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Integrated Fuzzy-Dematel, Fuzzy-Topsis Approach for Supplier Selection: A Case Study

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Abstract—*Selection of a good supplier depends on the many criteria. Identification of right and significant criteria is another big exercise and required brainstorming and differs application to application. Results or selection of good supplier is mostly depends on chosen criteria. Keeping in view, in this research, an integrated and two stage frame work has been proposed. In the first stage, Fuzzy DEMATEL is used to identified and rank the significant criteria. This approach has also been used not only for establishing the direct and indirect relations between criteria but also eliminating of insignificant criteria in second stage. In the second stage, results of first stage have been used as input weight to Fuzzy- TOPSIS after eliminating the insignificant criteria. In the proposed research initially five criteria i.e Delivery Time, Cost, Product Quality, Responsiveness (Support & Feedback, Adjustment to client), and Credit Term (Payment Adjustment) have been considered for the selection of a supplier. After first stage, product quality criteria has been eliminated being the least influencing factor as per the industrial case study considered to make the study realistic.*

Keywords*: Fuzzy-DEMATEL, Fuzzy-TOPSIS, Linguistic Variables*

1. INTRODUCTION

Due to increase of completion and fast changing market, selection of good supplier is very important. The whole selection is depending on the criteria which have been used for the ranking for the available suppliers. In this study five criteria have been proposed which are conflicts to each other. Thus for the logical decision MCDM (Multi Criteria Decision Making) is used. The goal of this study is to (1) Identification and ranking of criteria, by fuzzy DEMATEL (2) Selection of the optimal supplier through fuzzy-TOPSIS using weights obtained through fuzzy DEMATEL. There are number of applications where TOPSIS have been successfully applied to resolve the issues. Mohammadi *et al.* [1] used integration of Fuzzy AHP and TOPSIS methods to provide a strong decision support system for derivation of a suitable pattern for cultivation [1]. Yazdi *et al.* [2] demonstrated a new fuzzy hybrid TOPSIS approach for risk matrix with the help of a case study [2]. [3] A Generalised-Fuzzy-TOPSIS method as a versatile evaluation model has been proposed by Dwivedi *et al.* through an example of additive manufacturing technology and material selection. They have also demonstrated sensitivity analyses to assist managers in making more informed decisions [3]. [4] A three-phase methodology to identify barriers and solutions for implementation of green innovation in SMEs a three phase methodology has been employed by Gupta *et al.* using Fuzzy TOPSIS [4]. Sirisawat *et al.* [5] proposed Fuzzy AHP and fuzzy TOPSIS method for classification of reverse logistics barriers and ranking of both barriers and solutions of reverse logistics implementation in the electronics industry [5]. [6.] Han *et al.* Evaluated reverse logistics in the social commerce platform and used fuzzy TOPSIS in conjunction with FLINTSTONES (a software tool) [6]. Ervural at al.[7] proposed an integrated hybrid approach to analyze Turkey's energy sector using SWOT analysis, Analytic Network Process (ANP), TOPSIS to formulate energy strategy alternatives and priorities[7]. Liu *et al.* [8] constructed a risk identification and evaluation framework for charging infrastructure PPP project with integrated fuzzy TOPSIS [8]. A fuzzy TOPSIS technique has been proposed by Walczak *et al.* [9] for the personalized ranking of projects in a participatory budget (PB) [9]. [10] Two new techniques, linguistic fuzzy simple additive weighting (FSAW) and linguistic fuzzy technique for order of preference by similarity to the ideal solution (FTOPSIS) based on ordered fuzzy numbers (OFN) have been proposed by Roszkowska[10] .The systematic method of human errors analysis and TOPSIS and AHP were used to assess the important human error factors in ED by Min-chih et al.[11]. Shen Feng *et al.* proposed a new distance measure between IFSs to prove some of its useful properties. Then based on the proposed distance measure, fuzzy TOPSIS approach is used to handle the MCDM problems. [12]. A new interval type-2 fuzzy TOPSIS model is presented to resolve LGDM problems in complex and uncertain environments. Tong *et al.* [13]. Junior Francisco *et al.* demonstrated a new approach that used SCOR (Supply Chain Operations Reference) model to evaluate the suppliers in the dimensions cost and delivery performance and combines two fuzzy TOPSIS models for evaluating and categorizing the suppliers in four groups as per their performance evaluation.[14]. Pham *et al.* developed a benchmarking framework for selecting the locations of logistics centers based on brainstorming with experts using a hybrid of the fuzzy method and TOPSIS [15]. Marbini *et al.* proposed three versions of fuzzy TOPSIS for selecting undervalued stocks by dint of financial ratios and subjective judgments of experts [16].

