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An application of fuzzy TOPSIS method in an SWOT analysis

Adel Hatami-Marbini[a,1], **Saber Saati**[b]

[a]Department of Industrial Engineering, Tehran-South Branch, Islamic Azad University, Tehran, Iran

[b]Department of Mathematics, Tehran-North Branch, Islamic Azad University, Tehran, Iran

Abstract

Analysis of strengths, weaknesses, opportunities and threats (SWOT) is a method to formulate the strategy. Although the SWOT analysis successfully provides the key factors of the problem, it has some drawbacks in selecting appropriate strategy for the evaluation and final decision steps. During recent years, some multiple criteria decision making (MCDM) techniques such as analytic hierarchy process (AHP) and analytic network process (ANP) remove some of these deficiencies, but the nature of these decision usually is very complex and using crisp data is not suitable. In this paper, linguistic variable represented with fuzzy numbers are used to assess the ratings and weights. Then, a MCDM model based on fuzzy sets theory is proposed to handle the strategy selection problem with imprecise data. According to the concept of the TOPSIS in multiple-criteria group decision-making (MCGDM) problem, an index of closeness coefficient (CC) is defined to determine the ranking order of all strategies by calculating the distance to the both fuzzy ideal solution and fuzzy anti-ideal solution based on approach of ordering of the fuzzy numbers simultaneously. Finally, an example is given to highlight the procedure of the proposed method.

Keywords: SWOT analysis, MCGDM, Linguistic variables, Fuzzy sets theory, TOPSIS.

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[1] Corresponding Author. E-mail Address: adel-hatami@yahoo.com

1 Introduction

In today's fierce competitive environment characterized by thin profit margins, high consumer expectations for quality products and efficiency workforce, organizations are forced to take advantage of any opportunity to optimize and avoid threats their business processes.

Strategic management can be grasped as the collection of decisions and actions taken by business management, in consultation with all levels within the organization, to determine the long-term activities of the organization [9]. Strategic management has been widely used by all enterprises to withstand fierce market competition. The strategic management process consists of three stages: strategy formulation, strategy implementation, and strategy evaluation [5].

In the strategic management process, many approaches can be used to analyze strategic cases [6]. Among them, strengths, weaknesses, opportunities and threats (SWOT) analysis, which evaluates the opportunities, threats, strengths and weaknesses of an organization, is the most common [8]. SWOT analysis is a significant support tool for decision-making, and is often used as a means to systematically analyze an organization's internal and external environments [13, 15, 20, 21, 27].

The aim of the analysis of external opportunities and threats is to evaluate whether an organization can exploit opportunities and avert threats when facing an uncontrollable external environment, such as altering prices, political destabilization, social transition, foreign markets, etc. In addition to, the target of the analysis of internal strengths and weaknesses is to evaluate how an organization carries out its internal work, such as specialist management, quality of the product, research and development, etc [7, 2]. In fact, SWOT analysis can determine a perfect foundation for successful strategy formulation [12]. However, SWOT analysis has weaknesses in the measurement and evaluation steps [8, 4]. In literature review of conventional SWOT analysis reveals that the importance of the criteria is not quantified to provide the effect of each criterion on the proposed strategy [2, 17].

As planning processes are often complicated and difficult by numerous criteria, it may be that utilization of SWOT is insufficient. In other words, SWOT analysis can not provide an analytical means to attain performance ratings and weights of each SWOT factor, hence, SWOT analysis has not the ability to assess the appropriateness of decision alternatives based on these factors. While it does pinpoint the factors in the analysis, individual criteria are usually expressed briefly and very generally. Therefore, SWOT analysis cannot comprehensively assess the strategic decision-making process [19, 16].

