RESILIENT SUPPLIER SELECTION THROUGH FUZZY-TOPSIS

Thesis submitted in partial fulfillment of the requirements for the Degree of

Bachelor of Technology
in
Mechanical Engineering

Under the Guidance
of
Prof. S. DUTTA

By

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Rourkela
2013

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<u>Certificate of Approval</u>

This is to certify that the thesis entitled **Resilient supplier selection through fuzzy-TOPSIS** submitted by ***Sri Aditya*** 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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Acknowledgement

*I would like to express my deep sense of gratitude and indebtedness to **Dr. Saurav Datta**, Assistant Professor, Department of Mechanical Engineering, NIT Rourkela, my supervisor, whose invaluable encouragement, suggestions, and support leads to make successful completion of the thesis work. His meticulous guidance at each phase of this thesis has inspired and helped me innumerable ways. I am feeling felicitous in deep of my heart to work under such a young, dynamic, intelligent professor and his excellence of supervision.*

*I would also like to show my sincere thanks to **Prof. K. P. Maity**, Professor and Head of the Department, Mechanical Engineering; **Prof. S. S. Mahapatra**, Professor and **Prof. S. K. Patel**, Associate Professor, Department of Mechanical Engineering, NIT Rourkela, for their intellectual support and paving me with their precious comments and creative ideas. I am indebted to all of them.*

Last, but not the least, I offer my regards and thanks to all of those, whose names have not been explicitly mentioned, yet, have supported me in any respect during the completion of this report.

Aditya

Abstract

In resent business world, supply chain management (SCM) has become a key issue of conceptual and empirical research. As a fundamental decision-making for mangers, the quality of supplier performance not only affects the downstream business, but also determines the success of the whole supply chain. Therefore, resiliency planning is becoming a crucial strategic issue to choosing suitable suppliers in the supply chain; it directly impacts the benefits for managers of organizations. The resilient supplier selection is a complex multi-criteria problem in both quantitative and qualitative factors which may be in conflict and may also be uncertain. So in this context fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method helps to deal with inaccurate, incomplete and imperfect information to some extent. To avoid complicated aggregation of fuzzy numbers, these weighted ratings are defuzzified into crisp values by the ranking method of mean of removals. A closeness coefficient is defined to determine the ranking order of alternatives by calculating the distances to both fuzzy positive ideal solution and fuzzy negative ideal solution. A case study is proposed for resilient supplier evaluation in an automobile parts manufacturing industry in India.

***Keywords*:** Resilient Supplier Selection, Fuzzy Logic, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

Contents

1. Introduction and State of Art

In the today's competitive business world, all dimensions of product delivery viz., quality, flexibility, and response time need to be incorporated through effective design and operation of supply chain. Supplier evaluation and selection is one of the most important components of supply chain, which influence the long term commitments and performance of the company. Suppliers have varied strengths and weaknesses which require careful assessment by the purchasers before they are ranked based on some criteria. Therefore, every decision needs to be integrated by trading off performances of different suppliers at each supply chain stage (Liu, Hai and Lin, 2005).

Dickson (1966) highlighted, in one of the early works on supplier selection, identified over twenty supplier attributes which managers trade off when choosing a supplier. Since then, a considerable number of conceptual and empirical articles on supplier selection have appeared (an exhaustive review was done by Weberet al. (1991)).Toni and Tonchia (1996) proposed the main objective of supply chain performance measurement is to remain competitive in today's world class market using its values and perceptions. De Boer et al. (2001) proposed the fuzzy set theory as a way for improving the supplier selection process. In addition, to find the supplier with the best overall performance rating among suppliers, Erol et al. (2003) highlighted about the advantages of fuzzy set theory in supplier selection issues. Also Kumar et al. (2004) have applied a fuzzy goal programming approach for solving the supplier selection problem in supply chain providing a decision method for handle the vagueness and imprecision objectives. Ding and Liang (2005) highlighted, for selecting a suitable partner for strategic alliance applied fuzzy set theory to solving a complex and multi-criteria problem in an MCDM environment. Yang et al. (2008) used fuzzy AHP and employed the ISM method to clarify the interrelationships of intertwined sub-criteria in the complex structural hierarchy in a supplier selection problem. Faez et al. (2009) applied an integrated model based on the case-based reasoning method in a fuzzy environment and mathematical programming for a single item supplier selection issue. Now-a-days, in a supply chain the supplier selection includes the selection of the right supplier and their quota allocation which also needs to consider a variety of supplier attributes such as price and quality. A supplier selection problem must consider these various attributes because of their direct impact on final product dimensions such as cost and quality. Supplier selection decisions play an important role in supply chain management and have a significant impact on the competitiveness of an industry because purchases from supplier account for a large percentage of the total cost for many industries. Therefore, resiliency planning is becoming a crucial strategic issue to choosing suitable suppliers in the supply chain; it directly impacts the benefits for managers of organizations. Resilience supply chain is the ability of responsiveness to resume its true quality and services after any deformation market situation. The literal meaning of resilience is the capacity of a system to survive, adapt and grow in the face of change and uncertainty or ability of a system to absorb the impact of the failure of one or more components or a significant disturbance in its surroundings and then to still continue to provide an acceptable level of services.