The organization of the paper is as follows. Section 2 discusses the proposed methodology. Section 3 discuss the case study of a firm, section 4 solution of problem using integrated approach, section 5 result and discussion.

2. PROPOSED METHODOLOGY

The integrated MCDM methods i.e. DEMATEL and TOPSIS are fused with the Fuzzy Logic to minimize the randomness from the hierarchical values. Decision makers are usually more confident making linguistic judgments than crisp value judgments. DEMATEL having the capability to calculate interdependency between criteria. TOPSIS is also a MCDM technique, in which the most preferred alternative has the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution and vice versa. TOPSIS makes full use of attribute information, provide a ranking to alternative, and does not require attribute preferences to be independent. TOPSIS is easy to compute and easily understood, because the method is directly giving a definite value to calculate their final result. Fig 1 shows the flow chart of the proposed methodology of the integrated approach and Table 1 shows the Linguistic Variables and Triangular Fuzzy Numbers.

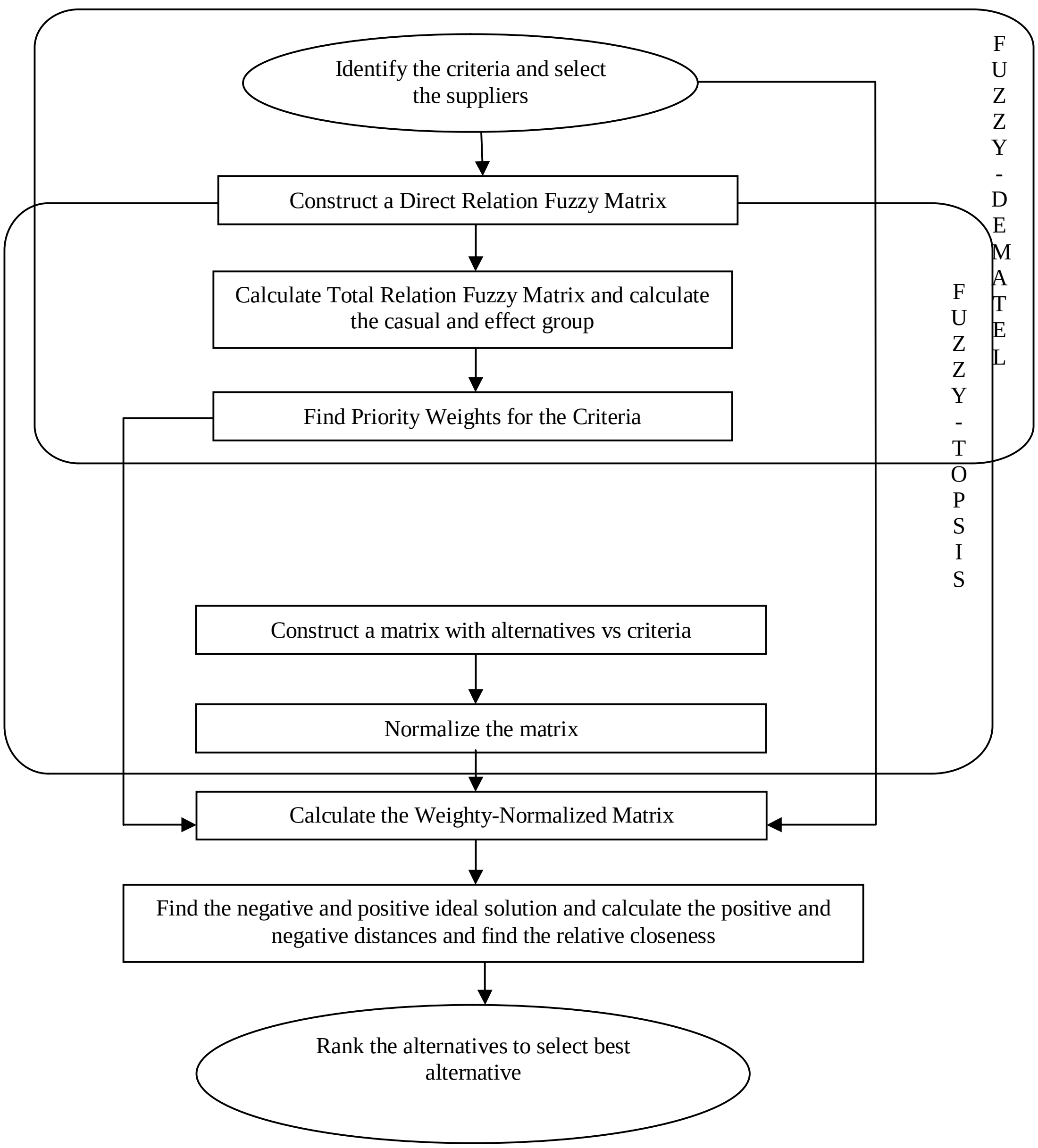

Figure 1: Flowchart of integrated approach

Table 1: Linguistic Variables and TFN

Linguistic Variables	Triangular Fuzzy Numbers
Very Low (VL)	(1,2,3)
Low (L)	(2,3,4)
Good (G)	(4,5,6)
High (H)	(6,7,8)
Very High (VH)	(7,8,9)

Step-1: The decision matrix for criteria v/s criteria will be prepared using DEMATEL approach with the help of following equations, importance of the criteria is calculated as:

$$W_i = \{(\check{D}_i^{def} + \check{R}_i^{def})^2 + (\check{D}_i^{def} - \check{R}_i^{def})^2\}^{\frac{1}{2}} \quad (1)$$

$$\check{D}_i = \left[\sum_{j=1}^{n} t_{ij}\right] \text{ (i = 1, 2, ….., n)} \quad (2)$$

$$\check{R}_i = \left[\sum_{j=1}^{n} t_{ij}\right] \text{ (j = 1, 2, ……, n)} \quad (3)$$

