SUPPLIER SELECTION IN RISK CONSIDERATION: A FUZZY BASED TOPSIS APPROACH

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Certificate of Approval

This is to certify that the thesis entitled **Supplier Selection in Risk Consideration: A Fuzzy Based TOPSIS Approach** submitted by ***Sri Debadatta Prasad Swain*** has been carried out under my supervision in partial fulfillment of the requirements for the Degree of ***Bachelor of Technology*** in ***Mechanical Engineering*** at **National Institute of Technology**, **NIT Rourkela**, and this work has not been submitted elsewhere before for any other academic degree/diploma.

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Debadatta Prasad Swain

Abstract

Supplier selection, the process of finding the right suppliers who are able to provide the buyer with the right quality products and/or services at the right price, at the right time and in the right quantities, is one of the most critical activities for establishing an effective supply chain. In classical Multi-Criteria Decision Making (MCDM) methods, the ratings and the weights of the criteria are known precisely. Owning to vagueness of the decision data, the crisp data are inadequate for real-life situations. Since human judgments including preferences are often vague and cannot be expressed by exact numerical values, the application of fuzzy concepts in decision making is deemed to be relevant. On the other hand, it is a hard problem since supplier selection is typically a MCDM problem involving several conflicting criteria on which decision maker's knowledge is usually vague and imprecise. In the present work, a risk-based suppliers' evaluation module is proposed. Linguistic values are used to assess the ratings and weights for the risk based supplier selection factors. These linguistic ratings can be expressed in triangular fuzzy numbers. Then, a hierarchy MCDM model based on fuzzy-sets theory is proposed to deal with the supplier selection problems in the supply chain system. According to the concept of the fuzzy TOPSIS (*Technique for Order Preference by Similarity to Ideal Solution*), a closeness coefficient is defined to determine the ranking order of all suppliers by calculating the both fuzzy positive-ideal solution and fuzzy negative-ideal solution, simultaneously. Empirical data have been analyzed and results obtained thereof, have been reported to exhibit application potential of the decision-support systems in appropriate situation.

Keywords: Supplier selection, Multi-Criteria Decision Making (MCDM), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

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1. Introduction and State of Art

Multiple attribute decision making (MADM) approach is often used to solve various decision making and/or selection problems. This approach often requires the decision makers to provide qualitative and/ or quantitative assessments for determining the performance of each alternative with respect to each criterion, and the relative importance of evaluation criteria with respect to the overall objective. Technique for order preference by similarity to an ideal solution (TOPSIS), known as a classical MADM method, has been developed by (Hwang and Yoon, 1981) for solving the MADM problem. If the assessment values are known to have various types of vagueness/imprecision or objectiveness, then the classical decision making techniques are not useful for such problems. We know that TOPSIS is one of the known classical MCDM methods, may provide the basis for developing supplier selection models that can effectively deal with these properties. It bases upon the concept that the chosen alternative should have the shortest distance from the Positive Ideal Solution and the farthest from the Negative Ideal Solution (Vimalet al., 2012).

A supplier may be an external vendor or an upstream process within the firm. SCM requires the coordination of the flow of the products, services and information among SC entities such as supplier, manufacturers, distributors and customers (Toloei Eshlaghy and Kalantary, 2011; Singh, 2012). Selection supplier is a strategic decision in the course of supply chain management. The selection of suppliers depends on the sourcing strategy of the buyer/manufacturer. It helps in optimizing the supply chain and thus increasing the efficiency of the supply chain. An incorrect supplier selection can drive the entire supply chain into confusion (Parthiban et al., 2010). According to (Wang and Elang, 2006), supplier selection or evaluation is the process of finding the supplier who is able to provide the customer with the products or services that have the right quality, the right price, the right quantity and at the right time (Parthiban et al., 2010). According to (Tahriri et al., 2008), "supplier selection problem has become one of the most important issues for establishing an effective supply chain system". Indeed, supplier selection and evaluation represents one of the significant roles of purchasing and supply management function.

