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2.5 FUZZY TOPSIS METHOD FOR EVALUATION OF OUTSOURCING STRATEGIES

Summary: This paper seeks to investigate the impacts of criteria on evaluation of suppliers, as well as the elements that make the supplier as "the preferred" one.
The Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is used to examine the studied firm's suppliers and find out the important criteria on evaluation of the suppliers. The core of TOPSIS method provides two main solutions; that is by ranking method of the mean of the integral values is applied to help derive the ideal and negative-ideal fuzzy solutions. The ideal and negative-ideal fuzzy solutions open the path to calculate the closeness coefficients. A supplier assessment questionnaire was conducted to three executives who actively work as decision makers on supplier issues of the studied firm. Via questionnaire and interviews, the leading and lagged elements of supplier assessment are sorted by closeness coefficients calculated.
The proposed method is chosen because it is typically used in multi criteria decision-making problems. Supplier topic itself, containing a process of selection (right quality, right price, right time, right quantities etc.), is also a problem for companies hence containing multiple criteria to establish a desirable supply chain which is a core issue of outsourcing.
This study helps the management to identify and sort the importance of criteria and the indicators to enhance the performance of their suppliers and their own business performance eventually.

Keywords: Supplier Chain Management, Outsourcing, Fuzzy TOPSIS, Supplier Assessment

1. INTRODUCTION

Managing the outcomes of globalisation firms generally acts two-sided; the first one is quality and the other one is cost effectiveness. In essence, to gain and sustain competitive advantage firms needed to be in business of total quality management logic where the supplier stands as the origin of the process. Required products and services must be provided with quality-oriented drive under some standards and intended value creation. Moreover, achieving standard quality; the right time, location and quantity become substantive as well.

In order gain success in cost effectiveness the principal thought is to lower the costs by outsourcing that refers to terminate activities excluded in value-creation. Besides, just in time production model with an aspect of desired quantity with minimum stock and storage cost became visible in the current business market. As this production logic emerge for the firms, the selection of supplier and establishment of relationship become more and more important.

In terms of providing success, the suppliers needed to be on the same logic and support the focal firm by all means. In this point, suppliers and firms should not be estimated separately as they are strictly bonded. Various factors such as organizational goals and risks, resources, benefits and capabilities have to be taken into consideration to evaluate and find the right supplier to work via win-win situation. Every criterion may be unique for firms, however, decision and selection period differ as mutual benefits are sought and criterial ranking differs firm to firm. To sustain the relationship short and long-term agreements are generally preferred as the affection is mutual as well.

Due to importance of supplier selection where many criteria needed to be evaluated, a systematic method of fuzzy TOPSIS is being used in this study. To decide the right supplier which is a multi-criteria problem for firms, we have done an evaluation in an aluminium company runs business in Bilecik city of Turkey through modifying TOPSIS tend to be an effective evaluation approach. In this study, we have identified some criteria in order to select the appropriate supplier and decision makers rated them in terms of importance. Modifying TOPSIS model presented which supplier has the significant importance. With previous studies in various industries, we tend to provide decision makers more information to make subtle decisions which is the sight of this paper.

2. LITERATURE REVIEW

The decision problem of selection suppliers can be a complex task as it generally relies on decision makers' judgement with lack of inadequate information and uncertainty, which makes the selection and evaluation process problematic. In the literature, evaluation and performance calculated via using various methods. Fuzzy TOPSIS being one of them, aimed to define alternative criteria are those under consideration requiring reliable solution.

The studies under the name of supplier selection are done in United States, as Dickson (1966) is one of first. In that study, 23 criteria were used as product quality, on time delivery and warranty policy emerged as the leading criteria (Dickson, 1966: 16-17). Liu and Hai (2005) used the criteria of quality, taking responsibility, delivery, financial structure, management, technical capacity, and convenience in supplier evaluation and selection process. Pi and Low (2006) has preferred the criteria of quality, on time delivery, price and service. Dağdeviren and Eren (2001) have chosen one out of four suppliers due to quality, supply performance, cost and technology criteria.