The horizontal axis vector ($\check{D}_i^{def}$+$\check{R}_i^{def}$), called 'Prominence', which represents the importance of the criterion, and the vertical axis vector ($\check{D}_i^{def}$–$\check{R}_i^{def}$), called 'Relation', which divides criteria into a casual group and an effect group. Now, if ($\check{D}_i^{def}$–$\check{R}_i^{def}$) is positive, then the factor belongs to casual group and the factor belongs to the effect group when vector ($\check{D}_i^{def}$–$\check{R}_i^{def}$) is negatively the selected criteria is indirectly effect the selection. The final weight can be calculated by normalizing the value obtained from equation no. 1 by using the equation no. 4 given below:

$$w_i = \frac{W_i}{\sum_{i=1}^{n} W_i} \quad (4)$$

Step 2: Prepare Decision Matrix of Alternatives with respect to Criteria.

Step 3. Normalize Fuzzy Assessment matrix where N_{ij} denotes the Normalized matix.

$$N_{ij} = \left(\frac{l_{ij}}{u_{ij}^*}, \frac{m_{ij}}{u_{ij}^*}, \frac{u_{ij}}{u_{ij}^*}\right), \text{ where} u_{ij}^* = \max_i u_{ij}, \text{ i=1,2, …, m \&j = 1, 2, …, n} \quad (5)$$

Step 4. Calculate the Weighty Normalized Decision Matrix, $V_{ij} = (v_{ij,l}, v_{ij,m}, v_{ij,u})$.

$$V_{ij} = (w_i * N_{ij}) \quad (6)$$

Here, weight (w_i) is used which is calculated through equation no 7.

Step 5. Determine the positive ideal and negative ideal solutions.

$$A^+ = \{v_1^+, v_2^+, \dots\dots\dots, v_n^+\} \{(v_{uj} | j \in J), (v_{dj} | j \in J')\} \quad (7)$$

$$A^- = \{v_1^-, v_2^-, \dots\dots\dots, v_n^-\} = \{(v_{dj} | j \in J), (v_{uj} | j \in J')\} \quad (8)$$

Where J is associated with positive criteria and J' is associated with negative criteria.

Here the value of positive ideal and negative ideal is chosen on the basis of value of 'm_{ij}'. Higher the value of 'm_{ij}', choose the fuzzy set as the positive ideal and lower the value of 'm_{ij}', choose the fuzzy set as negative ideal. In case, if we have equal value of 'm_{ij}' in two fuzzy sets i.e. $(m_{ij})_1 = (m_{ij})_2$, then first fuzzy set is chosen as the positive ideal if $[s(l_{ij} + m_{ij} + u_{ij})_1 > s(l_{ij} + m_{ij} + u_{ij})_2]$ and vice-versa. Now again, if we have equal value of 'm_{ij}' in two fuzzy sets i.e. $(m_{ij})_1 = (m_{ij})_2$, then second fuzzy set is chosen as the negative ideal if $[s(l_{ij} + m_{ij} + u_{ij})_1 > s(l_{ij} + m_{ij} + u_{ij})_2]$ and vice-versa.