In essential, the supplier selection problem in supply chain system is a group decision-making under multiple criteria. The degree of uncertainty, the number of decision makers and the nature of the criteria those have to be taken into account in solving this problem. In classical MCDM methods, the ratings and the weights of the criteria are known precisely (Delgado et al., 1991). Under many conditions, crisp data are inadequate to model real-life situations. Since human judgments including preferences are often vague and cannot estimate his preference with an exact numerical value. A more realistic approach may be to use linguistic assessments instead of numerical values. In other words, the ratings and weights of the criteria in the problem are assessed by means of linguistic variables (Bellman and Zadeh, 1970; Chen, 2000; Delgado et al., 1992; Herrera et al., 1996; Herrera and Herrera-Viedma, 2000). Bhutia and Phipon (2012) developed a methodology to evaluate suppliers in supply chain cycle based on AHP (Analytic Hierarchy Process) and TOPSIS. They have calculated the weights for each criterion based on AHP and then inputted these weights to the TOPSIS method to rank suppliers. In this work, we analyzed the concept of TOPSIS to develop a methodology for solving supplier selection problems in fuzzy environment (Chen, 2000). Considering the fuzziness in the decision data and group decision-making process, linguistic variables are used to assess the weights of all criteria and the ratings of each alternative with respect to each criterion. We can convert the decision matrix into a fuzzy decision matrix and construct a weighted-normalized fuzzy decision matrix once the decision-makers' fuzzy ratings have been pooled. According to the concept of TOPSIS, we define the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS). And, then, we can calculate the Euclidean distance of each alternative from FPIS and FNIS, respectively. Finally, a closeness coefficient of each alternative is defined to determine the ranking order of all alternatives. The higher value of closeness coefficient indicates that an alternative is closer to FPIS and farther from FNIS simultaneously.

2. Procedural Steps for Supplier Selection

Step 1: Recognize Supplier Selection Criteria. These criteria are attributes that a procurement department values in its arrangements with suppliers. Examples include criteria such as Cost & Value, Quality & Safety, and Agility.

Step 2: Determine Supplier Selection Constraints. Here some durable rules are adopted for the supplier selection process. Examples of constraints include: decisions to do business with only one supplier, requirements to select the low bidder, and a specific maximum amount of time in which delivery must take place.

Step 3: Proposed The Hierarchy of Constraints and Criteria. The hierarchy of constraints and criteria is a list of supplier selection constraints and criteria that sorts them in order from most important to least important. This helps to find out the weak characteristic of a supplier and overlooking in order to benefit from a positive characteristic of that supplier.

Step 4: Proposed a Standard Scale. For each criterion, we need to determine a way of awarding a supplier a "scale" of 0 to 1 on the supplier standard scale, with 0 being the worst and 1 being the best, based on the supplier's proposal.

Step 5: Utilize sound judgment in practical matters. While the supplier with the highest total scale value should be the most appreciate supplier, at that time we don't treat supplier selection simply by mathematical tool. At that time we use our professional judgment to determine if the supplier scale value truly led us to the optimal supplier selection. If so, award the business to the best supplier. If not, make the right supplier selection as long as our overriding of the scale value approach is done in strict compliance with ethical and organizational standards. (www.procurementandsupply.com)

2.1. Supplier Selection Criteria: Taxonomy Definitions

Performance indicator	Explanation
Performance Risk	The scale is purported to measure the perceived degree of performance risk associated with a specified product. Performance risk has to do with the uncertainty and consequences of a product failing to function at some expected level. **(www.marketingscales.com)**
Demand Risk	A risk that a demand forecast may not meet the actual consumer demand. A high forecast but low actual demand can mean unnecessary cost for the firm in terms of disposing or storing their surplus. On the other hand, low forecast but high actual demand can mean opportunity cost in terms of lost sales. **(www.businessdictionary.com)**
Environmental risk	Actual or potential threat of adverse effects on living organisms and environment by effluents, emissions, wastes, resource depletion, etc., arising out of an organization's activities. The effective management of environmental risk is often given as a motive for increased corporate engagement with environmental issues. **Roome (1992) and Hunt and Auster (1990)** describe schemes of environmental strategy choices as adhering strictly to environmental legislation (“compliance”) or engaging voluntarily in corporate environmental management to a level beyond that required for compliance with regulations and law (“compliance-plus”). (http://www.mbs.ac.uk)
Process risk	Probability of loss inherent in business processes.
Logistic risk	The science of planning, design, and support of business operations of procurement, purchasing, inventory, warehousing, distribution, transportation, customer support, financial and human resources. A probability or threat of damage, injury, liability, loss, or any other negative occurrence that is caused by external or internal vulnerabilities,

