SELECTION OF SUPPLIERS BY FUZZY TOPSIS MODEL; SAMPLE STUDY FROM TURKEY

Ali ELEREN, Ph.D.
Associate Professor
Faculty of Business Administration
Afyon Kocatepe University
Turkey

Cengiz YILMAZ, Ph.D.
Assistant Professor
Faculty of Business Administration
Afyon Kocatepe University
Turkey

Abstract

Health of textile firms relays on several strategic choices including selection of appropriate suppliers which involves consideration of many objective and subjective decision attributes and evaluating process is very complex and costly. Evaluation values for selection of suppliers are expressed with triangular numbers. Fuzzy matrix is appraised by measuring the distances between evolution values of each supplier's values that indicates the intensity of preferences. In according to the intensity of preferences a ranking order is for all suppliers prepared for decision making. Study took place in Uşak/Turkey which includes a survey questionnaire subjected to 102 companies and their owner managers to determine alternative supplier by using TOPSIS model. Results of the study lead us to determine the criterions which are limited to 15 criterions; likewise alternative suppliers are also limited to 9 options. Study aimed to list possible alternative supplier options by using TOPSIS model in according to their scores.

Keywords: Textile firms, fuzzy topsis, supplier selection

1. Introduction

Turkish textile sector was a prior sector in terms of employment and value add in the past. However, it is losing its grounds mainly because of fierce competition since the globalization. Today, small Turkish textile firms are directly competing with the Chinese, Indian and Pakistani firms who are benefiting cheap labor force, which used to be competitive advantage for the Turkish firms in the past, nevertheless not now. Several factors influence the competitiveness of a company; however in this study we only will examine the process of selection of supply chain by using fuzzy TOPSIS model. Correct selection of supply chain would reduce the productions costs (maximizing the profit), increase the customer satisfaction, secure the supply chain, contribute to the workflow, and reduce the inventory levels. Hence, the best selection of supply chain is a strategically important decision and would augment the firm's competitiveness.

In the literature there are several studies used different method for selection of supply chain, for example; Feng, Wang, & Wang (2001) applied a multiple objective programming for the selection, Soukup (1987) applied vendor performance model. Gregory (1986) implemented a matrix approach. Barbarosoglu & Yazgac used an analytic hierarchy model for the selection. Chou and Chang (2008) have implemented strategy-aligned fuzzy (SMART) approach. Chen(2006) developed a new fuzzy approach in fuzzy environment. There several methods exists that are mentioned (or not) in this study and their derivatives in the literature. Decision makers has to choose one which is appropriate for the specific organization

This study consists of two phases. First phase includes the statistical practices where data gathered from 102 weaving firms with the questionnaire which includes 43 questions. Results gave us the managers' perspectives on the criterions which are used for the selection of supply chain. These criterions are listed in according to their level of importance that Selection of the Supplying companies that are subjected to the search, are the ones who had at least one commercial transaction with the decision making company.

Second phase of the study includes the fuzzy TOPSIS practices: three SME are chosen and their managers appointed as decision makers. In this phase decision makers evaluated alternative suppliers with a grading scale starts from 1 pts to 10 pts.

Grading scales are subjected to Fuzzy TOPSIS, suppliers' scores are revealed and listed in according to their rankings for the decision makers' usage.

2. Decision Making with Fuzzy TOPSIS

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is such a technique that multi-variables could be taken into consideration during the decision making process. Technique is developed by Hwang and Yoon (1981) and (Chen, 2000). TOPSIS appraises the solutions both in consideration with the distance from positive ideal solutions and negative ideal solutions. The choices are ranked in according to distances from the best choice to the worst one (Janko and Bernroider, 2005). Following steps are followed during the calculations (Opricovic and Tzeng, 2004):

- Preparation of normalized decision matrix.
- Preparation of weighted decision matrix.
- Determination of positive and negative ideal solutions.
- Calculation of distances from ideal positive and negative solutions.
- Calculation of convergent values and percentage points.
- Ranking of possible solutions.

If decision makers needs to evaluate the solutions in terms of different qualitative and quantitative criterions and then wants to rank them, multi-criterion method should be used for the decision process (Chen, 2001). Triangular fuzzy numbers firstly applied by Negi (1989) in his PhD thesis; it is also mentioned in Chen and Hwang's (1992) book. However, some searchers have elucidated defects of TOPSIS algorithms. For example Chen (2000) evolved the rankings values from 0 to 10. Additionally he also has used the possible maximum and minimum values, $v_j^* = (1,1,1)$ and $v_j^- = (0,0,0)$, during the calculation of positive and negative distances from the ideal solution. Therefore, negative and positive distances became more distinct. Hence, analyst could be able to find out more clear results for rankings and comparisons. Initially, CHU Ta-Chung, (2002) applied the method for multi-criterion problems successfully for selection of plant location.