Step 6. Compute the distance of each alternative from positive ideal and negative ideal solutions.

$$d_i^+ = \sqrt{\sum_{j=1}^{n}\left[\frac{1}{3}(v_{ij} - v_j^+)^2\right]} = \sqrt{\sum_{j=1}^{n}[\tfrac{1}{3}(l_{ij} - l_j^+)^2 + (m_{ij} - m_j^+)^2 + (u_{ij} - u_j^+)^2]} \text{ i =1,2,…m} \quad (9)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}[\frac{1}{3}(v_{ij} - v_j^-)^2]} = \sqrt{\sum_{j=1}^{n}[\tfrac{1}{3}(l_{ij} - l_j^-)^2 + (m_{ij} - m_j^-)^2 + (u_{ij} - u_j^-)^2]} \text{ i = 1, 2, ….m.} \quad (10)$$

Step 7. Compute the relative distance of each alternative and ranking the alternatives.

$$C_i^- = \frac{d_i^-}{d_i^+ + d_i^-} \text{, i = 1, 2, ……, k} \quad (11)$$

The best possible alternative is determined by the values obtained from equation 21.

3. CASE STUDY

This section provides a case study of a firm where the proposed integrated MCDM approach is applied. This firm procures various types of raw materials i.e. metal sheets of different sizes, metal pipes, tubes, metal rods etc. from the market from various suppliers. After one to one discussion with MD of the firm, and Head, purchase section, it was revealed that the firm focus primarily on five criteria i.e. *Delivery Time*, *Cost*, *Product Quality*, *Product Variable*, *Responsiveness* (Support & Feedback, Adjustment to client), and *Credit Term* (Payment Adjustment). Criteria are considered first to rank using DEMATEL to supply various kinds of raw materials (metal sheets of various sizes and different materials) to the firm. The firm currently places their order as per the need to the five suppliers. The proposed integrated approach in the paper is validated five suppliers using five criteria and. In the interest of the firm, the name of suppliers is kept unknown and named them as SA, SB, SC, SD and SE. To apply the proposed integrated approach, the linguistic variables and triangular fuzzy numbers used is provided in table1. The detailed computational work of the proposed approach is shown in the following section.

4. PROBLEM SOLUTION USING INTEGRATED APPROACH

In this section, proposed integrated approach of Fuzzy-DEMATEL and Fuzzy-TOPSIS is used to rank the suppliers. Section 4.1 provides the calculation of Fuzzy-DEMATEL and Fuzzy-TOPSIS.

4.1 Fuzzy-DEMATEL and Fuzzy TOPSIS

After taking feedback from the management and purchase section a decision matrix was prepared between criteria v/s criteria and with the help of DEMATEL weights of each criteria is calculated and shown in following Table 2

Table 2: Criteria Priority Weights

Criteria	$\check{D}_i$	$\check{R}_i$	$(\check{D}_i^{def} + \check{R}_i^{def})$	$(\check{D}_i^{def} - \check{R}_i^{def})$	W_i	w_i
DT	1.388	0.0938	1.4807	1.2930	1.965	0.258
Cost	0.766	0.2927	1.0573	0.4719	1.157	0.152
PQ	0.3813	0.6626	1.0439	-0.2813	1.081	0.142
Resp.	0.3032	0.9195	1.2227	-0.6163	1.369	0.179
CT	0.1523	0.9209	1.0732	-0.7686	1.320	0.173

From the Table 2, the desired ranking of criteria is DT>RESP>CT>COST>PQ. Delivery Time and Cost are the two casual criteria and rest of three criteria i.e. Product Quality, Responsiveness and Credit Term are indirectly affect the supplier performance and shown by negative sign in the Table 2. the least important criteria is product quality and can be termed as insignificant criteria and can be eliminated from the study for further selection of supplier through fuzzy TOPSIS presented in next section. Above Table and reference has been taken after detail calculations from the unpublished and communicated paper of same authors.

Fuzzy TOPSIS is integrated here with Fuzzy DEMATEL. Input matrix to operate the Fuzzy TOPSIS has been shown below as Table 3.