In increasingly competitive global market, multiple-criteria decision making (MCDM) has found acceptance in areas of management science, the discipline has created many methodologies. Especially in the last years, the applications of MCDM methods are extended because computer usage has increased considerably. Decision-making is the procedure to find the best alternative among a set of possible alternatives. An MCDM problem with m alternatives and n criteria can be concisely expressed in matrix format as follows:

$$\text{D}= \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \end{array}, \qquad W = [W_1, W_2, \dots, W_n]$$

The conventional MCDM is a kind of MCDM problems [10], which the ratings and the weights of criteria are measured in crisp numbers. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), a family of classical MCDM technique, is a popular approach and has been widely used in the literature. Hwang and Yoon [10] were first suggested classic TOPSIS method. TOPSIS method is based on the idea that the most preferred alternative should be the shortest distance from the ideal solution and the longest distance from the anti-ideal solution. Note that the ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the anti-ideal solution maximizes the cost criteria and minimizes the benefit criteria. In real situations, these ratings and weights are usually difficult to be judged very precisely because of the existence of uncertainty and vagueness, but can be suitably characterized by linguistic terms which are fuzzy in nature and then set into fuzzy numbers. Such a method was extensively extended by many practitioners to deal with fuzzy MCDM problems [11, 26, 25].

The strategy selection problem is essentially multiple-criteria group decision-making (MCGDM). Some researchers have proposed several studies to evaluate SWOT analysis, using the traditional MCDM method (see [19, 16, 29]). Kurttila et al. [16] developed a hybrid method in which they used AHP technique in the SWOT analysis. Recently, Yüksel and Dağ̆deviren [29] similar to the work of [16], considered prioritization of the SWOT factors and sub-factors, and neither strategies nor alternatives are included in the hierarchical structures based on the strategic factors using ANP technique.

In this paper, we extended a fuzzy multiple-criteria group decision-making (FMCGDM) method called fuzzy TOPSIS. In fuzzy TOPSIS, the fuzziness in the decision data and group decision-making process is considered. In addition, linguistic variables are used to assess the weights of all criteria and the performance ratings of each alternative strategy with respect to each criterion. The weighted normalized fuzzy decision matrix is constructed. In this approach, the distance values of each alternative from ideal and anti-ideal solutions are calculated by using concept of ranking fuzzy numbers. Finally, the closeness coefficients are defined to attain the ranking order of all alternative strategies.

The organization of the paper is as follows. In section 2, basic definitions are introduced. The details of the proposed FMCGDM method are given in Section 3. An application of the method is described in Section 4 through an example. Finally, in Section 5 conclusions are presented.

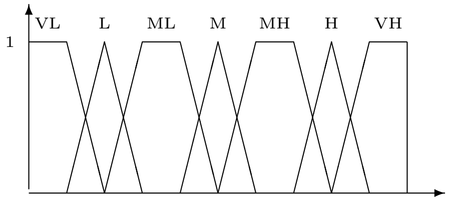

Fig 1. Linguistic variable for importance weights

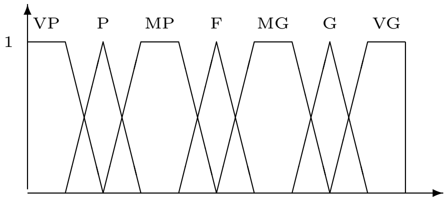

Fig 2. Linguistic variable for rating

2 Proposed Fuzzy TOPSIS method for SWOT analysis

In real-world situation, because of incomplete or non-obtainable information, the attributes (SWOT criteria) are often not exact, so they usually are fuzzy/imprecise, therefore, we propose a fuzzy TOPSIS for SWOT analysis in this paper. In this study, performance ratings and weights are evaluated with linguistic terms [3]. These linguistic ratings, employed by specialists to represent the fuzzy performances under certain criteria, are very good (VG), good (G), medium good (MG), fair (F), medium poor (MP), poor (P) and very poor (VP). The linguistic weights for presenting the importance of criteria are very high (VH), high (H), medium high (MH), medium (M), medium low (ML), low (L) and very low (VL). Assume that all linguistic terms can be represented with triangular fuzzy numbers, and that these fuzzy numbers are limited in the interval [0,1]. Thus these performance ratings would be not normalized. It is suggested that the decision-makers use linguistic variables shown in Figures 1 and 2 to determine the importance weights of criteria and rating of actions under various criteria. In fact, ranking and selecting of the obtained strategies by SWOT analysis is multiple-criteria group decision-making problem.