A triangular fuzzy number "n" is represented as (a,m,b) and μ_n (x) function of membership is expressed as below and represented as figure 1 (Chen, 2000):

$$\mu_n(x) = \begin{cases} 0, x < a \\ \dfrac{x-a}{b-a}, a \le x \le b \\ \dfrac{x-b}{m-b}, m \le x \le b \\ 0, x > b \end{cases} \qquad (1)$$

Insert Figure (1) about here

m=(m_1, m_2, m_3) and n=(n_1, n_2, n_3)

The distance, between triangles, is measured by vertex method and calculated with the following formula (Chen, 2000):

$$d(m,n) = \sqrt{\frac{1}{3}[(m_1-n_1)^2 + (m_2-n_2)^2 + (m_3-n_3)^2]} \qquad (2)$$

Linguistic variables could be expressed with the numbers such as 1,2,3,.. or could be expressed as fuzzy numbers for example: 1 "the lowest" vector weight to 5 the highest vector weight these vectors are linguistic variables (Chen,2000). Chen & et al.,(2005) suggested that ability to work with qualitative and quantitative criteria provides more flexibility to TOPSIS model. That is why fuzzy TOPSIS model is more suitable for problems where there are multi-criterions for decisions and alternative groups. Weighted importance of Different criterions is ranked linguistically by the decision makers. These linguistic variables could be identified as positive fuzzy triangular numbers as Table 1-2 (Chen, 2000):

Insert Table (1) and (2) about here

In literature several studies implemented different scales with 3, 5 and 9 digits however Chen preferred to use 7 digit scales. It is believed that, there is a direct relation in between the size of scale and the model's accuracy. On the other hand, smaller scales might diminish the model's accuracy.

A group of decision makers', which consists of m unit decision makers, x_{ij}^{m} and w_{j}^{m} th decision maker's importance level and its weights according to each criterion could be evaluated as below

$$X_{ij} = \frac{1}{m}[x_{ij}^{1}(+)x_{ij}^{2}(+)...(+)x_{im}^{n}] \quad (3)$$

$$W_{J} = \frac{1}{n}[w_{j}^{1}(+)w_{j}^{2}(+)...(+)w_{j}^{n}] \quad (4)$$

A set of numbers,' with n criterion and m choices, fuzzy matrix and weighted vector could be expressed:

$$D = \begin{matrix} & C_1 & C_2 & \cdots & C_n \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (4)$$

$$W = [w_1 \quad w_2 \quad \cdots \quad w_n]$$

Here x_{ij} ($\forall$i,j) and w_j (j=1,2…,n) are the linguistic variables. These linguistic variables could be defined as triangular fuzzy numbers $x_{ij} = (a_{ij}, b_{ij}, c_{ij})$ and $w_j = (w_{j1}, w_{j2}, w_{j3})$ weighted vectors.

The nature of method requires compatibility in between the objective criterions and subjective linguistic criterions otherwise making comparisons and analyses may not be appropriate. That is why there is a need for normalization which transforms subjective criterions to comparable scales.

Normalized fuzzy decision matrix denoted with R and formulated as;

$$R = [r_{ij}]_{mxn}$$

B is expressed as set of benefit criteria and measured with;

$$r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), \quad j \in B; \quad (5)$$

If $j \in B$ then $c_j^* = \max_i c_{ij}$

With the normalization, subjective criteria could be defined as triangular fuzzy numbers in between 0 and 1.

In consideration of weights and levels of importance, the weighted normalized fuzzy decision matrix can be composed of;

If $V = [v_{ij}]_{mxn}$ i=1,2,…,m , j= 1,2,…,n then the weighted decision matrix is;

$$v_{ij} = r_{ij}(.)w_j \quad (6)$$

According to normalized fuzzy decision matrix $\forall$i,j for v_{ij} elements are positive triangular fuzzy numbers and located in between [0,1] range.

If the positive ideal fuzzy solution (A^*) and the negative ideal fuzzy solution (A^-) then;

$$A^* = (v_1^*, v_2^*, ..., v_n^*)$$

$$A^- = (v_1^-, v_2^-, ..., v_n^-)$$

Here $v_j^* = (1,1,1)$ and $v_j^- = (0,0,0)$.

The distances between each alternative A^* and A^- are respectively:

$$d_i^* = \sum_{j=1}^{n} d(v_{ij}, v_j^*) \quad , \quad i=1,2,\ldots,m \quad (7)$$

$$d_i^- = \sum_{j=1}^{n} d(v_{ij}, v_j^-) \quad , \quad i=1,2,\ldots,m \qquad (8)$$

Here d($_i$) is the distance between two fuzzy numbers.
Closeness coefficient measured by using formula;

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \quad , \quad i=1,2,\ldots,m \qquad (9)$$

Here d_i^* positive distance from the ideal solution and d_i^- is the negative distance from the ideal solution.

3. Selection of Suppliers by Fuzzy TOPSIS Model

Fierce competition in the world requires the selection of most appropriate business choices, strategic decisions. For better strategic choices, understanding manufacturing and marketing practices are the key topics to improve firms' strategic positions. Strategies of the firms might vary; they would prefer to focus on lower cost or on the quality of the goods manufactured. In any case they should focus on choices consistent with the corporate strategy. Gulati (1995-1998) and Balakrishnan & Koza (1993) claims that selection of observations about the partners (suppliers) provides quite valuable information for selection. But Dacin and Hitt (1997) implies that selection of suppliers, screening the potential partners, is a time (cost) consuming process. However, screening partners provides valuable information in terms of potential partners' resources capabilities, reliabilities and appropriateness to the firms' corporate strategies. Lorange and roos (1993) indicates firm's strategic positioning and the strategic importance of the partners are some criterions that should be considered during the selection.