	and that may be avoided through preemptive action. (http://en.wikipedia.org) All business has some level of risk and the task of business is to minimize the risk and maximize the profit. In most cases risk is addressed through insurance, initially physical insurance such as Fire, theft, business interruption, public liability etc. then there are the personal insurances such as life cover, health, professional indemnity, key man etc.**(latus.edu.au)**

3. Fuzzy Preliminaries

3.1. Triangular fuzzy numbers

In a universe of discourse X, a fuzzy subset A of X is defined by a membership function $f_A(x)$, which maps each element x in X to a real number in the interval (0, 1). The function $f_A(x)$ value represents the grade of membership of x in A.

A fuzzy number A (Dubois and Prade., 1978), in real line is a triangular fuzzy number if its membership function $f_A : R \rightarrow (0, 1)$ is

$$f_A(x) = \begin{cases} (x-c)/(a-c), & c \le x \le a \\ (x-b)/(a-b), & a \le x \le b \\ 0 & otherwise \end{cases}$$

With $-\infty < c \le a \le b < \infty$.The triangular fuzzy number can be denoted by (c, a, b).

The parameter a gives the maximal grade off $f_A(x)$, i.e. $f_A(a) = 1$; it is the most probable value of the evaluation data. In addition, 'c'and 'b' are the lower and upper bounds of the available area for the evaluation data. They are used to reflect the fuzziness of the evaluation data. The narrower the interval (c, b), the lower the fuzziness of the evaluation data and the triangular fuzzy numbers are easy to use and easy to interpret. Here Fig.3. 1 represents triangular fuzzy number and Fig.3. 2 represents the crisps number (C_v).

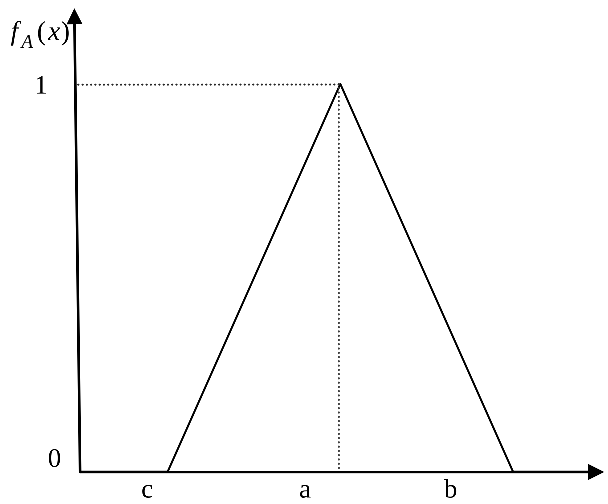

Fig.3.1: Triangular Fuzzy Numbers

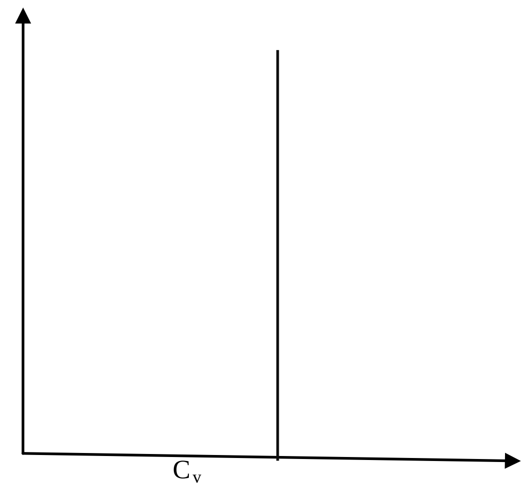

Fig.3.2: Crisp number

Let $A_1 = (c_1, a_1, b_1)$ and $A_2 = (c_2, a_2, b_2)$ be fuzzy numbers. According to the extension principle (Zadeh, 1965), the algebraic operations of any two fuzzy numbers A_1 and A_2 can be expressed as