In other study, Küçük and Ecer (2007) have used fuzzy TOPSIS method evaluation of suppliers by using 17 criteria. Durdudiler (2006) used criteria of sales performance, delivery, product return frequency, collaboration, and innovation to determine supplier performance by analytical hierarchy process. Because of ranking the criteria in terms of importance, sales performance was the most important while the sorting continued with delivery, collaboration, product return frequency, and innovation. In order to select the right project, fuzzy TOPSIS method was used and resulted with an ideal model in construction industry (Onursal, 2009).

3. FUZZY SET APPROACH

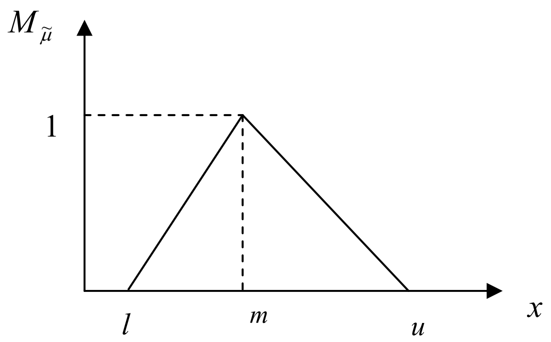
Fuzzy set has theory been introduced by Zadeh (1965) that is an effective approach referring vagueness and ambiguity of the human decision making process (Ecer, 2007). Real world is full of uncertain data in many technical and economical subjects. Fuzzy set approach mainly deals with inherent imprecision while it is also suitable for mathematical programming in the field.

In practice the use of triangular and trapezoidal fuzzy numbers are common. Triangular numbers are used in this study. The membership function of a triangular fuzzy number is shown as $\tilde{\mu}$. Basicly, a triangular fuzzy number is identified as *(l/m/u)*or *(l,m,u)*. Parameters of *l, m* and *u* are; least probable value, the most expected value and the most probable value in order. A triangular membership function is shown in Figure.1 (Özdemir and Seçme, 2009:85-86).

Each triangular fuzzy number has a linear indication of its left and right slide and the indication of membership function is shown as below:

$$\mu(x|\widetilde{M}) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \le x \le m, \\ (u-x)/(u-m), & m \le x \le u, \\ 0, & x > u \end{cases}$$

Figure 1.: Triangular membership function, $\tilde{\mu}$



Source: Özdemir and Seçme, 2009

4. FUZZY TOPSIS METHOD

TOPSIS method can be formulated as; n – dimensional field, m dotted geometric system with m alternative decision-making problem. In basis of alternative selection concept, the chosen alternative should have shortest distance to positive ideal solution while longest distance to negative ideal solution. An identified index of maximization of positive ideal solution and minimization of negative ideal solution determine which alternative is more beneficial with the ideal solution (Yoon and Hwang, 1995).

In literature, there are several fuzzy TOPSIS methods as their differences refer techniques or the numbers used. In some studies triangular fuzzy numbers were chosen while in the other the trapezoid ones. Addition to fuzzy numbers to facilitate the making of solution for group decisions and in linguistic uncertainty, some variables are used which apply words or sentences in a natural or artificial language to describe its degree of value. Fuzzy linguistic terms and their values per criteria are as mentioned below:

Table 1: Fuzzy Linguistic Terms and Their Values per Each Criterion in Triangular Numbers

Very High	(0,9, 1, 1)
High	(0,7, 0,9, 1)
Medium High	(0,5, 0,7, 0,9)
Medium	(0,3, 0,5, 0,7)
Medium Low	(0,1, 0,3, 0,5)
Low	(0, 0,1, 0,3)
Very Low	(0, 0, 1)

Source: Nguyen et. al., 2008

Table 2: Fuzzy Linguistic Terms and Their Values per Each Alternative in Triangular Numbers

Very High	(9, 10, 10)
High	(7, 9, 10)
Medium High	(5, 7, 9)
Medium	(3, 5, 7)
Medium Low	(1, 3, 5)
Low	(0, 1, 3)
Very Low	(0, 0, 1)

Source: Nguyen et. al., 2008.