Lin and chen (2004) identified 183 decision attributes for evaluating supply chain candidates and classified them under 8 headings. Cravens et al (2000) suggested the use of balance scorecards to assess the performance evaluation of suppliers. Harvey and Lusch (1995) presented a ranking approach for strategic alliances. Mikhailov (2002) developed a fuzzy approach by using AHP to overcome with fuzziness occurs during the comparison of importance of attributes. Lin and chen (2004) developed a fuzzy decision making framework for selecting supply chain to be allied with. Amid ghodsypour and o'Brien (2006) exhibited a fuzzy multi-objective linear model by applying an asymmetric fuzzy-decision making model. De Boer et al (2001) claims selection of suppliers might consist of four phases (1) problem definition (2) formulation of criterions (3) qualification of suppliers and (4) final selection. Selecting correct suppliers and providing a long term strategic relation with them would provide s strong and efficient supply chain that could seriously maximize the overall value of the manufacturer by reducing costs, reducing supply risk, securing quality of inputs and maximizing the customer satisfaction level.

3.1. Aim and the scope of the study

Aim of the study is to develop and apply a TOPSIS model that could help managers to select most appropriate supplier within the textile sector. Scope of the study is limited by the textile firms actively doing business within the city Uşak in Turkey and these firms' subcontractors. In the textile sector, fibers, pigments, chemicals and other additives are the main materials provided by the suppliers for manufacturing. There are nine textile firms within the region subjected to the study.

3.2. Methodology

The method used for the study consists of two phases. In the first phase; the decision criterions that are used for selection is determined by the questionnaire applied to 102 company manager/owners who are placed in Uşak/Turkey. Questionnaire consists of likert scaled, demographical questions (C.Alpha :0,832). Average wiegths of the criterions (over 2) put into consideration and listed in according to their rankings from Very Poor (1) to Very Good (5), as seen Table 1. These codes are used while determining fuzzy TOPSIS criterion matrix and weights. Questionnaire also provided information about the potential suppliers; later on number of suppliers are reduced (and limited) to 9. Majority of the studies related to TOPSIS method assigned only one decision maker whose personnel convictions might strongly influence the study. Conversely, our study includes three decision makers who are selected in according to their willingness to participate to the study and their technical capabilities. Their preferences weighted and ranked for placement into a one matrix which is used as the decision maker's preferences. Second phase includes the implementation of the fuzzy TOPSIS method for selection of suppliers. Here the enterprises who participated to the survey are classified as small, medium and large firms and the managers are nominated as decision makers.

3.3. Implementation

Implementation phase of fuzzy TOPSIS starts with the collection of preliminary data. Specifically establishing criterion matrix, which is essential for determination of criterions and its weights.

3.3.1. Determination of criterions used for selection of suppliers

Criterions that are used for selection of suppliers are determined by the sample survey that indicates the most important criteria are the cost of materials, the quality of material and securing the supply risk respectively. Obviously managers of the firms are more focused on cost and the quality to become more competitive. This criterion is followed by permanence of the input flow which also indicates that managers are mostly market oriented; they do not want to lose their market shares by interruptions. Here, the interesting consideration is that; integration with the suppliers is the least important criterion by the managers. This is may be because of manufacturers are using standardized inputs and the distances between the suppliers are so small to be neglected and therefore they think anyway we are already integrated with the possible suppliers.

Insert Table (3) about here

Here;

- A_i includes nine woven firms to whom the decision makers are making business with. These firms are different from each other interms of experience, size of capital and turnover, ownership, veriety of product, quality and price. They produce cotton, wool, polymer, yarn, accessories, paint, chemicals and other materials.
- c_i defined as variables of multiple evaluation criterions matrix, such as; cost/ price advantage, quality performance, sustainability, delivery performance, historical quality scores, Quality Assurance Systems, Experiences and References, Reliability, Product Complaints, Flexibility, Financial Status, Level of Knowledge and Technology, Level of Capacity, willingness, and finally integration capability.
- DM_i **:**decision makers, includes three manager/owner selected and appointed as decision makers. They are selected from the 102 candidates who are willing to participate survey and whose technical and managerial capabilities are sufficient enough for the study.

3.3.2. Hierarchical structure

Figure 2 represents the hiyerarchical structure of the selection model. Main purpose of the model is to allocate best possible alternative inconsidaration to criterian and their importance levels. 9 suppliers and 15 criterian are taken into account while evaluation proccess.

Insert Figure (2) about here

3.3.3. Composing criterians and decision matrix

To provide simplicity to the participants whole reviews prepareed in carried out with 5 likert scale, as seen table 4. Later on, this scale is translated into linguistic variables from VP to VG.

Insert Table (4) about here

Decision makers' importance levels on the basis of their criterions are expressed and listed linguistically starting from "very poor" to "very good". Here alternative methods evaluated relativelly in according to criterions. The number of decision makers are three importance levels of criterions are determined and listed linguistically from the lowest to the highest.

