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# Supplier selection using fuzzy TOPSIS multi criteria model for a small scale steel manufacturing unit

Sanjay Kumar, Saurabh Kumar, Asim Gopal Barman*

*Department of Mechanical Engineering, National Institute of Technology Patna, Patna 800005, India*

**Abstract**

Selection of supplier is very critical problem in supply chain management (SCM). In the recent years, selection of suppliers in the supply chain has become very decisive to mould a trade-off between the qualitative and quantitative criteria. These criteria are considered for making final decisions on supplier selection advertently and comprehensively. However, these decisions usually involve in various criteria or objectives to compromise among all possible conflicting parameters. This study deals with the uncertain issue of the supplier selection using integrated TOPSIS model for multi criteria decision making(MCDM). The advantage is that it distinguishes between the cost (less the better) and benefit (more the better) criteria and select the solutions which are closest and farthest from the positive and negative ideal solution. Sensitivity analysis is carried out to investigate the effect of criteria weights on the supplier selection. A computative model is illustrated for a small scale steel manufacturing unit in India.



*Keywords:* MCDM, Fuzzy TOPSIS, supplier selection, Steel manufacturing;

## 1. Introduction

Selection of supplier is very critical aspect in SCM where firms expend minimum 60 percent of its total sales on purchasing items like parts, components and raw materials [1]. Further, manufacturers procure services and goods using upto 70 percent of product cost [2]. Supplier selection is a region of enormous significance and must be considered as a tactical aspect in effectual SCM.

During 1990s, manufacturers attempted to develop strategic partnerships to improve their management's preference and competitiveness [3]. Supplier selection and evaluation are complex tasks for decision makers as they required to consider various criteria. Dickson [4] recognized 23 criteria for the selection of supplier based on which Weber et al. [5] measured supplier performance considering the criteria of price, delivery, quality, location, technical capability, productive capability, industry position, reputation, financial stability, maintainability and history. Evans [6] studied various key criteria for the selection of supplier such as price, quality and delivery.

* Corresponding author.
*E-mail address:* asim@nitp.ac.in

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Recently, the marketing management literature has been paid considerable attention to the supplier selection process. Few important criteria are: suppliers' profitability, technological capabilities, relationship closeness, conflict resolution and performance quality. Lin and Chang [7] emphasized that reputation, customer responsiveness, communication, relationship closeness and industry position are necessary in vendor selection. Due to inexact, imprecise, vague and uncertain nature of data, modeling of many situations may be insufficient or inexact [8].

The one of the most important business function is strategic sourcing (SS). Under the expanded heading of logistics, now SS is an essential segment of the firm program to cover the purchasing schemes. Companies are interested to find out how they can provide facilities to the customers rapidly with reasonable pricing compared to their competitors. So, managers realized that they should work in a mutual system with the best corporation in their logistics networks containing warehouses, suppliers, customers undoubtedly,production units and the distribution centers. The long-term viability of the company is determined on the selection of supplier decision [9].

Liao and Kao [10] analyzed issues related to selection of supplier in SCM. Both qualitative and quantitative criteria make multi criteria for selection of supplier problem more complex [11]. Methods are developed for decision makers in a suitable way to deal with the problem related to the selection of supplier more effectively [12]. The applications of various type fuzzy models are explored in the context of decision making problems [13]. Liao and Kao [10] presented MCGP and fuzzy TOPSIS approaches simultaneously for selection of supplier problems using trapezoidal fuzzy number. Asamoah et al. [14] reported an AHP approach in a pharmaceutical manufacturing unit in Ghana for evaluation and selection of suppliers. Kumar and Roy [15] studied factors which are qualitatively important to obtain suitable suppliers. Wang et al. [16] presented preemptive goal programming (PGP) and analytic hierarchy process (AHP) jointly for selection of supplier. The linguistic terms or vague concepts are represented in crisp value to formulate the model for real-life situations [17]. Amid et al. [2] proposed a multi objective linear model using fuzzy theory to overcome the blurriness of the information. Amid et al. [18] defined the supplier selection problems using fuzzy weighted max-min model to solve a problem effectively. Chen [19] studied about the elaboration of each criterion weight and each alternative by linguistic values which could be framed in triangular fuzzy numbers (TFN). Chang et al. [20] implemented a new method of MCGP to evaluate the houses in order to help home buyers to find a suitable house. Luthra et al. [21] analyzed the ecological pressure from markets, customer knowledge and various stakeholders. It helps managers and business professionals to assess the most effective supplier for sustainability in supply chain. Sureeyatanapas et al. [22] analyzed the TOPSIS method to make easy for practitioners to logically select a supplier even when unavailability and /or uncertainty of the estimation information emerge. Cheraghalipour and Farsad [23] proposed a decision making tool to solve the sustainable order allocation and selection of supplier problem in multi-item, multi-supplier and multi-period environment considering bulk rebate under disruption risks.