The steps of fuzzy TOPSIS method are the following:

Step 1: Determining decision makers and selection of criteria

Step 2: Determining the weights of the criteria.

Step 3: Normalize the decision matrix

Step 4: Calculate the aggregate weights for decision matrix.

Step 5: Determine the positive and negative solution.

Step 6: Calculate the distance from the positive ideal solution and the negative ideal solution for each alternative.

Step 7: Calculate the closeness coefficients.

Step 8: Rank the alternatives according to closeness coefficients.

Assume that in a sum of K decision maker with x_{ij}^{K}'s i. alternative's criteria value group; the formula for determination of alternative criterion as below:

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

w_j^K's Formula for weights of importance of the group included j. decision criteria:

$$\tilde{w}_j = \frac{1}{K}\left[w_j^{-1}(+)w_j^{-2}(+)\ldots(+)w_j^{-K}\right] \tag{2}$$

Normalization of decision matrix:

$$\tilde{r}_{ij} = \left(\frac{\tilde{a}_{ij}}{c_j^*}, \frac{\tilde{b}_{ij}}{c_j^*}, \frac{\tilde{c}_{ij}}{c_j^*}\right) \text{ j, benefit related criteria} \tag{3}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \text{ j, cost related criteria} \tag{4}$$

While:

$$c_j^* = \underset{i}{maks}\, c_{ij},\ j \in B \tag{5}$$

$$a_j^* = \min_i a_{ij},\ j \in C \tag{6}$$

Multiplying the aggregate weights for each normalized criterion:

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{mxn},\ i = 1,2,\ldots,m, \qquad j = 1,2,\ldots,n \tag{7}$$

$$\tilde{v}_{ij} = w_j \otimes \tilde{r}_{ij} \tag{8}$$

Determining positive and negative ideal solutions:

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

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

Calculation of the distance from the positive ideal solution and the negative ideal solution for each alternative (Önüt and Soner, 2007):

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

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

Ultimately calculation of the closeness coefficients and ranking of the alternatives accordingly:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \; i = 1,2,\ldots,m \tag{13}$$

5. METHODOLOGY

We aimed to rank the suppliers identifying the benefit scores using fuzzy TOPSIS method. The investigation is done in an aluminium company that has extrusion production, surface treatment, anodising unit, power coating line, mechanical treatment, shrink and cast house.

The studied firm has a 42-year business experience in the industry and is placed as 18th in the 2nd top 500 leading industrial companies' list constituted by ISO (İstanbul Chamber of Industry). Main reason to investigate this company as a case study is; collaboration with numerous suppliers, exporting products in ratio of 42% of total sales, and being one of the leader companies in related industry.

The suppliers included in our method were selected by procurement director and production manager as decision makers. In accordance with decision-makers' perspective and the previous studies were the major steps of criteria assignment. In-depth interview was conducted with duration of 58 min. to collect the data regarding the criteria. We have adopted 18 criteria from Küçük and Ecer (2007) study. Both procurement director and production manager evaluated four suppliers according to importance level of the given criteria. The evaluation form of importance levels of the criteria is shown at Appendix-1.