• Fuzzy addition, $\oplus$:

$$A_1 \oplus A_2 = (c_1 + c_2, a_1 + a_2, b_1 + b_2),$$

(1)

• Fuzzy subtraction, (-):

$$A_1 - A_2 = \left(c_1 - c_2, a_1 - a_2, b_1 - b_2\right), \quad (2)$$

• Fuzzy multiplication, $\otimes$:

$$k \otimes A_2 = (kc_2, ka_2, kb_2), \quad k \in R, \quad k \geq 0,$$

$$A_1 \otimes A_2 \cong (c_1 c_2, a_1 a_2, b_1 b_2), \quad c_1 \geq 0, \quad c_2 \geq 0, \quad (3)$$

• Fuzzy division, (/) :

$$A_1 / A_2 = (c_1 / b_2, a_1 / a_2, b_1 / c_2), \quad c_1 \geq 0, \quad c_2 \geq 0. \tag{4}$$

3.2. Fuzzy TOPSIS

Unlike AHP, fuzzy TOPSIS is a group decision-making process, where a group of decision-makers are enquired for their opinion on a subject matter. Generally the MCDM problems may be divided into two types of problems. One is the classical MCDM problems, in which the ratings and the weights of criteria are measured in crisp numbers (Yoon and Hwang, 1985; Parkan and Wu, 1999; Chu, 2002). Under many conditions, crisp numbered data are inadequate to model real-life situations since human judgments including preferences are often vague. Another is the fuzzy multi-criteria group decision-making (FMCGDM) problems, in which the ratings and the weights of criteria evaluated on imprecision, subjectivity and vagueness usually expressed by linguistic terms and then set into fuzzy numbers (Chen et al., 2006; Yang and Hung, 2007; Shih et al., 2007). The judgment values of linguistic data are quantified with triangular fuzzy numbers (TFNs). The reason for using TFNs to capture the vagueness of the linguistic assessments is that TFN is intuitively easy to use (Liang and Wang, 1994). The underlying logic of TOPSIS proposed by (Hwang and Yoon, 1981) is to define the ideal solution and negative ideal solution. The ideal solution is the solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution is the solution that maximizes the cost criteria and minimizes the benefit criteria. The best alternative is the one which has the shortest distance from the ideal solution and the farthest distance from the negative ideal solution. In this paper, we extend the concept of TOPSIS to develop a methodology for the selection of reverse logistics provider in fuzzy environment. Some basic definitions of fuzzy sets, fuzzy numbers and linguistic variables are reviewed from (Zimmermann, 1991; Chen, 1996;

Cheng and Lin, 2002; and Kannan, 2008). A FMCGDM problem with '*m*' alternatives and '*n*' criteria can be expressed in matrix format as given below:

$$y = (f_{ij})_{m\times n} = \begin{matrix} \\ f_1 \\ f_2 \\ \vdots \\ f_m \end{matrix} \begin{pmatrix} x_1 & x_1 & \cdots & x_n \\ f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mn} \end{pmatrix}$$

where, f_1, f_2, . . ., f_m are feasible alternatives, x_1, x_2, . . ., x_n are evaluation criteria, f_{ij} is the performance rating given by the decision-makers to alternative f_i against criterion X_j, and W_j is the weight of criterion X_j.

3.2.1. The Fuzzy TOPSIS based Ranking Procedure

TOPSIS (technique for order preference by similarity to ideal solution) method was firstly proposed by (Hwang and Yoon, 1981). The basic concept of this method is that the chosen alternative (appropriate alternative) should have the shortest distance from the positive ideal solution and the farthest distance from negative ideal solution. Positive ideal solution is a solution that maximizes the benefit criteria and minimizes adverse criteria, whereas the negative ideal solution minimizes the benefit criteria and maximizes the adverse criteria. The steps involved in TOPSIS method are as follows:

Step 1: A panel of five experts (decision-makers) was formed, and then identifies the evaluation criteria.