In this current study, multi supplier selection problem is addressed using fuzzy TOPSIS model. In the first case, linguistic terms are framed in TFN to compute rating and criteria weights for the selection of a supplier. In the second case, fuzzy TOPSIS model is applied to get the supplier closeness coefficients. Finally, sensitivity analysis is carried out for evaluating the possible effect of criteria weights on the performance estimation of suppliers.

## 2. Fuzzy TOPSIS

Zadeh [24] introduced fuzzy theory as an augmentation of the classical notation of set. A positive TFN can be expressed using three points such as: $\tilde{B} = (n, o, p)$ which is depicted in Fig. 1. Membership functions consist of the following conditions:

- *n to o* function increases
- *o to p* function decreases
- $n \leq o \leq p$

$$\mu_{\tilde{B}}(x) = \begin{cases} 0, & \text{for } x < n, x > p, \\ \frac{x-n}{o-n}, & \text{for } n \leq x \leq o, \\ \frac{p-x}{p-o}, & \text{for } o \leq x \leq p \end{cases}$$

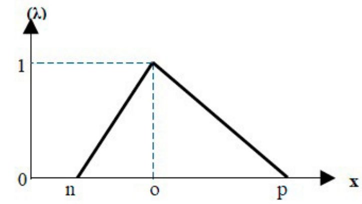


Fig. 1. Triangular Fuzzy Numbers

TOPSIS stands for technique for order preference by similarity to an ideal solution, which was originally developed by Hwang and Yoon, 1981. Two alternatives considered in TOPSIS are negative ideal solution and positive ideal solution. A positive ideal solution (PIS) aims to reduces the cost criteria and increases the benefit criteria and in case of negative ideal solution (NIS) the benefit criteria reduces and the cost criteria increases [25]. In fuzzy TOPSIS, criteria weights and alternative ratings are expressed in the linguistic terms which are then set to fuzzy number called TFN. The phases of formulated fuzzy TOPSIS methods are as follows:

1. To generate all possible alternatives (m), to determine the various evaluation criteria (n) and to create a pair of decision makers (k).
2. To decide proper linguistic terms intended for the importance weights of the criteria ($\tilde{w}_s = n_{rs}, o_{rs}, p_{rs}$). To decide linguistic ratings for alternatives with respect to weight of criteria ($\tilde{x}_{rs}$) expressed as TFN.
3. To obtain the aggregated fuzzy weight $\tilde{w}_s$ of criterion $C_s$ by aggregating weight of criteria. To get the aggregated fuzzy rating $\tilde{x}_{rs}$ of alternative $S_r$ under criterion $C_s$ assessed by expert.

$$\tilde{x}_{rs} = \frac{1}{k}[\tilde{x}_{rs}^1 + \tilde{x}_{rs}^2 + ... + \tilde{x}_{rs}^k];\ r = 1,2,..,m;\ s = 1,2,..,n \tag{1}$$

$$\tilde{w}_s = \frac{1}{k}[\tilde{w}_s^1 + \tilde{w}_s^2 + ... + \tilde{w}_s^k];\ s = 1,2,..,n \tag{2}$$

4. To create a fuzzy decision matrix.

$$\tilde{A} = \begin{bmatrix} S_1 \\ S_2 \\ \vdots \\ S_m \end{bmatrix} \begin{bmatrix} C_1 & C_2 & C_3 & \cdots & C_n \\ y_{11} & y_{12} & y_{13} & \cdots & y_{1n} \\ y_{21} & y_{22} & y_{23} & \cdots & y_{2n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ y_{m1} & y_{m2} & y_{m3} & \cdots & y_{mn} \end{bmatrix}; \tilde{w} = [\tilde{w}_1, \tilde{w}_2, ..., \tilde{w}_n];\ r = 1,2,..,m;\ s = 1,2,..,n \tag{3}$$