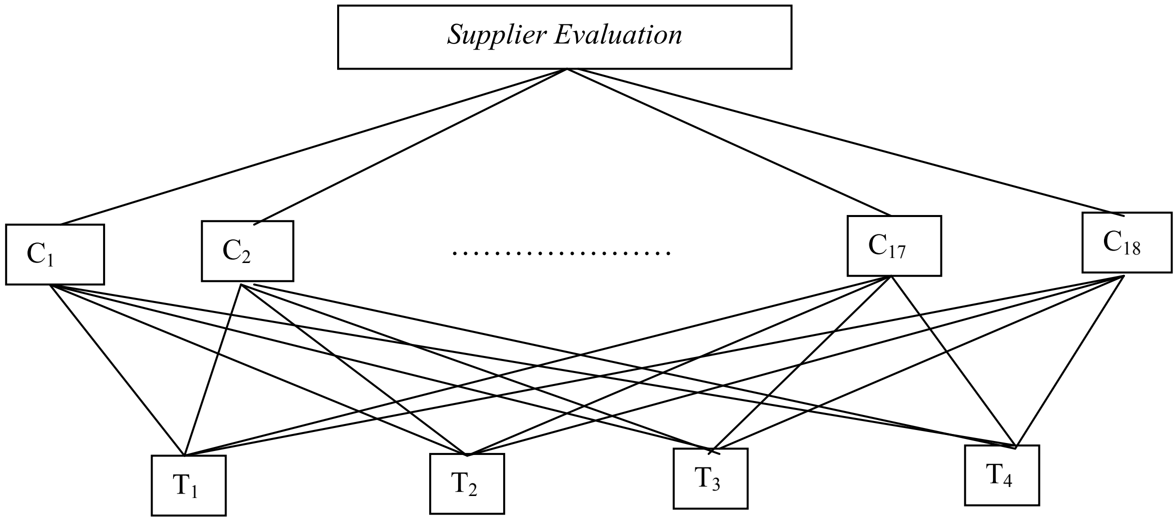
6. SUPPLIER EVALUATION BY FUZZY TOPSIS METHOD

Decision makers (DM1, DM2) have evaluated for suppliers (S1,….,S4) according to decision criteria (C1,….,C18) mentioned below:

(C_1) Price offered by supplier
(C_2) Transportation cost
(C_3) Quality of product
(C_4) Zero defected product
(C_5) Supplier's effort in quality improvement
(C_6) Holding a quality certificate
(C_7) Reliable for on time delivery
(C_8) Compatibility on demand change
(C_9) Easy to communicate
(C_{10}) Wealth of supplier
(C_{11}) Reputation
(C_{12}) Production ability and capacity
(C_{13}) Taking responsibility
(C_{14}) Resolution of conflicts
(C_{15}) Production of exact order quantity
(C_{16}) Delivery packing included
(C_{17}) Technological level
(C_{18}) Geographical distance

The hierarchical structure of decision problem is shown in Figure 2, and the procedure can be summarized as:

Figure 2: Hierarchical Structure



In Figure 2, decision-makers evaluate the decision criteria via linguistic variables. The assessment is shown in Table 3. As referring to formula (2), the most important criteria were "production of exact order quantity" according to decision makers.

Table 3: Assessment of Decision Criteria and Weight of Importance by Decision Makers

	DM_1	*DM_2*	*Weight of Importance*
C_1	H	M	(0.50, 0.70, 0.85)
C_2	H	M	(0.50, 0.70, 0.85)
C_3	VH	H	(0.80, 0.95, 1.00)
C_4	VH	MH	(0.70, 0.85, 0.95)
C_5	MH	MH	(0.50, 0.70, 0.90)
C_6	VH	MH	(0.70, 0.85, 0.95)
C_7	VH	H	(0.80, 0.95, 1.00)
C_8	H	H	(0.70, 0.90, 1.00)
C_9	H	MH	(0.60, 0.80, 0.95)
C_{10}	VH	MH	(0.70, 0.85, 0.95)
C_{11}	H	H	(0.70, 0.90, 1.00)
C_{12}	MH	VH	(0.70, 0.85, 0.95)
C_{13}	H	VH	(0.80, 0.95, 1.00)
C_{14}	VH	H	(0.80, 0.95, 1.00)
C_{15}	VH	VH	(0.90, 1.00, 1.00)
C_{16}	VH	M	(0.60, 0.75, 0.85)
C_{17}	H	H	(0.70, 0.90, 1.00)
C_{18}	H	M	(0.50, 0.70, 0.85)