Suppose that an expert team has K decision-makers conversant with the operations and missions of the organization and it can be denoted by E_k. Let C_j be a set of n criteria, called SWOT sub-factors, which affect the prosperity of the organization but may be managed by the organization, are identified. Finally, suppose A_i be a set of m alternative strategies that are obtained according to mission of organization and SWOT sub-factors.

Let a set of performance ratings of A_i $(i = 1, 2, \ldots,\ m)$ regarding to criteria C_j $(j = 1, 2, \ldots,\ n)$ denoted by $X = \{(x_{ij}, |\ i = 1, 2, \ldots, m,\ \ j = 1, 2, \ldots, n, \}$.

We assume the fuzzy performance ratings of all decision-makers be positive trapezoidal fuzzy numbers $\widetilde{R}_k = (r^l_k, r^\gamma_k, r^\zeta_k, r^u_k)$ $(k = 1, 2, \ldots, K)$, Therefore, the aggregated fuzzy performance rating can be formulated as [3],

$$\widetilde{R}_k = (r^l, r^\gamma, r^\zeta, r^u) \tag{1}$$

where,

$$r^l = \min_k \left\{r^l_k\right\} \qquad , r^\gamma = \frac{1}{K}\sum_{k=1}^{K} r^\gamma_k \qquad , r^\zeta = \frac{1}{K}\sum_{k=1}^{K} r^\zeta_k \qquad , r^u = \max_k \{r^u_k\}$$

Let the fuzzy performance rating (SWOT factors) of each alternative strategy and importance weight of the kth decision-maker be $\widetilde{x}_{ijk} = (x^l_{ijk}, x^\gamma_{ijk}, x^\zeta_{ijk}, x^u_{ijk}), \widetilde{W}_{jk} = (w^l_{ijk}, w^\gamma_{jk}, w^\zeta_{jk}, w^u_{jk})$ with $i = 1, 2, \ldots, m,\ j = 1, 2, \ldots, n$ and $k = 1, 2, \ldots, K$, respectively. Hence, the aggregated fuzzy ratings $\widetilde{x}_{ij}$ of actions regarding to each criterion can be calculated as,

$$\widetilde{x}_{ij} = (x^l_{ij}, x^\gamma_{ij}, x^\zeta_{ij}, x^u_{ij}) \tag{2}$$

where,

$$x^l_{ij} = \min_k \left\{x^l_{ijk}\right\} \quad , x^\gamma_{ij} = \frac{1}{K}\sum_{k=1}^{K} x^\gamma_{ijk} \quad , x^\zeta_{ij} = \frac{1}{K}\sum_{k=1}^{K} x^\zeta_{ijk} \quad , x^u_{ij} = \max_k \{r^u_k\}$$

In addition the aggregated fuzzy weights $\widetilde{W}_j$ of each criterion can be calculated as,

$$\widetilde{W}_j = (w^l_j, w^\gamma_j, w^\zeta_j, w^u_j) \tag{3}$$

where,

$$w^l_j = \min_k \left\{w^l_{jk}\right\} \quad , w^\gamma_j = \frac{1}{K}\sum_{k=1}^{K} w^\gamma_{jk} \quad , w^\zeta_j = \frac{1}{K}\sum_{k=1}^{K} w^\zeta_{jk} \quad , w^u_j = \max_k \left\{w^u_{jk}\right\}$$

Ultimately, one can be expressed the aggregated fuzzy performance ratings and weights of each SWOT factor in concise by using fuzzy decision matrix format as follows:

$$\widetilde{D} = \begin{bmatrix} \widetilde{x}_{11} & \widetilde{x}_{12} & \dots & \widetilde{x}_{1n} \\ \widetilde{x}_{21} & \widetilde{x}_{22} & \dots & \widetilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{x}_{m1} & \widetilde{x}_{m2} & \dots & \widetilde{x}_{mn} \end{bmatrix}, \qquad \widetilde{W} = [\widetilde{W}_1, \widetilde{W}_2, \dots, \widetilde{W}_n]$$