Insert Table (5) about here

In Table 5, each criterion are converted into trianguler fuzzy numbers. Decision maker's criterion (DM_1,DM_2,DM_3) are weighted to get the average criterian matrix. Hence decision maker's alternative criterions are simplified. Similar simplificatiıons takes place in the next satges of the study.

Insert Table (6) about here

Table 6 represents linguistic values related to the suppliers. This liguistic values are converted to triple fuzzy numbers. Then, by taking the averages, these values reduced to one column. Linguistic varriables in Tablo 6 are converted to fuzzy triangular numbers (see Table 7).

Insert Table (7) about here

Table 7 represents decision makers' evalutaions of alternative suppliers that is converted to triangular numbers on the basis of each criteria. Here, relative values are calculted inconsideration of evaluations of each decision maker. By using relative values these numbers are normalized.

3.3.4. Determination of all alternatives' distances, by using negative and positive distances

Here $A^* = [(1,1,1), (1,1,1), (1,1,1)]$ assumed as the positive ideal solution and $A^- = [(0,0,0), (0,0,0), (0,0,0)]$ assumed as negative ideal solution which are used as the basis for scoring and ranking. Negative and positive ideal solutions calculated by using A^* and A^- (see formula 7,8) and ideal solutions listed as below.

Insert Table (8) about here

Table 8 results of the study: distances to positive and negative ideal solutions, Closeness Coefficient Values, scores and the ranking of the firms. As table 8 indicates that the best selection as supplier is A_2(%100) which is followed by A_5(%82,9), A_6(%79,4)

4. Conclusion

Globalisation increased the level of competition all over the world. In a highly competitive business environmemt firms especially SME's has to be more carefull while taking their decisions If they are targetting growth or even to survive. Giving most appropriate decision in relation to targetted markets, customers, pricing, costing and supliers (etc.) are vital for the firms. In this study a fuzzy TOPSIS model practiced onto the textile sector companies for the selection of supply chain.

As mentioned before there are several methods and their derivatives can be exercised for the selection of suppliers chains. Since non of these methods is perfect, decision makers has to choose one of them in according to their needs, business environment which can be affected by their experiences and knowledges. However, academicians hasto rearch and try to move forward for finding better soltions and try to make these method applicable to several sectors. In this study we applied to fuzzy logic method to the textile sector in the ligth of determined criterions by using liguistic variables. By using the method, suppliers' status could be exemined and ranked that could be considered as objective information. Study indicates that the main criterions for the selection of supply chains are; costs, quality and sustainablity. According to these criterions the firms: A_2(%100), A_5(%82,9), A_6(%79,4) leaded in the ranking. However, while using the method using profeessionals whose have enough knowledge and experiences about the method and the sector is very important or otherwise method migth mislead the decision makers.

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Table 1: Linguistic Variables for the Importance Weight of Each Criterion. (Chen, 2000)

VP	VERY POOR	0,0	0,0	0,1
P	POOR	0,0	0,1	0,3
MP	MEDIUM POOR	0,1	0,3	0,5
F	FAIR	0,3	0,5	0,7
MG	MEDIUM GOOD	0,5	0,7	0,9
G	GOOD	0,7	0,9	1,0
VG	VERY GOOD	0,9	1,0	1,0

Table 2 linguistic variables for the level of importance (Chen,2000)

VP	VERY POOR	0	0	1
P	POOR	0	1	3
MP	MEDIUM POOR	1	3	5
F	FAİR	3	5	7
MG	MEDIUM GOOD	5	7	9
G	GOOD	7	9	10
VG	VERY GOOD	9	10	10

Table-3: criterions influencing selection of suppliers

Criterions **(C_i)**	**Av.**	**St.Dev**	**1**	**2**	**3**	**4**	**5**	**score**	**code**
1. cost / price advantage	4,21	1,11	7,88%	19,23%	34,23%	32,19%	6,47%	7	VG
2. quality	4,11	0,86	19,62%	21,72%	19,53%	21,04%	18,09%	7	VG
3. continuance	4,04	1,21	18,25%	26,63%	34,38%	12,01%	8,73%	7	VG
4. delivery perf	3,96	1,21	17,32%	15,55%	25,37%	24,33%	17,43%	7	VG
5. historical quality scores	3,89	1,22	11,92%	29,32%	40,11%	8,22%	10,43%	7	VG
6. quality assurance system	3,54	0,82	18,25%	26,63%	34,38%	12,01%	8,73%	6	G
7. experiences and refeernces	3,29	0,94	28,74%	10,55%	9,45%	34,82%	16,44%	5	MG
8. reliability	3,26	0,26	17,81%	22,93%	30,01%	23,11%	6,14%	5	MG
9. product complaints	2,98	0,95	16,04%	39,82%	25,72%	9,83%	8,59%	4	F
10. flexibility	2,92	1,25	18,25%	26,63%	34,38%	12,01%	8,73%	4	F
11. financial positioning	2,75	0,73	3,37%	44,32%	13,89%	25,91%	12,51%	4	F
12. information and tech level	2,42	0,67	12,29%	24,01%	13,19%	40,55%	9,96%	3	MP
13. capacity	2,39	0,73	12,00%	35,01%	40,06%	0,83%	12,10%	3	MP
14. williness	2,22	0,51	6,91%	31,23%	30,55%	21,23%	10,08%	2	P
15 integration with the suppliers	2,04	0,27	8,29%	37,08%	23,37%	19,38%	11,88%	1	VP
AVERAGE (n=102)	3,20								