VH: Very High, H: High, MH: Medium High, M: Medium, ML: Medium Low, L: Low, DM: Decision Maker

Source: By authors

Similar result was found in a study of textile industry; the order inconsistency was an important criteria needed to be considered in supplier evaluation (Taşer and Eğilmez, 2011). Second important criteria emerged as quality of product, being reliable for on time delivery, taking responsibility and resolution of conflicts while for the third one as; compatibility on demand change, reputation, technological level. In the order of importance, the fourth consisted of zero defected products, holding a quality certificate, wealth of supplier, production ability, and capacity. The fifth included Easy to communicate; the sixth Delivery packing included; the seventh Supplier's effort in quality improvement and the last important criteria ranked were price offered by supplier, transportation cost, and geographical distance.

According to Table 2. decision-makers used fuzzy linguistic terms in evaluation of the suppliers. After the evaluation the linguistic terms converted into fuzzy triangular numbers where fuzzy decision matrix, normalized fuzzy decision matrix and aggregated weight fuzzy decision matrix were derived from. Appendix-2, Appendix-3 and Appendix-4 refer to fuzzy decision matrix, normalized fuzzy decision matrix and aggregated weight fuzzy decision matrix in order. Following, A^* (FPIS- fuzzy positive ideal solution) and A^- (FNIS- fuzzy negative ideal solution) were determined. As the decision criteria composed of 18 criteria, meaning that n=18, by using equations of number (9) and (10) it is accepted as below (Chen, 2000:1-9);

A^*=[(1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1, 1, 1), (1,1,1), (1, 1, 1), (1, 1, 1), (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), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0,0,0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0), (0, 0, 0)

Using normalized fuzzy decision matrix, FPIS and FNIS values are calculated. To calculate the distance from FPIS, the members of aggregated weight fuzzy decision matrix extracted from (1, 1, 1). By using Vertex method, FPIS values are calculated via formula no.(11).

Similarly to calculate FNIS, the members of aggregated weight fuzzy decision matrix extracted from (0, 0, 0). By using Vertex method, FPIS values are calculated via formula no.(12).

$$\left.\begin{array}{l}\sqrt{\frac{1}{3}\left[(1-0{,}400)^2+(1-0{,}665)^2+(1-0{,}850)^2\right]}=0{,}4061\\ .\\ .\\ .\\ \sqrt{\frac{1}{3}\left[(1-0{,}450)^2+(1-0{,}700)^2+(1-0{,}800)^2\right]}=0{,}3719\end{array}\right\} d_1^*=5{,}1135$$

and

$$\left.\begin{array}{l}\sqrt{\frac{1}{3}\left[(0-0{,}400)^2+(0-0{,}665)^2+(0-0{,}850)^2\right]}=0{,}6645\\ .\\ .\\ .\\ \sqrt{\frac{1}{3}\left[(0-0{,}450)^2+(0-0{,}700)^2+(0-0{,}800)^2\right]}=0{,}6868\end{array}\right\} d_1^-=14{,}2091$$

In the same way, FPIS and FNIS values are calculated for the alternative suppliers where the results are shown in Table. 4 below.

Table 4: The Distance from A^* and A^-

Suppliers	*Distance From A^**	*Distance From A^-*
S_1	5,1135	14,2091
S_2	5,7419	13,5758
S_3	11,1163	8,0817
S_4	7,8574	11,5754

Source: By Authors

Meaning as the scores, closeness coefficients (CC) and rank order of the suppliers are mentioned as in Table 5 below. Exemplary CC for the first supplier is CC_i=(14,2091)/(5,1135 + 14,2091)=0,7354.