To avoid the complicated normalization formula used in classical TOPSIS, the linear scale transformation is used to transform the different criteria scale into comparable scale. Normalize fuzzy decision matrix $\widetilde{R} = [\widetilde{r}_{ij}]_{m\times n}$by the following equations:

$$\widetilde{r}_{ij} = (r^l_{ij}, r^\gamma_{ij}, r^\zeta_{ij}, r^u_{ij}) = (\frac{x^l_{ij}}{d^*_j}, \frac{x^\gamma_{ij}}{d^*_j}, \frac{x^\zeta_{ij}}{d^*_j}, \frac{x^u_{ij}}{d^*_j}) \qquad (j \in B) \tag{4}$$

$$\widetilde{r}_{ij} = (r^l_{ij}, r^\gamma_{ij}, r^\zeta_{ij}, r^u_{ij}) = (\frac{a^-_j}{x^u_{ij}}, \frac{a^-_j}{x^\zeta_{ij}}, \frac{a^-_j}{x^\gamma_{ij}}, \frac{a^-_j}{x^l_{ij}}) \qquad (j \in C)$$

where

$$d^*_j = \max_i \left\{x^u_{ij}\right\} \qquad , a^-_j = \min_k \left\{x^l_{ij}\right\}$$

and B and C are associated with benefit (such as the product quality, flexibility and ...) and cost (such as human cost, threat of China competitors and ...) criteria sets, respectively. In the normalization method, normalized $\widetilde{r}_{ij}$ are still trapezoidal fuzzy numbers. Therefore, the weighted normalized fuzzy decision matrix is constructed as:

$$\widetilde{V} = [\widetilde{v}_{ij}]_{m\times n} \tag{5}$$

where

$$\widetilde{v}_{ij} = (v^l_{ij}, v^\gamma_{ij}, v^\zeta_{ij}, v^u_{ij}) = (w^l_j x^l_{ij}, w^\gamma_j x^\gamma_{ij}, w^\zeta_j x^\zeta_{ij}, w^u_j x^u_{ij}) \qquad \forall i, j$$

It is obvious that the elements of weighted normalized fuzzy decision matrix $\widetilde{V}$ are approximately trapezoidal fuzzy numbers and between [0,1] as well. Therefore, the ideal solution can be defined as (1,1,...,1). As such, the anti-ideal solution can be defined as (0,0,...,0). In this paper, we determine the fuzzy ideal solution (A^*) and fuzzy anti-ideal solution (A^-) as follows:

$$A^* = (\widetilde{v^*_1}, \widetilde{v^*_2}, \dots, \widetilde{v^*_n}) = \{(\max_i \left\{v^u_{ij}\right\} | j \in B), (\min_i \left\{v^l_{ij}\right\} | j \in C)\} \tag{6}$$

$$A^- = (\widetilde{v_1^-}, \widetilde{v^-*_2}, \ldots, \widetilde{v_n^-}) = \{(\min_i \left\{v_{ij}^l\right\} |j \in C), (\max_i \left\{v_{ij}^u\right\} |j \in B)\}$$

where

$$\widetilde{v_j^*} = (v_j^{l*}, \gamma_j^{l*}, \zeta_j^{l*}, v_j^{u*}), \quad \widetilde{v_j^-} = (v_j^{l-}, \gamma_j^{l-}, \zeta_j^{l-}, v_j^{u-}), \quad \widetilde{v}_j = (v_{ij}, \gamma_{ij}, \zeta_{ij}, v_{ij})$$

The problem of ranking fuzzy numbers has been addressed by many researchers [1, 23, 24, 18, 22, 28]. Yao and Wu [28] defined the signed distance d^* on R to rank two fuzzy numbers $\widetilde{A}$ and $\widetilde{B}$ as follows:

$$d(\widetilde{A}, \widetilde{B}) = \frac{1}{2}\int_0^1 ([\widetilde{A}]_\alpha^L + [\widetilde{A}]_\alpha^U - [\widetilde{B}]_\alpha^L - [\widetilde{B}]_\alpha^U) d\alpha \tag{7}$$

In this formula, of course, $[\widetilde{\bullet}]_\alpha^L$ and $[\widetilde{\bullet}]_\alpha^U$ are the lower and upper bound of the α-cut of the fuzzy number respectively.