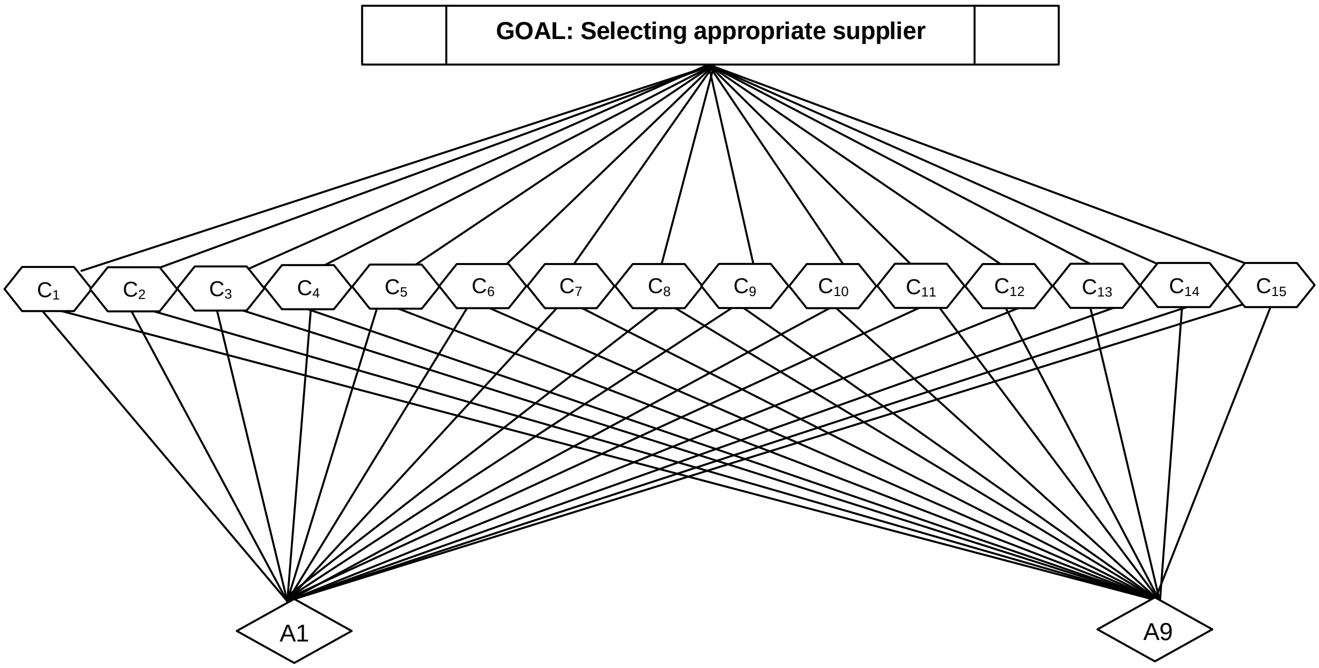

Figure 2 The hierarchical structure of the selection model

Table 4 Determination of Criterians Matrix by Using Lingusitic Variables.

CRITERIONS	DECISION MAKERS		
	DM_1	DM_2	DM_3
C_{01} : Cost / Price Advantages	VG	VG	VG
C_{02} : Quality Performance	VG	VG	G
C_{03} : Sustainability	VG	G	G
C_{04} : Delivery Performance	VG	G	MG
C_{05} : Historical Quality Scores	VG	MG	MG
C_{06} : Quality Assurance Systems	G	G	G
C_{07} : Experiences and References	MG	MG	MG
C_{08} : Reliability	MG	MG	F
C_{09} : Product Complaints	F	F	F
C_{10} : Flexibility	F	F	MP
C_{11} : Financial Status	F	MP	MP
C_{12} : Level of Knowledge and Technology	MP	MP	MP
C_{13} : Level of Capacity	MP	D	D
C_{14} : Willingness	D	D	VP
C_{15} : Integration Capability	VP	VP	VP

