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INTEGRATING NONHOMOGENEOUS PREFERENCE STRUCTURES IN SWOT ANALYSIS TO EVALUATE MULTIPLE ALTERNATIVES

Abstract. *SWOT analysis is an important strategic decision-making support tool and it is commonly used to systematically analyze strategic alternatives from their internal and external environments. However, one of its limitations is in the measurement and evaluation of prioritization of the SWOT elements. The purpose of this paper is to present a quantified SWOT analytical methodology to evaluate multiple alternatives simultaneously, in which a converted SWOT hierarchy is first used to provide the basic frame to perform analyses of decision situations. Next, a multiple criteria group decision-making (MCGDM) method with nonhomogeneous preference information is developed to assist in carrying out SWOT more analytically and in elaborating the results of the analyses. Finally, the derived decision results are holistically compared and analyzed in SWOT matrix. In this MCGDM method, the priorities of SWOT elements are derived from nonhomogeneous preference information (NPI), such as preference ordering, utility function, multiplicative preference relations, and fuzzy preference relations. The uniform and aggregation of the nonhomogeneous preference information as well as the derivation of the priorities are investigated. Finally, an example is shown to highlight the procedure of the proposed method at the end of this paper.*

Keywords: *SWOT analysis, multi-criteria group decision-making (MCGDM), nonhomogeneous preference information, multiple strategies evaluation.*

JEL Classification C43, C44, D81

1. INTRODUCTION

SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis, an important support tool for strategic decision-making, is commonly used to identify the level of strategies from their internal and external environments and systematically analyze the situations of strategies (Weihrich, 1982; Kotler, 1994; Wheelen and Hunger,1995; Kurttila et al., 2000; Kangas, 2003). It allows strategists to diagnose with greater detail all factors what determine the situations of strategies, to categorize these factors into internal (strengths, weaknesses) and external (opportunities, threats) ones. Thus, it enables them to compare opportunities and threats with strengths and weaknesses. By identifying their strengths, weaknesses, opportunities and threats, the strategies can be built upon their strengths, eliminate its weaknesses, and exploit its opportunities or use them to counter the threats (Yüksel and Dagdeviren, 2007). If used correctly, SWOT can provide a good basis for successful strategy formulation. When undertaking SWOT, unfortunately, often it merely pinpoints the number of factors in strength, weakness, opportunity or threat groups and the expression of individual factors is often of a very general nature and brief (Hill and Westbrook, 1997; Kajanus et al., 2004). It includes no means of analytically determining the relative importance of factors or of comprehensively assessing the fit between SWOT factors and alternatives. Thus, it lacks the possibility of comprehensively appraising the strategic decision-making situations (Kurttila et al., 2000; Kangas et al., 2003; Gao and Peng, 2011). Therefore, it has been reported that the result of SWOT analysis is too often only a superficial and imprecise listing or an incomplete qualitative examination of internal and external factors, or is simply discarded after the analysis (Hill and Westbrook, 1997).

In order to overcome the limitations of SWOT that cannot provide an analytical means to determine the importance of the identified factors or the ability to assess decision alternatives according to these factors, several attempts have been made to expand SWOT with quantitative methods recently: Kurttila et al. (2000) developed a hybrid SWOT method with AHP to make factors commensurable and to support a more quantitative basis in the strategic planning process. The idea of the hybrid SWOT-AHP method, in recent years, has been extensively applied and intensively studied in various fields (Gao and Peng, 2011). From the view of the subsequent studies, some quantified SWOT methods have been proposed by integrating SWOT with SMART (simple multi-attribute rating technique) method (Kajanus et al., 2004), SMAA-O (the stochastic multicriteria acceptability analysis with ordinal criteria) method (Kangas et al., 2003), the MCDM concept and fuzzy AHP method (Lee and Lin, 2008), statistical preference analysis techniques (Leskinen et al., 2006), MADM (multi-attribute decision making) technique based on the concept of grand strategy matrix (Chang and Huang, 2006), ANP (analytic network process) (Yüksel and Dagdeviren, 2007), FAHP (fuzzy analytic hierarchy process) (Zaerpour et al., 2008), fuzzy logic and fuzzy linear programming (Amin et al., 2011), and so on.