Step 2: Every decision-maker states the importance level (weight) of each criterion using a linguistic variable.

Step 3: Evaluate the ratings of alternatives with respect to each criterion using linguistic rating variables.

Step 4**:** Construct a fuzzy multi-criteria group decision making (FMCGDM) matrix, which consist crisps values of criteria and alternatives. The crisps value C_V is calculated as,

$$C_v = \frac{c + (4 \times a) + b}{6} \tag{5}$$

Where, a, b, c are the triangular fuzzy elements

Step 5: Construct the normalized decision matrix. The normalized value r_j is calculated as,

$$r_j = \frac{f_j}{\sqrt{\sum_{j=1}^{n} f_j^2}} \tag{6}$$

Step 6: Construct weighted normalized decision matrix. The weighted normalized v_j is calculated as,

$$v_j = w \times r_j \tag{7}$$

Step 7: Determine positive ideal solution (maximum value on each criterion) and negative ideal solution (minimum value on each criterion) from the weighted normalized decision matrix. In the below equation F^1 is the set of benefit criteria and F^2 is the set of cost criteria.

$$V^{*+} = \left\langle \begin{array}{ll} \max\limits_{1 \le j \le n}(v_j) & (f_j \in F^1) \\ \min\limits_{1 \le j \le n}(v_j) & (f_j \in F^2) \end{array} \right. \tag{8}$$

$$V^{*-} = \left\langle \begin{array}{ll} \max\limits_{1 \le j \le n}(v_j) & (f_j \in F^1) \\ \min\limits_{1 \le j \le n}(v_j) & (f_j \in F^2) \end{array} \right. \tag{9}$$

Step 7: Calculate the Euclidean distance between positive ideal solution and negative ideal solution for each alternative.

$$D^{*+}(x_j) = \sqrt{\sum_{j=1}^{m}(v_j - V^{*+})^2} \tag{10}$$

$$D^{*-}(x_j) = \sqrt{\sum_{j=1}^{m}(v_j - V^{*-})^2} \tag{11}$$

Step 8: Calculate the closeness coefficient of each alternative.