5. To normalize fuzzy decision matrix. Linear scale transformation is used to normalize the raw data to show various criteria scales into a comparable scale. It is denoted by $\tilde{U}$.

$$\tilde{U} = [\tilde{u_{rs}}]_{mxn};\ r = 1,2,..,m;\ s = 1,2,..,n \tag{4}$$

$$\tilde{u_{rs}} = (\frac{a_{rs}}{c_s^+}, \frac{b_{rs}}{c_s^+}, \frac{c_{rs}}{c_s^+});\ and\ c_s^+ = maxc_{rs}\ (benefit\ criteria) \tag{5}$$

$$\tilde{u_{rs}} = (\frac{a_s^-}{c_{rs}}, \frac{a_s^-}{b_{rs}}, \frac{a_s^-}{a_{rs}});\ and\ a_s^- = mina_{rs}\ (cost\ criteria) \tag{6}$$

6. To create a weighted normalized matrix. Multiplying the normalized fuzzy decision matrix $\tilde{u_{rs}}$ and the weights $\tilde{w_{rs}}$ of the evaluating criteria, to get weighted normalized matrix $\tilde{V}$.

$$\tilde{V} = [\tilde{v_{rs}}]_{mxn};\ r = 1, 2, .., m; s = 1, 2, .., n;\ where\ \tilde{v_{rs}} = \tilde{u_{rs}}(.)\tilde{w}_s \tag{7}$$

7. To compute fuzzy NIS and fuzzy PIS.

$$Z^+ = (\tilde{v_1^+}, \tilde{v_2^+}, .., \tilde{v_n^+});\ where\ \tilde{v_s^+} = maxv_{rs3};\ r = 1, 2, .., m;\ s = 1, 2, .., n \tag{8}$$

$$Z^- = (\tilde{v}_1, \tilde{v}_2, ..., \tilde{v}_n);\ where\ \tilde{v_s^-} = minv_{rs1};\ r = 1, 2, .., m;\ s = 1, 2, .., n \tag{9}$$

8. To find the distance of each alternative from fuzzy NIS and fuzzy PIS.

$$d_r^+ = \sum_{s=1}^{n} d_v(\tilde{v_{rs}}, \tilde{v_s^+});\ r = 1, 2, .., m \tag{10}$$

$$d_r^- = \sum_{s=1}^{n} d_v(\tilde{v_{rs}}, \tilde{v_s^-});\ r = 1, 2, .., m \tag{11}$$

Where, $d_v(\tilde{a}, \tilde{b})$ is the distance between two fuzzy numbers $\tilde{a}$ and $\tilde{b}$.

9. To calculate closeness coefficients ($CC_r$) for each alternative. The ($CC_r$) shows the distance to the fuzzy NIS and fuzzy PIS concurrently.

$$CC_r = \frac{d_r^-}{d_r^- + d_r^+};\ r = 1, 2, .., m \tag{12}$$

10. To rank the alternatives or suppliers. Based on the decreasing order of ($CC_r$), the various alternatives are ranked.

## 3. A Case Study

A well known manufacturing unit of iron and steel industry in eastern part of India is facing performance issues of suppliers. For achieving the competitive advantage in the market, its management selects the suppliers for raw materials. A decision making committee consists of three experts (decision makers) DMs1, DMs2 and DMs3 has been constituted to choose a supplier from four equally certified suppliers or alternatives (S1, S2, S3, S4). The name of the steel manufacturing unit and the names of suppliers are not disclosed due to confidential policy of the concerned iron and steel manufacturing company. From a complete set of criteria for iron and steel industry, five criteria are considered to evaluate supplier selection. The various criteria are given below-

1. Cost (C1)
2. Delivery capabilities (C2)
3. Quality of product (C3)
4. Performance (C4)
5. Reputation (C5)

Fig. 2. shows the hierarchy structure of the decision problem. Using fuzzy TOPSIS methodology the problem has been solved and the steps of computations are summarized as follows:

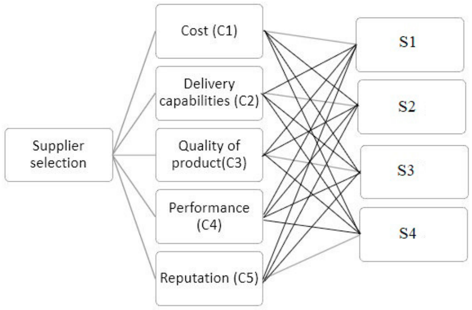


Fig. 2. Hierarchy structure of decision problem

1. Generate all possible alternatives (S1, S2, S3 and S4), determine the various evaluating criteria (C1, C2, C3, C4 and C5) and make a group of three decision makers (DMs1, DMs2, DMs3).
   Decision makers evaluate the match between the literature and preferences through the group of criteria implemented from Dicksons [4] criteria.
2. Decide proper linguistic terms intended for the importance weights of the criteria. Decide linguistic ratings for alternatives with respect to weight of criteria expressed as TFN. It is shown in Table 1 and 2 [26].

Table 1. Various linguistic terms for rating criteria

| Linguistic terms | Corresponding TFN |
|---|---|
| Very Good (VG) | (7,9,9) |
| Good (G) | (5,7,9) |
| Moderate (M) | (3,5,7) |
| Poor (P) | (1,3,5) |
| Very Poor (VP) | (1,1,3) |

Table 2. Various linguistic terms for pair wise comparisons of each criterion

| Linguistic terms | Fuzzy Numbers |
|---|---|
| Extremely High (EH) | (0.7,0.9,0.9) |
| Very High (VH) | (0.5,0.7,0.9) |
| High (H) | (0.3,0.5,0.7) |
| Low (L) | (0.1,0.3,0.5) |
| Very Low (VL) | (0.1,0.1,0.3) |

3. Determine the aggregated fuzzy weight of criterion by aggregating weight of criteria. By considering the experts opinion on criterion to get aggregated fuzzy ratings of alternatives.
4. Table 3 shows fuzzy decision matrix by converting the linguistics terms into TFN.
5. A normalized fuzzy decision matrix has been made using Table 3. A weighted normalized fuzzy decision matrix (Table 5) is obtained using the normalized fuzzy decision matrix as shown in Table 4.
6. Computations are performed to obtain the fuzzy PIS $Z^{+}$(FPIS) and fuzzy NIS $Z^{-}$ (FNIS) are shown below:
   $Z^{+}$=[(0.5,0.5,0.5),(0.834,0.834,0.834),(0.9,0.9,0.9),(0.834,0.834,0.834),(0.9,0.9,0.9)]
   $Z^{-}$=[(0.0185,0.0185,0.0185),(0.0556,0.0556,0.0556),(0.1641,0.1641,0.1641),(0.1765,0.1765,0.1765), (0.1469,0.1469,0.1469)]
7. Compute the distance of various alternative or suppliers from FNIS and FPIS with respect to each criteria as shown in Table 6.

Table 3. Fuzzy aggregated decision matrix and fuzzy weights of criteria

| Criteria | Alternatives | | | | Aggregate fuzzy weights |
|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | |
| C1 | (1,1.67,3.67) | (1,2.34,4.34) | (2.34,4.34,6.34) | (6.34,8.34,9) | (0.167,0.3,0.5) |
| C2 | (1,1.67,3.67) | (1.67,2.34,4.34) | (3.67,5.67,7.67) | (6.34,8.34,9) | (0.5,0.7,0.83) |
| C3 | (6.34,8.34,9) | (3.67,5.67,7.67) | (6.34,8.34,9) | (2.34,4.34,6.34) | (0.63,0.83,0.9) |
| C4 | (3.67,5.67,7.67) | (3.67,5.67,7.67) | (5,7,9) | (7,9,9) | (0.43,0.63,0.8) |
| C5 | (6.34,8.34,9) | (3.67,5.67,7.67) | (4.34,6.34,8.34) | (2.34,4.34,6.34) | (0.57,0.77,0.9) |

Table 4. Normalized fuzzy decision matrix

| Criteria | Alternatives | | | |
|---|---|---|---|---|
| | S1 | S2 | S3 | S4 |
| C1 | (0.12,0.185,0.407) | (0.12,0.26,0.48) | (0.26,0.481,0.703) | (0.7,0.93,1) |
| C2 | (0.12,0.185,0.407) | (0.185,0.26,0.48) | (0.407,0.63,0.852) | (0.7,0.93,1) |
| C3 | (0.7.4,0.926,1) | (0.407,0.63,0.852) | (0.703,0.926,1) | (0.26,0.481,0.704) |
| C4 | (0.407,0.63,0.851) | (0.407,0.63,0.852) | (0.556,0.778,1) | (0.778,1,1) |
| C5 | (0.703,0.926,1) | (0.407,0.63,0.852) | (0.481,0.703,0.926) | (0.26,0.481,0.703) |