As Zaerpour et al. (2008) pointed out that the integration of SWOT and MCDM is a quite novel methodology and has not received enough attentions in studies and applications. According to reviewed above, additionally, it is clear that the hybrid SWOT–MCDM methods are indeed favorable because they both overcome the limitation and improve the usability of SWOT. The integration of SWOT and MCDM cannot only, as the general framework, assist to structure the problem and keep the entire decision-support process under the decision-makers' control, but also measure quantitatively priorities of the factors included in SWOT analysis and make them commensurable as regards their intensities (Kurttila et al., 2000).

However, in some practical cases, the decision makers (DMs) participating SWOT analysis may belong to distinct areas and will have different backgrounds, levels of knowledge, experiences, cultures and circumstances (Gao and Peng, 2011, Peng et al., 2013). Naturally, they tend to use different representation formats to express their personal preferences for the SWOT elements. Therefore, it might be more natural and convenient for multiple DMs to express their preference in multiple formats, i.e. nonhomogeneous preference information, for parts or all of the SWOT factors. Gao and Peng (2011) paid attention to the case and presented a quantified SWOT method with three well-known types of uncertain preference relations (interval multiplicative preference relations, interval fuzzy preference relations and uncertain linguistic preference relations). However, the method cannot evaluate and analyze the strategic situations between several alternatives simultaneously and without considering the consistency of preference information in the process of decision making.

In this paper, we further extend the usability of SWOT analysis and consider the situation where the multiple strategic alternatives are evaluated and analyzed by SWOT methodology simultaneously, the preference information on SWOT factors is provided by multiple DMs and in four common preference formats, such as preference ordering, utility function, multiplicative preference relations, and fuzzy preference relations. The rest of this paper is set out as follows. Section 2 introduces hierarchical SWOT structure and SWOT matrix to support the structured analysis of problem and results, Section 3 investigates MCGDM method with nonhomogeneous preference information, Section 4 presents a novel SWOT methodology for evaluating multiple strategic alternatives. Section 5 illustrates an application of the methodology with a numerical example. Section 6 concludes this paper.

2. HIERARCHICAL SWOT FRAMEWORK AND MATRIX

HIERARCHICAL SWOT FRAMEWORK

SWOT analysis aims to identify and classify the strengths and weaknesses of an organization and the opportunities and threats in the environment. In order to compare multiple strategic alternatives and analyze their strategic situations with

SWOT analysis as well as to measure the SWOT factors of strategic alternatives by the MCDM technique, we convert the SWOT framework into a hierarchical structure. We also add strategic alternatives at the lowest level of hierarchical structure. Then we get a SWOT hierarchy, which is shown as Figure 1. For convenience, the SWOT factors, SWOT groups and strategic alternatives are viewed as SWOT decision elements of the SWOT hierarchy. Then the priorities of the elements of the hierarchy are assessed by DMs using multiple preference structures. That is, the SWOT hierarchy serves as the general framework that helps to structure the decision problem.

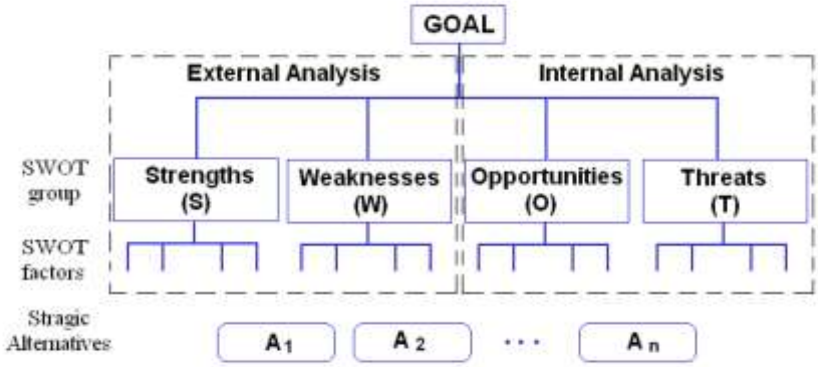

Figure 1. Hierarchical presentation of SWOT analysis

SWOT MATRIX

The SWOT matrix(sometimes call TOWS matrix), presented by Weihrich (1982), is a variation of SWOT analysis, which helps one to systematically integrate strengths, weaknesses, opportunities, threats and to show the distinct relationships between external and internal factors. The general structure of SWOT matrix is shown as Figure 2, where the ordinate stand for the external environment (opportunities, threats), while the abscissa stand for the internal environment (strengths, weaknesses), the identified SWOT factors can be fed into the corresponding quadrants in the SWOT matrix, and four quadrants in the SWOT matrix indicates four conceptually distinct alternative strategies respectively:

- (1) The first quadrant stands for the strengths and opportunities of strategic alternatives. These strategies in this quadrant are those of aggressive, which involves maximizing both strengths and opportunities.
- (2) The second quadrant stands for the strategic alternatives facing opportunities but possessing greater weaknesses than strengths. When the strategies in this quadrant are those of reorientation, the most urgent issue is to minimize the weaknesses and to maximize the opportunities.