According to (Pettit, Fiksel, and Croxton, 2011), resilience capability facilitates a supply chain returning to its original state following disruptions; and more specifically, preparing for unexpected events, responding to disruptions, and recovering from them to continue its operation (Christopher and Peck, 2004; Sheffi and Rice 2005). Sheffi and Rice (2005) also provided a comprehensive analysis of the need for managers to examine the concept of resiliency in their supply chains. Resiliency refers to a firm's capacity to survive, adapt and grow in the face of change and uncertainty (Fiksel, 2006; Ponomarov & Holcomb, 2009). It is the capacity of a system to survive, adapt, and grow in the face of change and uncertainty

(Pettit, Fiksel, and Croxton , 2010) and the ability of the supply chain to return to its former state (before disruption) or to move toward a new state that is more desirable (Datta, Christopher and Allen, 2007). Regarding resilience, we can refer to conceptual studies that mainly consist of a review of the literature and definitions (Rice and Caniato, 2003; Ponomarov and Holcomb, 2009) or guidelines that are based on interesting instances (Sheffi, 2005). Pettit, Fiksel, and Croxton (2008) provided a framework for supply chain resilience based on vulnerabilities and capabilities.

In this work the assessment of resilient suppler selection is fruitful through TOPSIS method, it is known as a classical multiple criteria decision-making (MCDM) method, has been developed by (Hwang and Yoon, 1981) for solving the MCDM problems. The basic principle of the TOPSIS is that the chosen alternative should have the "closer distance "from the positive ideal solution and the "farthest distance "from the negative ideal solution. The TOPSIS introduces two "reference" points, but it does not consider the relative importance of the distances from these points.

Here, we first convert the decision matrix into a fuzzy decision matrix and construct a weighted fuzzy decision matrix once the decision makers' fuzzy ratings have been pooled. The new process of normalization by use of fuzzy distance value and normal fuzzy deviation approach are applied for normalization and detection of the crisp value. According to the concept of TOPSIS, we define the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS). Finally, a closeness coefficient is applied to calculate the ranking order of all alternatives. The higher value of the closeness coefficient indicates that an alternative is closer to FPIS and farther from FNIS simultaneously.

The rest of the report is organized as follows: Section 2 describes the basic definitions of resilience, highlighted about resilience supply chain and taxonomy definitions resilient supplier selection frame work. In Section 3, we highlighted about triangular fuzzy number and fuzzy operational rules. In Section 4 we discussed about TOPSIS to deal with fuzzy data and understanding the proposed method through an empirical case study. Finally, the conclusions are pointed out in Section 5.

2. Resilient Supply Chain

From the organizational perspective resilience has been defined in terms of adjustment to capacities or abilities. Definitions that are relevant to this research include (Serhiy et al. 2009): The capacity to adjust and maintain desirable functions under challenging or straining conditions (Weick et al., 1999; Bunderson and Sutcliffe, 2002; Edmondson, 1999). A dynamic capacity of organizational adaptability that grows and develops overtime (Wildavsky, 1988); and the ability to bounce back from disruptive events or hardship (Sutcliffe and Vogus, 2003). The ability to recover from disruptive events was also examined by (Mitroff and Alpasan, 2003). They state that resilient organizations are proactive and recover better from hardship. However, resilience is more than just recovery; it also implies a certain level of flexibility and ability to adapt to both positive and negative influences of the environment. To summarize, the organizational perspective emphasizes important aspects of resilience such as adapt.