Table 5 Determination of Criterians Matrix by Using Triangular Fuzzy Numbers

CRITERIONS	DECISION MAKERS								
	DM_1			DM_2			DM_3		
C_{01}	0,90	1,00	1,00	0,90	1,00	1,00	0,90	1,00	1,00
C_{02}	0,90	1,00	1,00	0,90	1,00	1,00	0,70	0,90	1,00
C_{03}	0,90	1,00	1,00	0,70	0,90	1,00	0,70	0,90	1,00
C_{04}	0,90	1,00	1,00	0,70	0,90	1,00	0,50	0,70	0,90
C_{05}	0,90	1,00	1,00	0,50	0,70	0,90	0,50	0,70	0,90
C_{06}	0,70	0,90	1,00	0,70	0,90	1,00	0,70	0,90	1,00
C_{07}	0,50	0,70	0,90	0,50	0,70	0,90	0,50	0,70	0,90
C_{08}	0,50	0,70	0,90	0,50	0,70	0,90	0,30	0,50	0,70
C_{09}	0,30	0,50	0,70	0,30	0,50	0,70	0,30	0,50	0,70
C_{10}	0,30	0,50	0,70	0,30	0,50	0,70	0,10	0,30	0,50
C_{11}	0,30	0,50	0,70	0,10	0,30	0,50	0,10	0,30	0,50
C_{12}	0,10	0,30	0,50	0,10	0,30	0,50	0,10	0,30	0,50
C_{13}	0,10	0,30	0,50	0,00	0,10	0,30	0,00	0,10	0,30
C_{14}	0,00	0,10	0,30	0,00	0,10	0,30	0,00	0,00	0,10
C_{15}	0,00	0,00	0,10	0,00	0,00	0,10	0,00	0,00	0,10

Table 6 Determination Matrix of Alternative Suppliers by Using Linguistic Variables

CRITERIONS		DECISION MAKERS		
		DM1	DM2	DM3
C_{01} : Cost /Price Advantage	A_1	MG	MG	MG
	A_2	G	G	F
	A_3	F	MP	F
	A_4	VG	G	MG
	A_5	F	MP	MP
	A_6	MG	MG	MP
	A_7	MP	P	P
	A_8	MP	P	P
	A_9	VP	VP	VP
C_{02} : Quality Performance	A_1	F	F	F
	A_2	VG	VG	MG
	A_3	P	P	VP
	A_4	G	VG	MG
	A_5	MP	MP	MP
	A_6	MP	MG	MP
	A_7	P	P	P
	A_8	P	P	VP
	A_9	P	VP	VP
C_{03} : Sustainability	A_1	MP	MP	MP
	A_2	VG	G	G
	A_3	F	F	P
	A_4	P	P	P
	A_5	F	MP	MP
	A_6	MP	MG	MG
	A_7	VP	VP	P
	A_8	MP	P	VP
	A_9	VP	VP	VP
C_{04} : Delivery Performance	A_1	MP	P	MP
	A_2	G	G	G
	A_3	F	VP	MP
	A_4	VG	VG	G
	A_5	VG	VG	VG
	A_6	F	MP	P
	A_7	MP	MP	MP
	A_8	VP	VP	P
	A_9	P	VP	P
C_{05} : Historical Quality Scores	A_1	VG	MP	VP
	A_2	G	G	G
	A_3	MP	MP	VP
	A_4	MP	MP	P
	A_5	MP	P	P
	A_6	MP	F	VP
	A_7	MP	P	VP
	A_8	P	P	P
	A_9	MG	VP	VP

CRITERIONS		DECISION MAKERS		
		DM1	DM2	DM3
C_{06} : Quality Assurance Systems	A_1	F	F	F
	A_2	VG	VG	VG
	A_3	MP	MG	VP
	A_4	G	VG	G
	A_5	VG	VG	VG
	A_6	MG	F	MG
	A_7	VP	F	P
	A_8	MG	F	MP
	A_9	VP	MP	P
C_{07} : Experiences and References	A_1	VP	VP	VP
	A_2	P	P	MP
	A_3	VP	VP	P
	A_4	MP	P	MP
	A_5	VP	VP	VP
	A_6	P	F	MP
	A_7	MG	MP	F
	A_8	MG	MG	MP
	A_9	VP	VP	VP
C_{08} : Reliability	A_1	G	G	VP
	A_2	G	G	G
	A_3	MG	MP	VP
	A_4	MP	P	P
	A_5	VG	VG	VG
	A_6	VG	VG	VG
	A_7	VP	P	VP
	A_8	VP	MP	VP
	A_9	VP	P	VP
C_{09} : Product Complaints	A_1	MG	MG	MG
	A_2	G	VG	G
	A_3	VP	VP	VP
	A_4	MG	MG	MG
	A_5	MG	MG	F
	A_6	G	VG	G
	A_7	VP	VP	VP
	A_8	VG	VG	VG
	A_9	P	P	P
C_{10} : Flexibility	A_1	VP	P	VP
	A_2	VP	P	VP
	A_3	VP	VP	VP
	A_4	P	P	P
	A_5	VG	VG	VG
	A_6	G	G	G
	A_7	VP	VP	VP
	A_8	MG	MG	MG
	A_9	VP	VP	VP