$$C^{*}(x_j) = \frac{D^{*-}(x_j)}{D^{*+}(x_j) + D^{*-}(x_j)} \tag{12}$$

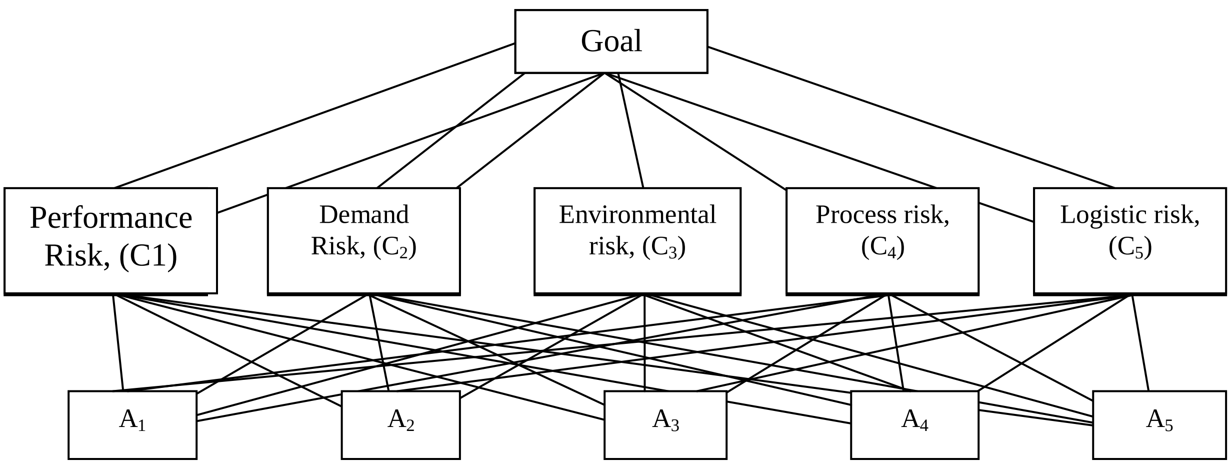

Fig. 3.3: Hierarchical structure of decision problem

4. Empirical research

Supplier selection is an important part of the business as well as production strategy for industrial organizations. Selection of best supplier enhances the quality and economic growth of enterprise but, still it is being a difficult task to select an appropriate supplier. Therefore, the proposed model has been used to evaluate and select the most suitable supplier of an automobile parts manufacturing industry in India.

Aforesaid appraisement module has been adopted as case application in an automobile parts manufacturing industry in India. A single-level performance appraisal hierarchy has been designed as shown in Table 4.1.

Table 4.1: Evaluation Index System of Supplier Selection

Evaluation Index of Supplier Selection, C	Performance Risk, (C_1)
	Demand Risk, (C_2)
	Environmental risk, (C_3)
	Process risk, (C_4)
	Logistic risk, (C_5)

For evaluating priority weight of evaluation indices, a committee of five decision-makers (DMs), has been formed to express their subjective preferences in linguistic terms. In order to provide priority weight against various criteria; the decision-making group has been instructed to use the following linguistic terms: **Very Low (VL)**, **Low (L)**, **Medium (M)**, **High (H)**, and **Very High (VH)**. Similarly, the decision-making group has also been instructed to use the linguistic scale to express their subjective judgment against performance rating of each evaluation indices of alternatives. The following linguistic scale has been utilized to assign performance appropriateness rating against indices: **Negligible (N)**, **Minor (M)**, **Tolerable (T)**, **Alarming (A)** and **Extreme (E)**. The five-member linguistic terms and their corresponding fuzzy numbers are shown in Table 4.2.

Table 4.2: Five-member linguistic terms and their corresponding fuzzy numbers

Linguistic terms for weight assignment	Linguistic terms for ratings	fuzzy numbers
Very low, VL	Negligible, N	(0.00, 0.00, 0.25)
Low, L	Minor, M	(0.00, 0.25, 0.50)
Medium, M	Tolerable, T	(0.25, 0.50, 0.75)
High, H	Alarming, A	(0.50, 0.75, 1.00)
Very High, VH	Extreme, E	(0.75, 1.00, 1.00)

After the linguistic variables for assessing the performance ratings and priority weight of different evaluation indices has been accepted by the decision-makers (DMs), the decision-makers have been asked to use aforesaid linguistic scales to assess performance rating against each of the alternatives criteria shown in Tables 4.4-4.8. Similarly, subjective priority weight evaluation index has been assessed by the DMs and that sown in Table 4.3.

Table 4.3: Fuzzy priority weight (in linguistic scale) of indices assigned by DMs

Performance metrics	Priority weights in linguistic term				
	DM1	DM2	DM3	DM4	DM5
C_1	VH	VH	H	H	H
C_2	H	H	H	H	VH
C_3	H	VH	H	VH	H
C_4	VH	VH	VH	VH	VH
C_5	H	M	H	H	H

Table 4.4: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative1)**

Performance metrics	Ratings in linguistic term(A_1)				
	DM1	DM2	DM3	DM4	DM5
C_1	T	A	A	A	A
C_2	A	A	T	E	E
C_3	A	A	A	E	E
C_4	A	E	E	E	A
C_5	E	E	E	E	A

Table 4.5: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative2)**

Performance metrics	Ratings in linguistic term (A_2)				
	DM1	DM2	DM3	DM4	DM5
C_1	T	T	A	T	T
C_2	T	T	A	A	E
C_3	A	A	A	E	E
C_4	A	T	T	T	A
C_5	A	A	E	E	E