A resilient supply chain must be adaptable, as the desired state in many cases is different from the original one. Christopher (2005) states that resilient processes are flexible and agile and are able to change quickly and the dynamic nature of this adaptive capability allows the supply chain to recover after being disrupted, returning to its original state or achieving a more desirable state of supply chain operations, ability, flexibility, maintenance, and recovery.

Resilient Supplier Selection Criteria: Taxonomy Definitions

Performance indicator	**Explanation**
Strategic stock	Comparatively large stock of essential goods or materials, built up to withstand long holdups or scarcity due to natural calamities, strikes, or war. In comparison, buffer stocks are held for stabilizing prices to protect local exporters from losses resulting from wild swings in world commodity prices. [Source: www.businessdictionary.com]
Lead time reduction	The most effective way for businesses to reduce stock is by reducing the supply lead time. Lead time can be defined as the time it takes from when firm first determine a need for a product until it arrives on firm's doorstep. If lead time was zero, inventory could be zero. [Source: www.corelogistics.com.au]
Flexible transportation	Flexible transportation is a general term describing a range of strategies typically utilized in planes, trains, automobiles transportation. Any device used to move an item from one location to another.
Optimal use of assets	A portfolio management strategy that involves rebalancing a portfolio so as to bring the asset mix back to its long-term target. Such rebalancing would generally involve reducing positions in the best-performing asset class, while adding to positions in underperforming assets. The general premise of dynamic asset allocation is to reduce the fluctuation risks and achieve returns that exceed the target benchmark. [Source: www.investopedia.com]
Multiple sourcing	The purchase of individual items used to create a product from different, multiple providers in order to keep production on track in the event of a failure to produce at one particular source. This reduces production risk in the event that the supply chain has a problem. [Source: www.businessdictionary.com]
Demand aggregation	Total level of demand for desired goods and services (at any time by all groups within a national economy) that makes up the gross domestic product (GDP). Aggregate demand is the sum of consumption expenditure,

	investment expenditure, government expenditure, and net exports. [Source: www.businessdictionary.com]
Teamwork	The process of working collaboratively with a group of people in order to achieve a goal. Teamwork is often a crucial part of a business, as it is often necessary for colleagues to work well together, trying their best in any circumstance. Teamwork means that people will try to cooperate, using their individual skills and providing constructive feedback, despite any personal conflict between individuals. [Source: www.businessdictionary.com]

3. 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 lineis a triangular fuzzy number if its membership function $f_A : R \to (0, 1)$ 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. 1 represents triangular fuzzy number and Fig. 2 represents the crisps number (C_v).

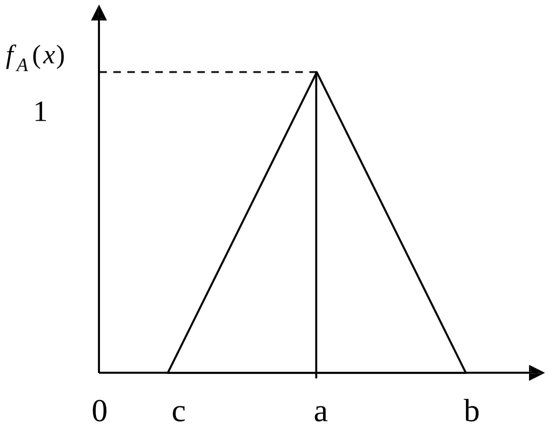

Fig. 1: Triangular Fuzzy Numbers

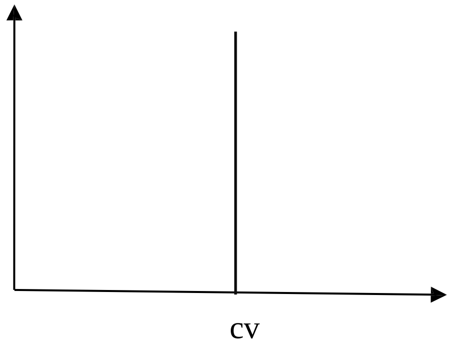

Fig. 2: Crisp number

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, $\oplus$:

$$A_1 \oplus A_2 = (c_1 + c_2, a_1 + a_2, b_1 + b_2), \tag{1}$$

• Fuzzy subtraction, (-):

$$A_1 - A_2 = (c_1 - b_2, a_1 + a_2, b_1 + c_2), \tag{2}$$

• Fuzzy multiplication, $\otimes$:

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

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

• Fuzzy division, $(/)$:

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

4. TOPSIS Method

TOPSIS method was introduced for the first time by (Yoon and Hwang, 1981) and was appraised by surveyors and different operators. TOPSIS is a decision making technique. It is a goal based approach for finding the alternative that is closest to the ideal solution. In this method, options are graded based on ideal solution similarity. If an option is more similar to an ideal solution, it has a higher grade. Ideal solution is a solution that is the best from any aspect that does not exist practically and we try to approximate it. Basically, for measuring similarity of a design (or option) to ideal level and non ideal, we consider distance of that design from ideal and non-ideal solution. General TOPSIS process with 8 steps is listed below:-

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 (Rao and Shankar, 2012),

$$C_v = \left(\frac{c+7a+b}{9}\right)\left(\frac{7w}{18}\right) \tag{5}$$

Here, 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.

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

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

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.

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

5. Empirical research

An automobile part manufacturing company desires to select a suitable material supplier to purchase the key components of new products. After preliminary screening, four alternatives (A_1, A_2, A_3 and A_4) remain for further evaluation. A committee of five decision-makers, D_1,

D_2, D_3, D_4 and D_5, has been formed to select the most suitable resilient supplier. Seven benefit criteria are considered:

- Strategic stock , C1
- Lead time reduction , C2
- Flexible transportation , C3
- Optimal use of assets, C4
- Multiple sourcing , C5
- Demand aggregation , C6
- Team work , C7
- The hierarchical structure of this decision problem is shown in Fig. 3. The proposed method is currently applied to solve this problem, the computational procedure of which is summarized as follows:
- Step 1: 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). The five-member linguistic terms and their corresponding fuzzy numbers are shown in Table 1

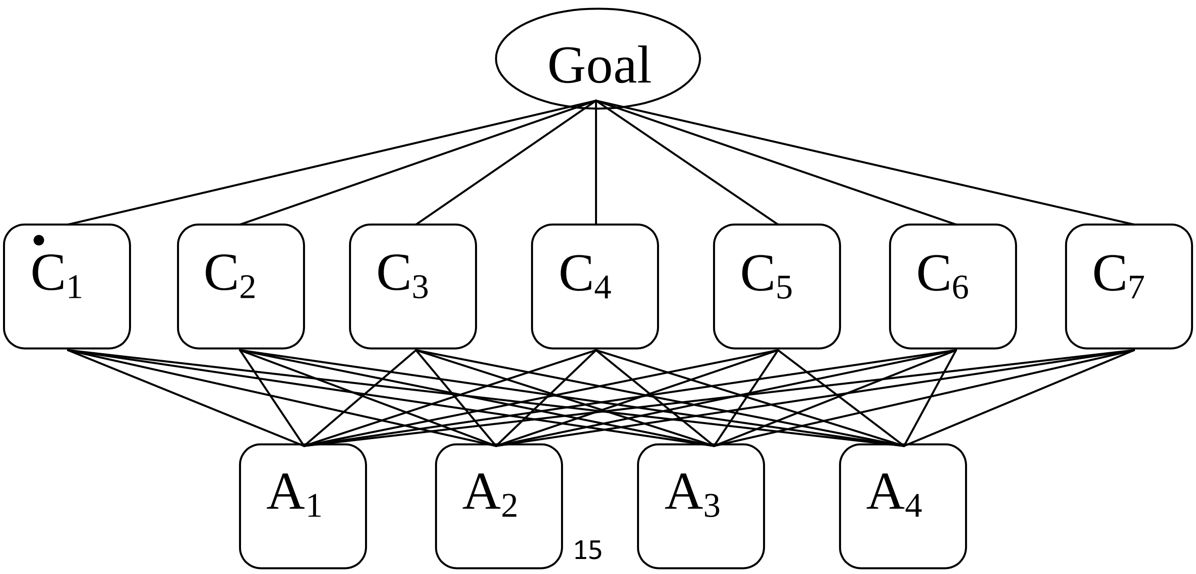

Fig. 3: Hierarchical structure of decision problem

Step 2: 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: Very Poor (VP), Poor (P), Medium, (M), Satisfactory (S) and Extremely Satisfactory (ES). The five-member linguistic terms and their corresponding fuzzy numbers are shown in Table 1.