Based on (4), the following definition for comparing and ranking fuzzy numbers is extended as:

$$\begin{aligned} \widetilde{B} \prec \widetilde{A} \quad & if \quad d(\widetilde{A} \prec \widetilde{B}) > 0 \\ \widetilde{B} \succ \widetilde{A} \quad & if \quad d(\widetilde{A} < \widetilde{B}) > 0 \\ \widetilde{B} \approx \widetilde{A} \quad & if \quad d(\widetilde{A} \prec \widetilde{B}) = 0 \end{aligned} \tag{8}$$

The distance measurement of each alternative (alternative strategies) from $\widetilde{A}$ and $\widetilde{B}$ based on (4) can be currently calculated as:

$$\begin{aligned} d_i^* = \sum_{j=1}^n d(\widetilde{v}_j^*, \widetilde{v}_{ij}) = (\frac{1}{2}) \sum_{j=1}^n (v_{j1}^* + v_{j4}^* - v_{ij1} - v_{ij4}) + (\frac{1}{4}) \sum_{j=1}^n (v_{j2}^* + v_{j3}^* - v_{j1}^* \\ -v_{j4}^* - v_{ij2} - v_{ij3} + v_{ij1} + v_{ij4}), \quad \forall i \\ d_i^- = \sum_{j=1}^n d(\widetilde{v}_{ij}, \widetilde{v}_j^-) = (\frac{1}{2}) \sum_{j=1}^n (v_{ij1} + v_{ij4} - v_{j1}^- - v_{j4}^-) + (\frac{1}{4}) \sum_{j=1}^n (v_{ij2} + v_{ij3} \\ -v_{ij1} - v_{ij4} + v_{j1}^- + v_{j4}^- - v_{j2}^- - v_{j3}^-), \quad \forall i \end{aligned} \tag{9}$$

The purpose of this technique is that the chosen alternative should have the shortest distance from the ideal solution and the farthest distance from the anti-ideal solution, simultaneously. Therefore, a closeness coefficient index is defined to determine the ranking order of all alternatives strategies. The closeness coefficient for each alternative is obtained as:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \quad i = 1, 2, \ldots, m \tag{10}$$

It is evident that an alternative A_i is closer to the A^* and farther from A^- as CC_i approaches to 1. Therefore, using the closeness coefficient, we can determine the rank of alternatives $A_i, i = 1, 2, \ldots, m$ and select the best one from among a set of practical alternative strategies.

As a summary, the fuzzy TOPSIS method based on α-cut sets can be summed up as follows:

- Organize a group of experts, and identify the evaluation criteria (SWOT sub-factors) and determine the alternative strategies according to SWOT sub-factors.
- Construct the weighted normalized fuzzy decision matrix $V = [\widetilde{v}_{ij}]_{m \times n}$ by Eqs. (6).
- Determine the ideal solution and the anti-ideal solution by Eqs. (7).
- Calculate the distance measurement of each alternative (alternative strategy) from the ideal solution and anti-ideal solution by Eqs. (8).
- Compute the closeness coefficient of each alternative strategy by (11).
- Rank alternative strategies in terms of their closeness coefficients.

3 Numerical example of SWOT analysis

In this section, SWOT analysis utilizing proposed approach is performed on an organization which produces and exports cosmetics that desire to select appropriate strategy for competing with competitors. The team of the three experts (DM_1, DM_2, DM_3) is considered the nine SWOT sub-factors $(C_1, C_2, \ldots, C_9)$ which affect the success of the organization using the most important external and internal environment analysis.