Table 5. Weighted normalized fuzzy decision matrix

| Criteria | Alternatives | | | |
|---|---|---|---|---|
| | S1 | S2 | S3 | S4 |
| C1 | (0.0185,0.0555,0.2037) | (0.0185,0.0777,0.2407) | (0.0432 0.1444 0.3518) | (0.1172,0.2777,0.5) |
| C2 | (0.0556,0.1296,0.3395) | (0.0926,0.1815,0.4012) | (0.2037,0.4407,0.7098) | (0.3518,0.6481,0.8333) |
| C3 | (0.4456,0.7716,0.9) | (0.2580,0.5246,0.7667) | (0.4456,0.7716,0.9) | (0.1642,0.4012,0.6334) |
| C4 | (0.1765,0.3987,0.7098) | (0.1765,0.3987,0.7098) | (0.2407,0.4926,0.8334) | (0.337,0.6334,0.8334) |
| C5 | (0.3987,0.7098,0.9) | (0.2308,0.4828,0.7667) | (0.2728,0.5395,0.8334) | (0.1469,0.3691,0.6334) |

Table 6. Distance $d_v(Z_r, Z^+)$ and $d_v(Z_r, Z^-)$ for alternatives

| Criteria | $d_v(Z_r, Z^+)$ | | | | $d_v(Z_r, Z^-)$ | | | |
|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S1 | S2 | S3 | S4 |
| C1 | 0.4152 | 0.3988 | 0.3449 | 0.255 | 0.1090 | 0.1327 | 0.2062 | 0.3208 |
| C2 | 0.6693 | 0.6219 | 0.4342 | 0.2978 | 0.1694 | 0.2135 | 0.4466 | 0.5898 |
| C3 | 0.2725 | 0.4361 | 0.2725 | 0.5358 | 0.5743 | 0.4089 | 0.5743 | 0.3034 |
| C4 | 0.4602 | 0.4602 | 0.3946 | 0.3089 | 0.3335 | 0.3335 | 0.4224 | 0.4710 |
| C5 | 0.3095 | 0.4617 | 0.4194 | 0.5537 | 0.5619 | 0.4098 | 0.4622 | 0.3087 |

8. Compute the closeness coefficient ($CC_r$) of each alternatives, as per Table 7.

Table 7. Computation of ($d_r^+$),($d_r^-$), and ($CC_r$)

| | Alternatives | | | |
|---|---|---|---|---|
| | S1 | S2 | S3 | S4 |
| $d_r^-$ | 1.7483 | 1.4986 | 2.1119 | 1.9940 |
| $d_r^+$ | 2.1268 | 2.3789 | 1.8656 | 1.9519 |
| $CC_r$ | 0.4511 | 0.3865 | 0.5309 | 0.5053 |

## 4. Sensitivity Analysis

Sensitivity analysis is shown in a graphical representation where it represents the fluctuations of the outcome when the input data changes. In this study, the criteria weight of the supplier is changed from very low to excellent. The ranking order of various alternatives varies according to the criteria weight. There are ten cases taken into consideration. A radar diagram has been plotted to demonstrate the sensitivity analysis conducted on the basis of fuzzy TOPSIS