Table 1: Five-member linguistic terms and their corresponding fuzzy numbers

Linguistic terms for weight assignment	Linguistic terms for ratings	fuzzy numbers
Very low, VL	Very poor, VP	(0.00, 0.00, 0.25)
Low, L	Poor, P	(0.00, 0.25, 0.50)
Medium, M	Medium, M	(0.25, 0.50, 0.75)
High, H	Satisfactory, S	(0.50, 0.75, 1.00)
Very High, VH	Extremely Satisfactory, ES	(0.75, 1.00, 1.00)

Step 3: 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 (Table 1) to assess performance rating against each of the alternatives criteria shown in Tables 3-6. Similarly, subjective priority weight evaluation index has been assessed by the DMs and that sown in Table 2.

Table 2: 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
C_6	VH	VH	H	H	H

C_7	H	H	H	H	VH

Table 3: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 1)**

Performance metrics	Ratings in linguistic term (A_1)				
	DM1	DM2	DM3	DM4	DM5
C_1	M	S	S	M	M
C_2	S	S	M	M	ES
C_3	S	M	M	M	M
C_4	M	S	S	S	ES
C_5	S	M	M	ES	ES
C_6	M	S	S	M	M
C_7	S	S	M	M	ES

Table 4: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 2)**

Performance metrics	Ratings in linguistic term (A_2)				
	DM1	DM2	DM3	DM4	DM5
C_1	M	M	S	M	M
C_2	M	M	S	S	ES
C_3	S	S	S	ES	ES
C_4	S	M	M	M	S
C_5	S	S	ES	ES	ES
C_6	M	M	S	M	M
C_7	M	M	S	S	ES

Table 5: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 3)**

Performance metrics	Ratings in linguistic term(A_3)				
	DM1	DM2	DM3	DM4	DM5
C_1	M	S	S	S	S
C_2	S	S	M	ES	ES
C_3	S	S	S	ES	ES
C_4	S	ES	ES	ES	S
C_5	ES	ES	ES	ES	S
C_6	M	S	S	S	S
C_7	S	S	M	ES	ES

Table 6: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 4)**

Performance metrics	Ratings in linguistic term (A_4)				
	DM1	DM2	DM3	DM4	DM5
C_1	S	S	M	M	M
C_2	S	S	M	P	P
C_3	M	M	M	P	M
C_4	S	M	M	M	M
C_5	S	S	M	M	P
C_6	S	S	M	M	M
C_7	S	S	M	P	P

Step 4: Then the linguistic values shown in Table 2 converted into triangular fuzzy numbers to construct the fuzzy decision matrix and determine the fuzzy weight of each criterion as well as its crisps values, as in Table 7. In same way we determined the fuzzy rating of each criterion (Tables 3-6) of all alternatives and the appropriateness rating of alternatives as well as its crisps values are shown in Table 8 and Table 9.

Step 5: The normalized fuzzy decision matrix is constructed as in Table 10.

Step 6: Weighted normalized fuzzy decision matrix is constructed as in Table 11.

Table 7: Aggregated priority weight and calculated crisps value

Level	Aggregated fuzzy weight, w_i	Crisps Value(C_V)
C_1	[0.60, 0.85, 1.00]	0.326
C_2	[0.55, 0.80, 1.00]	0.309
C_3	[0.60, 0.85, 1.00]	0.326
C_4	[0.75, 1.00, 1.00]	0.378
C_5	[0.45, 0.70, 0.95]	0.272
C_6	[0.60, 0.85, 1.00]	0.326
C_7	[0.55, 0.80, 1.00]	0.309

Table 8: Aggregated appropriateness rating, (Alternative1-4)

Level	Alternative-1	Alternative-2	Alternative-3	Alternative-4
C_1	[0.35, 0.60, 0.85]	[0.30, 0.55, 0.80]	[0.45, 0.70, 0.95]	[0.35, 0.60, 0.85]
C_2	[0.45, 0.70, 0.90]	[0.45, 0.70, 0.90]	[0.55, 0.80, 0.95]	[0.25, 0.50, 0.75]
C_3	[0.30, 0.55, 0.95]	[0.60, 0.85, 1.00]	[0.60, 0.85, 1.00]	[0.20, 0.45, 0.70]