The SWOT matrix is shown in Table 1 based on these sub-factors. Using the SWOT matrix, the expert team chooses four alternative strategies (CS, IS, JA, MS) that they are as follows:

CS Strategy: Cooperating with suitable suppliers,

IS Strategy: Investing with southeast countries,

Internal factors		External factors	
Weaknesses	Strengths	Threats	Opportunities
Distance of market(C_1)	Specialist management(C_3)	China products(C_6)	Foreign markets(C_8)
Negative feeling about Iranian products(C_2)	Quality of the products(C_4)	Current problems in Middle East(C_7)	Investment motives (C_9)
–	Qualified workforce(C_5)	–	–

Table 1: SWOT matrix

JA Strategy: Joint investment with American countries,

MS Strategy: Making use of subcontractors.

The relative importance weights of the nine criteria are described using linguistic variables such as very high, high etc., which are defined in Table 2. The ratings (i.e. criteria values) are also characterized by linguistic variables such as very good, good, medium good, and the like, which are defined in Table 3. The three DMs express their opinions on the importance weights of the five criteria (sub-factor) and the ratings of each alternative strategy with respect to the nine criteria independently. Tables 4 and 5 show the initial assessment information provided by the three DMs, where aggregated fuzzy numbers are attained by proposed method. As far as this example is concerned, due to the fact that the nine criteria are all assessed using the same set of linguistic variables defined in Table 3, the normalization process is calculated. Table 6 shows the weighted normalized fuzzy decision matrix, from which the ideal and anti-ideal solutions can easily be determined as

$A^* = [(0.9, 0.9, 0.9, 0.9), (1, 1, 1, 1), (1, 1, 1, 1), (0.8, 0.8, 0.8, 0.8), (1, 1, 1, 1), (1, 1, 1, 1)$
$, (0.5, 0.5, 0.5, 0.5), (1, 1, 1, 1), (0.9, 0.9, 0.9, 0.9)]$

$$A^- = [(0.07, 0.07, 0.07, 0.07), (0.4, 0.4, 0.4, 0.4), (0.28, 0.28, 0.28, 0.28), (0, 0, 0, 0)$$
$$, (0, 0, 0, 0), (0.4, 0.4, 0.4, 0.4), (0, 0, 0, 0), (0.35, 0.35, 0.35, 0.35), (0.2, 0.2, 0.2, 0.2)]$$

Linguistic variable	Trapezoidal fuzzy number
Very low(VL)	$(0, 0, 0.1, 0.2)$
Low(L)	$(0.1, 0.2, 0.2, 0.3)$
Medium low(ML)	$(0.2, 0.3, 0.4, 0.5)$
Medium(M)	$(0.4, 0.5, 0.5, 0.6)$
Medium high(MH)	$(0.5, 0.6, 0.7, 0.8)$
High(H)	$(0.7, 0.8, 0.8, 0.9)$
high(VH)	$(0.8, 0.9, 0.9, 1)$

Table 2: Linguistic variables for the importance weights of the criteria

Linguistic variable	Trapezoidal fuzzy number
Very good(VG)	$(0, 0, 1, 2)$
Good(G)	$(1, 2, 2, 3)$
Medium good(MG)	$(2, 3, 4, 5)$
Fair(F)	$(4, 5, 5, 6)$
Medium poor(MP)	$(5, 6, 7, 8)$
Poor(P)	$(7, 8, 8, 9)$
Very poor(VP)	$(8, 9, 9, 10)$

Table 3: Linguistic variables for the consequence ratings of strategies

Criteria	DM_1	DM_2	DM_3	Aggregated fuzzy numbers
C_1	H	H	H	$(0.7, 0.8, 0.8, 0.9)$
C_2	VH	VH	VH	$(0.8, 0.9, 1, 1)$
C_3	VH	VH	H	$(0.7, 0.87, 0.93, 1)$
C_4	MH	M	M	$(0.4, 0.53, 0.57, 0.8)$
C_5	H	VH	H	$(0.7, 0.83, 0.87, 1)$
C_6	VH	VH	VH	$(0.8, 0.9, 1, 1)$
C_7	VL	VL	ML	$(0, 0.1, 0.2, 0.5)$
C_8	H	H	VH	$(0.7, 0.83, 0.87, 1)$
C_9	H	M	MH	$(0.4, 0.63, 0.67, 0.9)$