CRITERIONS		DECISION MAKERS		
		DM1	DM2	DM3
C_{11} : Financial Status	A_1	VP	P	VP
	A_2	VP	P	P
	A_3	VP	VP	VP
	A_4	P	P	MP
	A_5	MP	MP	MP
	A_6	P	MP	VP
	A_7	VP	P	VP
	A_8	MP	MP	MP
	A_9	VP	VP	VP
C_{12} : Level of Knowledge and Tec	A_1	VP	VP	VP
	A_2	P	MP	VP
	A_3	VP	VP	VP
	A_4	MP	P	MP
	A_5	VG	VG	G
	A_6	F	MP	MP
	A_7	VG	VG	VG
	A_8	VP	VP	VP
	A_9	MP	MP	MP
C_{13} :Level of Capacity	A_1	F	G	VP
	A_2	MG	VG	G
	A_3	VP	VP	VP
	A_4	MP	G	MG
	A_5	VG	VG	MG
	A_6	MG	VG	F
	A_7	VP	P	VP
	A_8	F	F	F
	A_9	VP	MP	VP
C_{14} :Willingness	A_1	MG	VG	VG
	A_2	P	MP	F
	A_3	VP	P	VP
	A_4	MP	P	P
	A_5	F	F	F
	A_6	MG	VG	VG
	A_7	VP	VG	VP
	A_8	G	VG	G
	A_9	G	G	G
C_{15} : Integration Capability	A_1	G	MP	F
	A_2	MP	MG	MG
	A_3	VP	VP	VP
	A_4	MP	MP	P
	A_5	G	G	G
	A_6	VP	VP	VP
	A_7	VG	VG	F
	A_8	VP	VP	VP
	A_9	MG	MG	F

Table 7 Determination Matrix of Alternative Suppliers by Using Triple Fuzzy Trianguler Variables

CRITERIONS		DECISION MAKERS								
		DM_1			DM_2			DM_3		
C01 : Cost / Price Advantages	A_1	5	7	9	5	7	9	5	7	9
	A_2	7	9	10	7	9	10	3	5	7
	A_3	3	5	7	1	3	5	3	5	7
	A_4	9	10	10	7	9	10	5	7	9
	A_5	3	5	7	1	3	5	1	3	5
	A_6	5	7	9	5	7	9	1	3	5
	A_7	1	3	0	0	1	3	0	1	3
	A_8	1	3	0	0	1	3	0	1	3
	A_9	0	0	0	0	0	1	0	0	1
C02 : Quality Performance	A_1	3	5	7	3	5	7	3	5	7
	A_2	9	10	10	9	10	10	5	7	9
	A_3	0	1	3	0	1	3	0	0	1
	A_4	7	9	10	9	10	10	5	7	9
	A_5	1	3	5	1	3	5	1	3	5
	A_6	1	3	5	5	7	9	1	3	5
	A_7	0	1	0	0	1	3	0	1	3
	A_8	0	1	0	0	1	3	0	0	1
	A_9	0	1	0	0	0	1	0	0	1
C03 : Sustainability	A_1	1	3	5	1	3	5	1	3	5
	A_2	9	10	10	7	9	10	7	9	10
	A_3	3	5	7	3	5	7	0	1	3
	A_4	0	1	3	0	1	3	0	1	3
	A_5	3	5	7	1	3	5	1	3	5
	A_6	1	3	5	5	7	9	5	7	9
	A_7	0	0	0	0	0	1	0	1	3
	A_8	1	3	0	0	1	3	0	0	1
	A_9	0	0	0	0	0	1	0	0	1
C04 : Delivery Performance	A_1	1	3	5	0	1	3	1	3	5
	A_2	7	9	10	7	9	10	7	9	10
	A_3	3	5	7	0	0	1	1	3	5
	A_4	9	10	10	9	10	10	7	9	10
	A_5	9	10	10	9	10	10	9	10	10
	A_6	3	5	7	1	3	5	0	1	3
	A_7	1	3	0	1	3	5	1	3	5
	A_8	0	0	0	0	0	1	0	1	3
	A_9	0	1	0	0	0	1	0	1	3
C05 : Historical Quality Scores	A_1	9	10	10	1	3	5	0	0	1
	A_2	7	9	10	7	9	10	7	9	10
	A_3	1	3	5	1	3	5	0	0	1
	A_4	1	3	5	1	3	5	0	1	3
	A_5	1	3	5	0	1	3	0	1	3
	A_6	1	3	5	3	5	7	0	0	1
	A_7	1	3	0	0	1	3	0	0	1
	A_8	0	1	0	0	1	3	0	1	3
	A_9	5	7	0	0	0	1	0	0	1
C06 : Quality Assurance Systems	A_1	3	5	7	3	5	7	3	5	7
	A_2	9	10	10	9	10	10	9	10	10
	A_3	1	3	5	5	7	9	0	0	1
	A_4	7	9	10	9	10	10	7	9	10
	A_5	9	10	10	9	10	10	9	10	10
	A_6	5	7	9	3	5	7	5	7	9
	A_7	0	0	0	3	5	7	0	1	3
	A_8	5	7	0	3	5	7	1	3	5
	A_9	0	0	0	1	3	5	0	1	3
C07 : Experiences and References	A_1	0	0	1	0	0	1	0	0	0
	A_2	0	1	3	0	1	3	1	3	0
	A_3	0	0	1	0	0	1	0	1	0
	A_4	1	3	5	0	1	3	1	3	0
	A_5	0	0	1	0	0	1	0	0	0
	A_6	0	1	3	3	5	7	1	3	0
	A_7	5	7	0	1	3	5	3	5	0
	A_8	5	7	0	5	7	9	1	3	0
	A_9	0	0	0	0	0	1	0	0	0
C08 : Reliability	A_1	7	9	10	7	9	10	0	0	1
	A_2	7	9	10	7	9	10	7	9	10
	A_3	5	7	9	1	3	5	0	0	1
	A_4	1	3	5	0	1	3	0	1	3
	A_5	9	10	10	9	10	10	9	10	10
	A_6	9	10	10	9	10	10	9	10	10
	A_7	0	0	0	0	1	3	0	0	1
	A_8	0	0	0	1	3	5	0	0	1
	A_9	0	0	0	0	1	3	0	0	1