Table 5: CC and Rank Orders of Suppliers

Suppliers	CC_i	*Rank Order*
S_1	0,7354	1
S_2	0,7028	2
S_3	0,4210	4
S_4	0,5957	3

Source: By Authors

As it can be seen from Table 6, in terms of rank order supplier with highest CC is the best. Thus, the best choice of suppliers is as $S_1 > S_2 > S_4 > S_3$.

7. CONCLUSION

In this study we aimed to evaluate four suppliers of an aluminium firm operated in Bilecik under the subject of supplier chain- supplier choice tested via TOPSIS method. According to TOPSIS method, two decision makers responsible for purchasing evaluated alternative suppliers and determined 18 criteria attained the objective of the firm. First, DMs assessed the weights of decision criteria by the linguistic terms of very high, high, medium high, medium, medium low, low, very low and after assessed four alternative suppliers as very good, good, medium good, normal, low good and not good.

One of the most important character of TOPSIS method is to enable giving different weight of importance to decision criteria. In this way, assessment's accuracy and reliability increases. The most important criteria of DMs were "reliable for on time delivery". The assessment using linguistic terms were converted into fuzzy triangular number and in accordance with the TOPSIS algorithm; the aggregated weights and the closeness coefficients for each supplier were calculated and finally ranked in order. In ranking, the first supplier recommended as the best supplier. According to closeness coefficients for each supplier, first ranking with the highest CC is of S_1. Furthermore, CC scores of S_1 and S_2 were in a very close range (0.7354- 0.7028) and draws attention. In situations such as the characteristic of the suppliers alike where making decisions is hard, TOPSIS method happens to be helpful in decision process. The most important factor in implication is, to reach the professionals as decision makers in the industry. In this context, decision makers should be objective, the criteria needed to be settled correctly and so the alternatives and the criteria can be assessed accurately. As fuzzy TOPSIS method is very helpful on the supplier selection in the study, it can be used in various industries where the linguistic terms adequate for comparing many decision criteria to reach the alternatives. It also can be used when the group decision in question such as; human resources management, marketing management, production management and management and organization fields.

Further studies can be done by using ELECTRE, PROMETHEE, VIKOR, VZA, AHP methods as an alternative. The comparison of the findings can be helpful to gain different dimensions for selecting the right supplier.

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Appendix-1 Evaluation of criteria for the importance level

CRITERIA	Very H,gh	High	Medium High	Medium	Medium Low	Low	Very Low
Price offered by supplier							
Transportation cost							
Quality of product							
Zero defected product							
Supplier's effort in quality improvement							
Holding a quality certificate							
Reliable for on time delivery							
Compatibility on demand change							
Easy to communicate							
Wealth of supplier							
Reputation							
Production ability and capacity							
Taking responsibility							
Resolution of conflicts							
Production of exact order quantity							
Delivery packing included							
Technological level							
Geographical distance							

Appendix-2 Fuzzy Decision Matrix

	c7	*c8*	*c9*	*c10*	*c11*	*c12*
T1	(9, 10, 10)	(9, 10, 10)	(8, 9.5, 10)	(8, 9.5, 10)	(7, 9, 10)	(8, 9.5, 10)
T2	(8, 9.5, 10)	(5, 7, 8.5)	(8, 9.5, 10)	(9, 10, 10)	(8, 9.5, 10)	(7, 8.5, 9.5)
T3	(4, 6, 8)	(5, 7, 8.5)	(3, 5, 7)	(1, 3, 5)	(3, 5, 7)	(1.5, 3, 5)
T4	(6, 8, 9.5)	(4, 6, 8)	(5, 7, 8.5)	(3, 5, 7)	(7, 9, 10)	(5, 7, 9)