Table 4: Importance weights of the nine criteria by three DMs

Criteria	Alternative strategies	DM_1	DM_2	DM_3	Aggregated fuzzy numbers
C_1	CS	MG	MG	MG	$(1, 5.5, 7, 8)$
	IS	G	G	G	$(2, 7.67, 8, 9)$
	JA	VG	VG	G	$(3, 8.33, 9.33, 10)$
	MS	G	G	G	$(4, 7.67, 8, 9)$
C_2	CS	MG	MG	VG	$(5, 6.67, 8, 10)$
	IS	VG	VG	VG	$(6, 8.67, 10, 10)$
	JA	VG	G	G	$(7, 8, 8.67, 10)$
	MS	G	G	MG	$(5, 7, 7.67, 9)$
C_3	CS	G	G	G	$(7, 7.67, 8, 9)$
	IS	VG	VG	VG	$(8, 8.67, 10, 10)$
	JA	VG	VG	G	$(7, 8.33, 9.33, 10)$
	MS	MG	F	G	$4, 6, 6.67, 9)$
C_4	CS	G	G	G	$(7, 7.67, 8, 9)$
	IS	P	VP	P	$(0, 1, 1.67, 3)$
	JA	VG	VG	VG	$(8, 8.67, 10, 10)$
	MS	VG	G	G	$(7, 8, 8.67, 10)$
C_5	CS	G	G	G	$(7, 7.67, 8, 9)$
	IS	VG	VG	VG	$(8, 8.67, 10, 10)$
	JA	P	VP	P	$(0, 1, 1.67, 3)$
	MS	G	G	VG	$(7, 8, 8.67, 10)$
C_6	CS	MG	G	VG	$(7, 7.33, 8.33, 10)$
	IS	VG	G	MG	$(5, 7.33, 8.33, 10)$
	JA	G	VG	G	$(7, 8, 8.67, 10)$
	MS	VG	MG	MG	$(5, 6.67, 8, 10)$
C_7	CS	F	MG	G	$(5, 6, 6.67, 9)$
	IS	MG	G	MG	$(5, 6.33, 7.33, 9)$
	JA	MG	VG	G	$(7, 7.33, 8.33, 10)$
	MS	G	MG	VG	$(5, 7.33, 8.33, 10)$
C_8	CS	G	VG	MG	$(5, 7.33, 8.33, 10)$
	IS	VG	MG	VG	$(5, 7.67, 9, 10)$
	JA	G	MG	MG	$(5, 6.33, 7.33, 9)$
	MS	VG	G	VG	$(7, 8.33, 9.33, 10)$
C_9	CS	MG	G	G	$(7, 7, 7.67, 9)$
	IS	VG	VG	MG	$(5, 7.67, 9, 10)$
	JA	G	G	G	$(7, 7.67, 8, 9)$
	MS	MG	G	MG	$(5, 6.33, 7.33, 9)$

Table 5: Ratings of four strategies with respect to the nine sub-factors by the three DMs

We then determine the distance values of each alternative from ideal solution and anti-ideal solution. They are shown in Tables 7. The closeness coefficients, which are defined to determine the ranking order of all alternative strategies, are given in Table 8. Clearly, the CS strategy (Cooperating with suitable suppliers) is found to be the best alternative, which is shown in Table 8. The maintenance priorities of the four alternative strategies can finally be ranked as $CS \succ MS \succ IS \succ JA$, where the symbol '$\succ$' means 'is superior or preferred to'.