Table 3: Input Matrix for Fuzzy TOPSIS

Supplier	**DT**	**COST**	**RESP**	**CT**
SA	(0.1411, 0.2026, 0.2786)	(0.1521, 0.2018, 0.2605)	(0.1527, 0.2038, 0.2585)	(0.1537, 0.2035, 0.2568)
SB	(0.1483, 0.2030, 0.2681)	(0.1588, 0.2018, 0.2517)	(0.1441, 0.2012, 0.2729)	(0.1519, 0.2014, 0.2615)
SC	(0.1482, 0.2009, 0.2707)	(0.1481, 0.1982, 0.2697)	(0.1531, 0.2011, 0.2609)	(0.1567, 0.2009, 0.2557)
SD	(0.1413, 0.1967, 0.2851)	(0.1545, 0.1996, 0.2597)	(0.1572, 0.1975, 0.2597)	(0.1443, 0.1967, 0.2768)
SE	(0.1429, 0.1967, 0.2859)	(0.1529, 0.1985, 0.2631)	(0.1456, 0.1964, 0.2764)	(0.1559, 0.1976, 0.2605)

Now normalize the above matrix (Table 3) to obtain the Normalized Decision Matrix given below as Table 4.

Table 4: Normalized Matrix (FTOPSIS)

Supplier	DT	COST	RESP	CT
SA	(0.4935, 0.7086, 0.9745)	(0.5320, 0.7058, 0.9112)	(0.5341, 0.7128, 0.9042)	(0.5376, 0.7118, 0.8982)
SB	(0.5187, 0.7100, 0.9377)	(0.5554, 0.7058, 0.8804)	(0.5040, 0.7037, 0.9545)	(0.5313, 0.7044, 0.9147)
SC	(0.5184, 0.7027, 0.9468)	(0.5180, 0.6932, 0.9433)	(0.5355, 0.7034, 0.9126)	(0.5481, 0.7027, 0.8944)
SD	(0.4942, 0.6880, 0.9972)	(0.5404, 0.6981, 0.9084)	(0.5498, 0.6908, 0.9084)	(0.5047, 0.6880, 0.9682)
SE	(0.4998, 0.6880, 1.0000)	(0.5348, 0.6943, 0.9203)	(0.5093, 0.6870, 0.9668)	(0.5453, 0.6912, 0.9112)

Using equations mentioned above to calculate the weighty normalized matrix. Then choose the positive ideal and negative ideal values by using the equations. Then find the distance from positive ideal and negative ideal values. Table 22, gives the final ranking (called Relative Closeness here) for the Fuzzy TOPSIS method.

Table 5: Relative Closeness (FTOPSIS)

Supplier	**DT**	**COST**	**RESP**	**CT**	**d^+**	**d^-**	**CI^-**
SA	(0.1274, 0.1829, 0.2515)	(0.0809, 0.1074, 0.1386)	(0.0960, 0.1282, 0.1626)	(0.0932, 0.1234, 0.1558)	0.0070	0.5130	0.9866
SB	(0.1339, 0.1833, 0.2420)	(0.0845, 0.1074, 0.1339)	(0.0906, 0.1265, 0.1716)	(0.0921, 0.1222, 0.1586)	0.0154	0.5152	0.9710
SC	(0.1338, 0.1814, 0.2444)	(0.0788, 0.1054, 0.1435)	(0.0963, 0.1265, 0.1641)	(0.0950, 0.1218, 0.1551)	0.0127	0.5139	0.9759
SD	(0.1276, 0.1776, 0.2574)	(0.0822, 0.1062, 0.1382)	(0.0989, 0.1242, 0.1633)	(0.0875, 0.1193, 0.1679)	0.0247	0.5014	0.9531
SE	(0.1290, 0.1776, 0.2581)	(0.0813, 0.1056, 0.1400)	(0.0916, 0.1235, 0.1738)	(0.0946, 0.1198, 0.1580)	0.0291	0.4932	0.9443
A^+	(0.1339, 0.1833, 0.2420)	(0.0809, 0.1074, 0.1386)	(0.0960, 0.1282, 0.1626)	(0.0932, 0.1234, 0.1558)			
A^-	(0.1276, 0.1776, 0.2574)	(0.0788, 0.1054, 0.1435)	(0.0916, 0.1235, 0.1738)	(0.0875, 0.1193, 0.1679)			

Table 5, also shows that Supplier A (SA) is the most desirable supplier with very high ranking value and the Supplier E (SE) is the least possible alternative. Fuzzy-TOPSIS.

5. RESULT AND DISCUSSION

It is clearly predictable that if a supplier is more committed to Delivery Time, more supportive and having good Credit Term with buyer then buyer can also pay slightly higher cost to him. Further, Suppler A is found the best supplier for the considered industrial case study. Supplier B and Supplier C are interchangeably good and both can be preferred depend on the situations. Supplier D and Supplier E is the least desirable

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