	c1	*c2*	*c3*	*c4*	*c5*	*c6*
T1	(8, 9.5, 10)	(9, 10, 10)	(8, 9.5, 10)	(7, 9, 10)	(7, 9, 10)	(9, 10, 10)
T2	(7, 9, 10)	(6, 7.5, 8.5)	(8, 9.5, 10)	(8, 9.5, 10)	(8, 9.5, 10)	(9, 10, 10)
T3	(5, 7, 8.5)	(4, 6, 8)	(2 ,4, 6)	(1, 3, 5)	(1, 3, 5)	(0, 0.5, 2)
T4	(6, 8, 9.5)	(3, 5, 7)	(6, 8, 9.5)	(6, 8, 9.5)	(3, 5, 7)	(5, 7, 8.5)

	c13	*c14*	*c15*	*c16*	*c17*	*c18*
T1	(9, 10, 10)	(8, 9.5, 10)	(8, 9.5, 10)	(8, 9.5, 10)	(8, 9.5, 10)	(9, 10, 10)
T2	(6, 8, 9.5)	(8, 9.5, 10)	(9, 10, 10)	(9, 10, 10)	(7, 9, 10)	(5, 7, 8.5)
T3	(3.5, 5, 6.5)	(0.5, 2, 4)	(3, 5, 7)	(5, 7, 8.5)	(5, 7, 8.5)	(8, 9.5, 10)
T4	(6, 8, 9.5)	(5, 7, 9)	(7, 9, 10)	(7, 9, 10)	(6, 8, 9.5)	(4, 6, 8)

Appendix-3 Normalized Fuzzy Decision Matrix

	c1	*c2*	*c3*	*c4*	*c5*	*c6*
T1	(0.8, 0.95, 1)	(0.9, 1, 1)	(0.8, 0.95, 1)	(0.7, 0.9, 1)	(0.7, 0.9, 1)	(0.9, 1, 1)
T2	(0.7, 0.9, 1)	(0.6, 0.75, 0.85)	(0.8, 0.95, 1)	(0.8, 0.95, 1)	(0.8, 0.95, 1)	(0.9, 1, 1)
T3	(0.5, 0.7, 0.85)	(0.4, 0.6, 0.8)	(0.2 ,0.4, 0.6)	(0.1, 0.3, 0.5)	(0.1, 0.3, 0.5)	(0, 0.05, 0.2)
T4	(0.6, 0.8, 0.95)	(0.3, 0.5, 0.7)	(0.6, 0.8, 0.95)	(0.6, 0.8, 0.95)	(0.3, 0.5, 0.7)	(0.5, 0.7, 0.85)

	c7	*c8*	*c9*	*c10*	*c11*	*c12*
T1	(0.9, 1, 1)	(0.9, 1, 1)	(0.8, 0.95, 1)	(0.8, 0.95, 1)	(0.7, 0.9, 1)	(0.8, 0.95, 1)
T2	(0.8, 0.95, 1)	(0.5, 0.7, 0.85)	(0.8, 0.95, 1)	(0.9, 1, 1)	(0.8, 0.95, 1)	(0.7, 0.85, 0.95)
T3	(0.4, 0.6, 0.8)	(0.5, 0.7, 0.85)	(0.3, 0.5, 0.7)	(0.1, 0.3, 0.5)	(0.3, 0.5, 0.7)	(0.15, 0.3, 0.5)
T4	(0.6, 0.8, 0.95)	(0.4, 0.6, 0.8)	(0.5, 0.7, 0.85)	(0.3, 0.5, 0.7)	(0.7, 0.9, 1)	(0.5, 0.7, 0.9)

	c13	*c14*	*c15*	*c16*	*c17*	*c18*
T1	(0.9, 1, 1)	(0.8, 0.95, 1)	(0.8, 0.95, 1)	(0.8, 0.95, 1)	(0.8, 0.95, 1)	(0.9, 1, 1)
T2	(0.6, 0.8, 0.95)	(0.8, 0.95, 1)	(0.9, 1, 1)	(0.9, 1, 1)	(0.7, 0.9, 1)	(0.5, 0.7, 0.85)
T3	(0.35, 0.5, 0.65)	(0.05, 0.2, 0.4)	(0.3, 0.5, 0.7)	(0.5, 0.7, 0.85)	(0.5, 0.7, 0.85)	(0.8, 0.95, 1)
T4	(0.6, 0.8, 0.95)	(0.5, 0.7, 0.9)	(0.7, 0.9, 1)	(0.7, 0.9, 1)	(0.6, 0.8, 0.95)	(0.4, 0.6, 0.8)