Table 8. Criteria weight changes for sensitivity analysis

| Case no. | Criteria weight changes | Overall Scores ($CC_r$) | | | | Ranking |
|---|---|---|---|---|---|---|
| | | S1 | S2 | S3 | S4 | |
| Case 1 | $W_{c1-c5} = (0.1, 0.1, 0.3)$ | 0.3520 | 0.3320 | 0.4231 | 0.4268 | $S2 < S1 < S3 < S4$ |
| Case 2 | $W_{c1-c5} = (0.1, 0.3, 0.5)$ | 0.3818 | 0.3640 | 0.4623 | 0.4686 | $S2 < S1 < S3 < S4$ |
| Case 3 | $W_{c1-c5} = (0.3, 0.5, 0.7)$ | 0.4000 | 0.3650 | 0.4875 | 0.5015 | $S2 < S1 < S3 < S4$ |
| Case 4 | $W_{c1-c5} = (0.5, 0.7, 0.9)$ | 0.4086 | 0.3658 | 0.5043 | 0.5238 | $S2 < S1 < S3 < S4$ |
| Case 5 | $W_{c1-c5} = (0.7, 0.9, 0.9)$ | 0.4453 | 0.3842 | 0.5626 | 0.5923 | $S2 < S1 < S3 < S4$ |
| Case 6 | $W_{c1} = (0.7, 0.9, 0.9)$, $W_{c2-c5} = (0.1, 0.1, 0.3)$ | 0.3128 | 0.3131 | 0.4356 | 0.5448 | $S1 < S2 < S3 < S4$ |
| Case 7 | $W_{c2} = (0.7, 0.9, 0.9)$, $W_{c1}$, $W_{c3-c5} = (0.1, 0.1, 0.3)$ | 0.3128 | 0.3163 | 0.4650 | 0.5448 | $S1 < S2 < S3 < S4$ |
| Case 8 | $W_{c3} = (0.7, 0.9, 0.9)$, $W_{c1-c2}$ and $W_{c4-c5} = (0.1, 0.1, 0.3)$ | 0.4709 | 0.3857 | 0.5225 | 0.4188 | $S2 < S4 < S1 < S3$ |
| Case 9 | $W_{c4} = (0.7, 0.9, 0.9)$, $W_{c1-c3}$ and $W_{c5} = (0.1, 0.1, 0.3)$ | 0.3792 | 0.3627 | 0.4742 | 0.5209 | $S2 < S1 < S3 < S4$ |
| Case 10 | $W_{c5} = (0.7, 0.9, 0.9)$, $W_{c1-c4} = (0.1, 0.1, 0.3)$ | 0.4709 | 0.3857 | 0.4749 | 0.4188 | $S2 < S4 < S1 < S3$ |

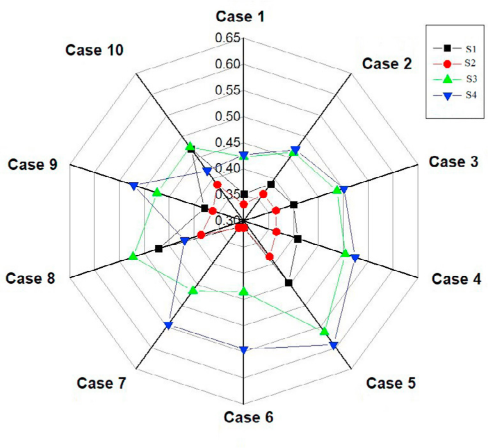


Fig. 3. Results of sensitivity analysis

method as shown in Fig. 3. The radar diagram shows the closeness coefficient of each supplier at 10 different cases. If there is any change in criteria weight of supplier then its outcome will change in terms of closeness coefficient of suppliers. In all 10 different cases the closeness coefficient for all suppliers have been computed and are shown in Fig. 3. It can also be observed from Table 8 and Fig. 3. that out of 10 cases, the alternative S4 (supplier4) has the maximum score in 8 cases and also S2 has the minimum in 8 cases among all ten cases.

## 5. Conclusions

Being one of the most crucial decision making events for organization, supplier selection plays an important role to acquire competitive benefits. To accomplish this goal, the management should apply a successful model and select appropriate criteria for selection of supplier. Linguistic variables play a significant role in decision making process as these determine the performance values which cannot be exhibited into the numerical values. Consequently, with the help of fuzzy set theory DMs' preferences and experiences are converted into fruitful results by applying linguistic terms to evaluate each criterion with respect to every multiplier. Generally, selection of supplier and evaluation are uncertain and vague. Firstly, it provides the information about various challenges that the firm face while choosing the best supplier in a manufacturing unit for producing the good quality products. Secondly, it identifies the area required for implementation of performances and gives the better understanding for the selection of supplier that comes under the fuzzy conditions. In last step, sensitivity analysis has been performed to investigate the effect of criteria weights on selection of supplier. By relating the closeness coefficient results of the four alternatives as shown in Table 7, it is concluded that S3 is the most preferred supplier and S2 is the least preferred supplier.

Furthermore, this proposed model can be used in various MCDM problems such as location selection, project organization, promotion activities and new products development when accessible data are inexact, inaccurate, uncertain and rough by nature.

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