Criteria	CS	IS	JA	MS
C_1	$(0.09, 0.11, 0.15, 0.9)$	$(0.08, 0.1, 0.11, 0.45)$	$(0.07, 0.09, 0.1, 0.3)$	$(0.08, 0.1, 0.14, 0.23)$
C_2	$(0.4, 0.56, 0.75, 1)$	$(0.4, 0.45, 0.58, 0.83)$	$(0.4, 0.52, 0.63, 0.714)$	$(0.44, 0.59, 0.71, 1)$
C_3	$(0.49, 0.67, 0.74, 0.9)$	$(0.56, 0.75, 0.93, 1)$	$(0.49, 0.73, 0.87, 1)$	$(0.28, 0.52, 0.62, 0.9)$
C_4	$(0.28, 0.41, 0.46, 0.72)$	$(0, 0.05, 0.1, 0.24)$	$(0.32, 0.46, 0.57, 0.8)$	$(0.28, 0.42, 0.49, 0.8)$
C_5	$(0.49, 0.64, 0.7, 0.9)$	$(0.56, 0.72, 0.87, 1)$	$(0, 0.08, 0.15, 0.3)$	$(0.49, 0.66, 0.75, 1)$
C_6	$(0.4, 0.54, 0.68, 0.71)$	$(0.4, 0.54, 0.68, 1)$	$(0.4, 0.52, 0.63, 0.71)$	$(0.4, 0.56, 0.75, 1)$
C_7	$(0, 0.08, 0.17, 0.5)$	$(0, 0.07, 0.16, 0.5)$	$(0, 0.06, 0.14, 0.36)$	$(0, 0.06, 0.14, 0.5)$
C_8	$(0.35, 0.61, 0.73, 1)$	$(0.35, 0.64, 0.78, 1)$	$(0.35, 0.53, 0.64, 0.9)$	$(0.49, 0.69, 0.81, 1)$
C_9	$(0.28, 0.44, 0.51, 0.81)$	$(0.2, 0.48, 0.6, 0.9)$	$(0.28, 0.48, 0.54, 0.81)$	$(0.2, 0.4, 0.49, 0.81)$

Table 6: Weighted normalized fuzzy decision matrix

Sub − factor	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
$d(CS, A^*)$	0.588	0.322	0.300	0.334	0.319	0.416	0.315	0.329	0.389
$d(IS, A^*)$	0.717	0.435	0.189	0.703	0.213	0.345	0.319	0.308	0.354
$d(JA, A^*)$	0.762	0.436	0.229	0.263	0.868	0.436	0.362	0.397	0.373
$d(MS, A^*)$	0.773	0.314	0.420	0.301	0.273	0.322	0.326	0.252	0.425
$d(CS, A^-)$	0.242	0.278	0.420	0.466	0.681	0.184	0.186	0.321	0.311
$d(IS, A^-)$	0.113	0.165	0.531	0.097	0.788	0.256	0.182	0.343	0.347
$d(JA, A^-)$	0.068	0.165	0.491	0.538	0.132	0.165	0.138	0.253	0.327
$d(MS, A^-)$	0.057	0.286	0.301	0.500	0.727	0.278	0.174	0.398	0.275

Table 7: The distance values of each alternative from A^* and A^-

CC				Rank			
CS	IS	JA	MS	CS	IS	JA	MS
0.483	0.441	0.356	0.468	1	3	4	2

Table 8: Closeness coefficient of each strategies and its ranking

In cases where the imprecise/fuzzy ratings and weights are expressed, fuzzy TOPSIS may be performed in order to obtain the alternative priorities so that organizations are able to make strategically appropriate decisions.

4 Conclusions

SWOT analysis of external opportunities and threats as well as the internal strengths and weaknesses of the enterprises is important for strategy formulation and development. However, SWOT analysis is not capable of quantitatively determining the weights and effects of the strategic factors on the alternatives. Although several studies do perform such quantitative method, these studies consider with precious data. It is generally inadequate to assume data to be crisp and unsuited to real-life situations. Since strategy selection problem often adhere to vague and imperious data in the fierce competition environment. In this paper, alternative strategies of SWOT analysis are evaluated under fuzzy environment. In other words, it is appropriate for assessing of feasible strategies with respect to criteria and importance weights using linguistic variable instead of numerical measurements. Therefore, TOPSIS for fuzzy data has been developed and an algorithm to determine the most preferable strategy among all feasible strategies, when data is fuzzy, is presented. The weighted normalized fuzzy decision matrix is constructed. In this approach, the distance values of each alternative from ideal and anti-ideal solutions are calculated by using concept of ranking fuzzy numbers. Finally, the closeness coefficients are defined to attain the ranking order of all alternative strategies. In fact, this method is very simple and flexible. Hence, it is expected that proposed in this study may have more potential management applications in future research.

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