Appendix-4 Aggregated Weight Normalized Fuzzy Decision Matrix

	c1	*c2*	*c3*	*c4*
T1	(0.400, 0.665, 0.850)	(0.450, 0.700, 0.850)	(0.640, 0.902, 1.000)	(0.490, 0.765, 0.950)
T2	(0.350, 0.630, 0.850)	(0.300, 0.525, 0.722)	(0.640, 0.902, 1.000)	(0.560, 0.807, 0.950)
T3	(0.250, 0.490, 0.722)	(0.200, 0.420, 0.680)	(0.160, 0.380, 0.600)	(0.070, 0.255, 0.475)
T4	(0.300, 0.560, 0.807)	(0.150, 0.350, 0.595)	(0.480, 0.760, 0.950)	(0.420, 0.680, 0.902)

	c5	*c6*	*c7*	*c8*
T1	(0.350, 0.630, 0.900)	(0.630, 0.850, 0.950)	(0.720, 0.950, 1.000)	(0.630, 0.900, 1.000)
T2	(0.400, 0.665, 0.900)	(0.630, 0.850, 0.950)	(0.642, 0.902, 1.000)	(0.350, 0.630, 0.850)
T3	(0.050, 0.210, 0.450)	(0.000, 0.042, 0.190)	(0.320, 0.570, 0.800)	(0.350, 0.630, 0.850)
T4	(0.150, 0.350, 0.630)	(0.350, 0.595, 0.807)	(0.480, 0.760, 0.950)	(0.280, 0.540, 0.800)

	c9	*c10*	*c11*	*c12*
T1	(0.480, 0.760, 0.950)	(0.560, 0.807, 0.950)	(0.490, 0.810, 1.000)	(0.560, 0.807, 0.950)
T2	(0.480, 0.760, 0.950)	(0.630, 0.850, 0.950)	(0.560, 0.855, 1.000)	(0.490, 0.722, 0.902)
T3	(0.180, 0.400, 0.665)	(0.070, 0.255, 0.475)	(0.210, 0.450, 0.700)	(0.105, 0.255, 0.475)
T4	(0.300, 0.560, 0.807)	(0.210, 0.425, 0.665)	(0.490, 0.810, 1.000)	(0.350, 0.595, 0.855)

	c13	*c14*	*c15*	*c16*
T1	(0.720, 0.950, 1.000)	(0.640, 0.902, 1.000)	(0.720, 0.950, 1.000)	(0.480, 0.712, 0.850)
T2	(0.480, 0.760, 0.950)	(0.640, 0.902, 1.000)	(0.810, 1.000, 1.000)	(0.540, 0.750, 0.850)
T3	(0.280, 0.475, 0.650)	(0.040, 0.190, 0.400)	(0.270, 0.500, 0.700)	(0.300, 0.525, 0.722)
T4	(0.480, 0.760, 0.950)	(0.400, 0.665, 0.900)	(0.630, 0.900, 1.000)	(0.720, 0.675, 0.850)

	c17	*c18*
T1	(0.560, 0.855, 1.000)	(0.450, 0.700, 0.850)
T2	(0.490, 0.810, 1.000)	(0.250, 0.490, 0.722)
T3	(0.350, 0.630, 0.850)	(0.400, 0.665, 0.850)
T4	(0.420, 0.720, 0.950)	(0.200, 0.420, 0.680)