C_4	[0.50, 0.75, 0.95]	[0.35, 0.60, 0.85]	[0.65, 0.90, 1.00]	[0.30, 0.55, 0.80]
C_5	[0.50, 0.75, 0.90]	[0.65, 0.90, 1.00]	[0.70, 0.95, 1.00]	[0.30, 0.55, 0.80]
C_6	[0.35, 0.60, 0.85]	[0.30, 0.55, 0.80]	[0.45, 0.70, 0.95]	[0.35, 0.60, 0.85]
C_7	[0.45, 0.70, 0.90]	[0.45, 0.70, 0.90]	[0.55, 0.80, 0.95]	[0.25, 0.50, 0.75]

Table 9: A fuzzy multi-criteria group decision making (FMCGDM) matrix

Alternatives	Criteria						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.233	0.270	0.220	0.290	0.287	0.233	0.27
A_2	0.214	0.270	0.326	0.233	0.344	0.214	0.27
A_3	0.428	0.497	0.534	0.568	0.603	0.428	0.497
A_4	0.233	0.194	0.175	0.214	0.214	0.233	0.194

Table 10: Normalized decision matrix

Alternatives	Criteria						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.401	0.412	0.321	0.407	0.367	0.401	0.412
A_2	0.368	0.412	0.475	0.327	0.440	0.368	0.412
A_3	0.737	0.758	0.778	0.798	0.772	0.737	0.758
A_4	0.401	0.296	0.255	0.301	0.274	0.401	0.296

Table 11: Weighted normalized decision matrix

Alternatives	Criteria						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.131	0.127	0.105	0.154	0.100	0.131	0.121
A_2	0.120	0.127	0.155	0.124	0.120	0.120	0.127
A_3	0.240	0.234	0.254	0.302	0.210	0.240	0.234
A_4	0.131	0.091	0.083	0.114	0.075	0.131	0.091

Step 7: Determine FPIS ($V_1{}^{*+}$) and FNIS ($V_2{}^{*-}$) as

$V_1{}^{*+}$ = (0.240, 0.234, 0.254, 0.302, 0.210, 0.240, 0.234) and

$V_2{}^{*-}$ = (0.120, 0.091, 0.083, 0.114, 0.075, 0.131, 0.091)

Step 8: Calculate the positive distance (D^{*+}) and negative distance (Distance D^{*-}) of four possible suppliers as

D^{*+} = (0.321, 0.318, 0.001, 0.384)

$D^{*-} = (0.074, 0.100, 0.387, 0.011)$

Step 9: Calculate the closeness coefficient (C*) of each supplier as

$C^*_1 = 0.187$ $C^*_3 = 0.999$

$C^*_2 = 0.239$ $C^*_4 = 0.027$

Step 10: According to the closeness coefficients, the ranking order of four suppliers is $\mathbf{A_3 > A_2 > A_1 > A_4}$. Here, the results of ranking order are identical when the different membership functions of linguistic variables are used in the proposed method. Therefore, it can confirm that this proposed method is very effective to deal with the problem of supplier selection. The ranking of alternatives correspond to closeness coefficients are shown in Table 12.

Table 12: The related closeness coefficient and ranking

Alternatives	Closeness coefficients(C*)	Ranking
A_1	0.187	3
A_2	0.239	2
$\mathbf{A_3}$	**0.999**	**1**
A_4	0.027	4

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 A_3 is best alternative supplier.

6. Conclusion

In this work, different criteria have been integrated to measure the supplier rating. The effectiveness of the methodology has been demonstrated using a case study of automobile parts manufacturing company where the integration of the TOPSIS and supplier selection index is used to rate and choose the best supplier effective in resilient situation.

The major advantages of this work have been summarized as follows:

- ❖ Development and implementation of an efficient decision-making tool to support resilient supplier evaluation.
- ❖ Concept of fuzzy TOPSIS is used to determine the decision weights using multi-dimensional parameters.
- ❖ The proposed approach is quite straightforward in the consideration of the different supplier selection factors compared to the conventional approaches for the same and supplier performance measurement.
- ❖ The appraisement index system has been extended with the capability to search ill performing areas which require future progress.

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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