian petrochemical company based on the literature review, four criteria (quality, delivery, price, and lead time) were selected. Although various kinds of criteria have been studied for supplier selection in previous research, "number of employees" has not been studied as a significant criterion in supplier selection. Based on the five decision makers' opinions, the number of employees affects the supplier's production outputs during the COVID-19 pandemic situation. Besides the four criteria, "number of employees" was considered to assess the three suppliers in this research.

Employing a MCDM technique would be an appropriate solution when assessing different alternatives based on several criteria. In this study, the fuzzy TOPSIS technique was employed to assess three suppliers based on five criteria.

The fuzzy set can be applied in case one encounters a vague situation. Due to the unexpected and unpredictable COVID-19 pandemic situation, in this study, fuzzy TOPSIS is applied to assist decision makers in reaching a specific solution.

Applying fuzzy TOPSIS and considering "number of employees" as one of the main criteria, supplier "PA" with a closeness coefficient of 0.72 was selected as the first appropriate supplier for the Iranian petrochemical company. If "number of employees" as one of the main criteria were not considered by decision makers in supplier selection, the rank of the suppliers would be PE ≻ PA ≻ PS, i.e. supplier "PE", which has previously received the lowest closeness coefficient, is the most appropriate supplier for the petrochemical factory. Therefore, considering the number of employees as one of the main criteria in selecting suppliers will help decision makers choose an appropriate supplier during the COVID-19 pandemic situation.

Most previous studies considered cost (Azadi et al., 2015; Orji and Wei, 2014; Wen et al., 2013; Sarkis et al., 2012), quality (Tavana et al., 2016; Jia et al., 2015; Singh et al., 2014; Govindan et al., 2013), lead time (Girubha et al., 2016; Su et al., 2015; Chaharsooghi and Ashrafi, 2014; Wen et al., 2013; Lin et al., 2012), and delivery (Girubha et al., 2016; Azadi et al., 2015; Kuo et al., 2010) as the main criteria for the supplier selection problem. In my study, in addition to the mentioned criteria, "number of employees" is introduced as one of the main important criteria to select the appropriate supplier during an unstable situation such as the COVID-19 pandemic situation. Ignoring such an important criterion may result in a wrong decision regarding supplier selection.

The limitations of this study are as follows: firstly, this study uses only the fuzzy TOPSIS technique for selecting a proper supplier. Other MCDM techniques, such as VIekriterijumsko KOmpromisno Rangiranje (VIKOR), ELimination Et Choice Translating REality (ELECTRE), or a combination of these two, could also have been applied in this study. The Best Worst Method (BWM) could also be employed to achieve criteria weights. Secondly, in this study, a single company is considered as a case study.

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