Table 4.6: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative3)**

Performance metrics	Ratings in linguistic term (A_3)				
	DM1	DM2	DM3	DM4	DM5
C_1	T	A	A	T	T
C_2	A	A	T	T	E
C_3	A	T	T	T	T
C_4	T	A	A	A	E
C_5	A	T	T	E	E

Table 4.7: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative4)**

Performance metrics	Ratings in linguistic term (A_4)				
	DM1	DM2	DM3	DM4	DM5
C_1	A	A	T	T	M
C_2	A	A	T	M	M
C_3	T	T	T	M	M
C_4	A	T	T	T	T
C_5	A	A	T	M	M

Table 4.8: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative5)**

Performance metrics	Ratings in linguistic term (A_5)				
	DM1	DM2	DM3	DM4	DM5
C_1	A	T	T	T	T
C_2	T	T	M	M	M
C_3	T	M	M	M	M
C_4	A	M	M	N	N
C_5	A	M	T	N	M

Using the concept of Triangular Fuzzy Numbers (TFNs) in fuzzy set theory, the linguistic variables have been approximated by Triangular Fuzzy Numbers. Next, the aggregated decision-making cum evaluation matrix has been constructed. The aggregated fuzzy appropriateness rating against an individual index with corresponding importance weight has been computed.

By using the fuzzy operational rules (Eq. 1-4), estimating the aggregated weight as well as aggregated rating (pulled opinion of th*e* decision-makers) for each of the selection criterion and then convert linguistic term assigned (indices) by DMs to fuzzy number strictly follow the Five-member linguistic terms and their corresponding fuzzy numbers. So, the aggregated fuzzy priority weight and aggregated fuzzy rating of indices calculated values are shown in Table 4.9 and Table 4.10, respectively.

Table 4.9: Aggregated Priority weight (Level) and calculated crisps value

Level	Aggregated fuzzy weight, w_i	Crisps Value(C_V)
C_1	[0.60, 0.85, 1.00]	0.833
C_2	[0.55, 0.80, 1.00]	0.792
C_3	[0.60, 0.85, 1.00]	0.833
C_4	[0.75, 1.00, 1.00]	0.958
C_5	[0.45, 0.70, 0.95]	0.700

Table 4.10: Aggregated Appropriateness rating (Level) (Alternative1-5)

Level	Alternative-1	Alternative-2	Alternative-3	Alternative-4	Alternative-5
C_1	[0.45, 0.70, 0.95]	[0.30, 0.55, 0.80]	[0.35, 0.60, 0.85]	[0.30, 0.55, 0.80]	[0.30, 0.55, 0.80]
C_2	[0.55, 0.80, 0.95]	[0.45, 0.70, 0.90]	[0.45, 0.70, 0.90]	[0.25, 0.50, 0.75]	[0.10, 0.35, 0.60]
C_3	[0.60, 0.85, 1.00]	[0.60, 0.85, 1.00]	[0.30, 0.55, 0.95]	[0.15, 0.40, 0.65]	[0.05, 0.30, 0.55]
C_4	[0.65, 0.90, 1.00]	[0.35, 0.60, 0.85]	[0.50, 0.75, 0.95]	[0.30, 0.55, 0.80]	[0.10, 0.25, 0.50]
C_5	[0.70, 0.95, 1.00]	[0.65, 0.90, 1.00]	[0.50, 0.75, 0.90]	[0.25, 0.50, 0.75]	[0.15, 0.35, 0.60]

After estimated aggregated fuzzy priority weight and aggregated fuzzy rating of indices, then we proceed after converted the indices in to crisp value of estimated aggregated fuzzy priority weight and aggregated fuzzy rating by using Eq. (5) and the vales are shown in Table 4.9 (crisps weight value) and Table 4.11 (crisps rating value). Then we constructed a fuzzy multi-criteria group decision making (FMCGDM) matrix (Table 4.11).