CRITERIONS		DECISION MAKERS								
		DM_1			DM_2			DM_3		
C09 : Product Complaints	A_1	5	7	9	5	7	9	5	7	9
	A_2	7	9	10	9	10	10	7	9	10
	A_3	0	0	1	0	0	1	0	0	1
	A_4	5	7	9	5	7	9	5	7	9
	A_5	5	7	9	5	7	9	3	5	7
	A_6	7	9	10	9	10	10	7	9	10
	A_7	0	0	0	0	0	1	0	0	1
	A_8	9	10	0	9	10	10	9	10	10
	A_9	0	1	0	0	1	3	0	1	3
C10 : Flexibility	A_1	0	0	1	0	1	3	0	0	1
	A_2	0	0	1	0	1	3	0	0	1
	A_3	0	0	1	0	0	1	0	0	1
	A_4	0	1	3	0	1	3	0	1	3
	A_5	9	10	10	9	10	10	9	10	10
	A_6	7	9	10	7	9	10	7	9	10
	A_7	0	0	0	0	0	1	0	0	1
	A_8	5	7	0	5	7	9	5	7	9
	A_9	0	0	0	0	0	1	0	0	1
C11 : Financial Status	A_1	0	0	1	0	1	3	0	0	1
	A_2	0	0	1	0	1	3	0	1	3
	A_3	0	0	1	0	0	1	0	0	1
	A_4	0	1	3	0	1	3	1	3	5
	A_5	1	3	5	1	3	5	1	3	5
	A_6	0	1	3	1	3	5	0	0	1
	A_7	0	0	0	0	1	3	0	0	1
	A_8	1	3	0	1	3	5	1	3	5
	A_9	0	0	0	0	0	1	0	0	1
C12 : Level of Knowledge and Tec	A_1	0	0	1	0	0	1	0	0	1
	A_2	0	1	3	1	3	5	0	0	1
	A_3	0	0	1	0	0	1	0	0	1
	A_4	1	3	5	0	1	3	1	3	5
	A_5	9	10	10	9	10	10	7	9	10
	A_6	3	5	7	1	3	5	1	3	5
	A_7	9	10	0	9	10	10	9	10	10
	A_8	0	0	0	0	0	1	0	0	1
	A_9	1	3	0	1	3	5	1	3	5
C13 : Level of Capacity	A_1	3	5	7	7	9	10	0	0	1
	A_2	5	7	9	9	10	10	7	9	10
	A_3	0	0	1	0	0	1	0	0	1
	A_4	1	3	5	7	9	10	5	7	9
	A_5	9	10	10	9	10	10	5	7	9
	A_6	5	7	9	9	10	10	3	5	7
	A_7	0	0	0	0	1	3	0	0	1
	A_8	3	5	0	3	5	7	3	5	7
	A_9	0	0	0	1	3	5	0	0	1
C14 : Willingness	A_1	5	7	9	9	10	10	9	10	10
	A_2	0	1	3	1	3	5	3	5	7
	A_3	0	0	1	0	1	3	0	0	1
	A_4	1	3	5	0	1	3	0	1	3
	A_5	3	5	7	3	5	7	3	5	7
	A_6	5	7	9	9	10	10	9	10	10
	A_7	0	0	0	9	10	10	0	0	1
	A_8	7	9	0	9	10	10	7	9	10
	A_9	7	9	0	7	9	10	7	9	10
C15 : Integration Capabilities	A_1	7	9	10	1	3	5	3	5	7
	A_2	1	3	5	5	7	9	5	7	9
	A_3	0	0	1	0	0	1	0	0	1
	A_4	1	3	5	1	3	5	0	1	3
	A_5	7	9	10	7	9	10	7	9	10
	A_6	0	0	1	0	0	1	0	0	1
	A_7	9	10	0	9	10	10	3	5	7
	A_8	0	0	0	0	0	1	0	0	1
	A_9	5	7	0	5	7	9	3	5	7

Table 8 Scoring and ranking of alternative suppliers

Suppliers	**d^+**	**d^-**	**Closeness Coefficient (CC)**	**Score%**	**Ranking**
A_1	20,18	6,97	0,257	61,9%	5
A_2	16,04	11,38	0,415	100,0%	1
A_3	22,70	4,05	0,151	36,5%	7
A_4	18,46	8,86	0,324	78,1%	4
A_5	17,99	9,44	0,344	82,9%	2
A_6	18,36	9,03	0,330	79,4%	3
A_7	23,60	2,93	0,110	26,6%	8
A_8	22,41	4,11	0,155	37,3%	6
A_9	24,72	1,72	0,065	15,7%	9