Table 4.11: A fuzzy multi-criteria group decision making (FMCGDM) matrix

Alternatives	Criteria				
	C_1	C_2	C_3	C_4	C_5
A_1	0.700	0.783	0.833	0.875	0.917
A_2	0.550	0.692	0.833	0.600	0.875
A_3	0.600	0.692	0.575	0.742	0.733
A_4	0.550	0.500	0.400	0.550	0.500
A_5	0.550	0.350	0.300	0.267	0.358

Then we normalized the fuzzy multi-criteria group decision making (FMCGDM) matrix by help of Eq. (6) and the normalized decision matrix shown in Table 4.12.

Table 4.12: Normalized Decision Matrix

Alternatives	Criteria				
	C_1	C_2	C_3	C_4	C_5
A_1	0.528	0.562	0.594	0.611	0.577
A_2	0.415	0.496	0.594	0.419	0.551
A_3	0.453	0.496	0.410	0.518	0.462
A_4	0.415	0.359	0.285	0.384	0.315
A_5	0.415	0.251	0.214	0.186	0.225

After constructed the normalization decision matrix, we proceed to calculate weighted normalized decision Matrix by using Eq. (7) and shown in Table 4.13.

Table 4.13: Weighted Normalized Decision Matrix

Alternatives	Criteria				
	C_1	C_2	C_3	C_4	C_5
A_1	0.440	0.445	0.495	0.585	0.404
A_2	0.346	0.393	0.495	0.401	0.386
A_3	0.377	0.393	0.341	0.496	0.323
A_4	0.346	0.284	0.237	0.368	0.220
A_5	0.346	0.199	0.178	0.179	0.158

Then we calculated the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS) by using Eq. (8- 9) and the values are shown in Table 4.14.

Table 4.14: Positive and Negative Ideal Solution

Ideal solution	Criteria				
	C_1	C_2	C_3	C_4	C_5
V_1*^+	0.346	0.199	0.178	0.179	0.158
V_2*^-	0.440	0.445	0.495	0.585	0.404

According to the concept of TOPSIS, we calculated the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS). And, then, we can calculate the Euclidean distance of each alternative from FPIS and FNIS, respectively. Finally, a closeness coefficient of each alternative is calculated by using the Eq. (10-12) to determine the ranking order of all alternatives. The higher value of closeness coefficient (**0.000, 0.304, 0.326, 0.656** and **1.000**) indicates that an alternative is closer to FPIS and farther from FNIS simultaneously. According to the closeness coefficient (C*), the ranking of each alternative are shown in Table 4.15.

Table 4.15: The Distance of alternative to positive/negative ideal solution, the related closeness coefficient and ranking

Alternatives	Distance $D*^+$	Distance $D*^-$	Closeness coefficients(C*)	Ranking
A_1	0.629	0.000	0.000	5
A_2	0.489	0.214	0.304	4
A_3	0.439	0.212	0.326	3
A_4	0.224	0.427	0.656	2
A_5	**0.000**	**0.629**	**1.000**	**1**

The fuzzy TOPSIS method is very flexible. According to the closeness coefficient(C*), we can determine not only the ranking order but also the assessment status of all possible suppliers.

Significantly, the proposed method provides more objective information for supplier selection and evaluation in supply chain system. Here we finalized the alternative $\mathbf{A_5}$ is best alternative supplier.

5. Conclusion

In supply chains, relationship between a manufacturer and suppliers is typically a difficult and important link in the channel of distribution. The study discussed that how to select the best supplier in supplier selection problems when decision makers set the target value (expected level) of each criterion. Although many approaches can solve the problem, the study proposed an effective direction and a procedure to fuzzy-TOPSIS method to solve the problem.

The main advantages of using TOPSIS method are "TOPSIS logic is rational and understandable", "The computation processes are straightforward", "The concept permits the pursuit of best alternatives criterion depicted in an easy procedural steps" and "The importance weights are incorporated comparison procedures" (Shahroudi and Tonekaboni, 2012). Therefore, decision making for selection of suitable supplier is of special importance.

This method is also simple to understand and permits the pursuit of best alternatives criterion depicted in a simple mathematical calculation. Summarized results from case study of automobile parts manufacturing industry determine that this model could be used for decision making optimization in supplier selection.

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