- (3) The third quadrant stands for the strategic alternatives are of weaknesses and facing external threats. It is obviously that the position is generally the worst, and a defensive strategy should be adopted to reduce the effects of their threats by taking their weaknesses into account.

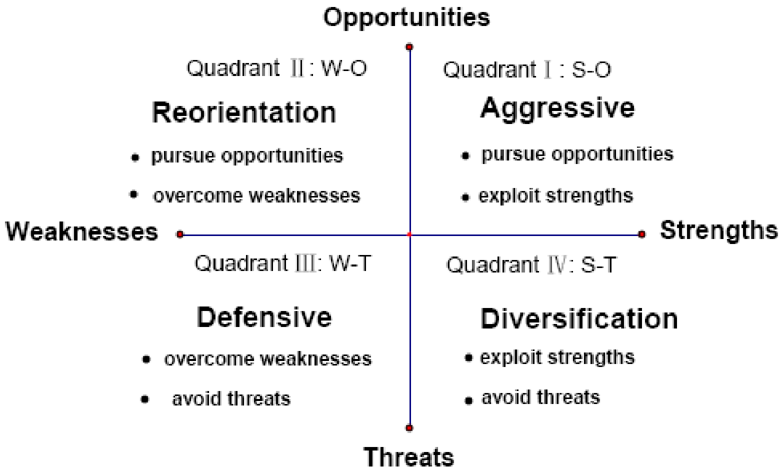

Figure 2. SWOT matrix

- (4) The fourth quadrant stands for the strategic alternatives possessing competition strength but facing greater threats than opportunities, which involves using the organization's strengths to remove or reduce the effects of threats of some unfavorable situations, diversification strategies are conducive to diminished with the effects of threats. Strategic alternatives in this quadrant should maximize the strengths while minimizing the threats in the environment.

Carrying out the analytical procedure of the SWOT matrix in this study is to park the strategic alternatives in the four quadrants of the coordinate, and then manage and propose the most suitable strategies and right directions by comparing and analyzing positions in the SWOT matrix.

3. DECISION MAKING WITH NONHOMOGENEOUS PREFERENCE INFORMATION

In practical SWOT decision analysis, different decision makers may use different preference formats to express their preference(Chiclana et al., 1998; 2001; Ma et al., 2006; Xu, 2007; Gao and Peng, 2011). In this section, we introduce relevant knowledge of decision making with four well-known types of preference information (preference ordering, utility function, multiplicative preference relations, and fuzzy preference relations).

NONHOMOGENEOUS PREFERENCE INFORMATION

1. Preference ordering In the case, a expert, DM_k, provides his/her preferences on X as an individual preference ordering, $O^k = \{o^k(1),...,o^k(n)\}$, where $o^k(\cdot)$ is a permutation function over the index set, $\{1,...,n\}$, for the expert, DM_k. Therefore an ordered vector of alternatives, from the best one to the worst one, is given (Chiclana et al., 1998; 2001).

2. Utility function In the case, a expert, DM_k, provides his/her preferences on X as a set of n utility values, $U_k = \{u_i^k \mid i = 1,...,n\}$; $u_i^k \in [0,1]$, where u_i^k represents the utility evaluation given by the expert DM_k to the alternative x_i. Thus, the higher the evaluation, the better the alternative satisfies the DM (Chiclana et al., 1998; 2001).

3. Multiplicative preference relations In the case, a expert, DM_k, provides his/her preferences on X is described by an multiplicative preference relation $A^k = (a_{ij}^k)_{n\times n} \subset X \times X$, where a_{ij}^k indicates the preference degree of the alternative x_i over x_j provided by the expert DM_k, it is interpreted as x_i is a_{ij}^k times as good as x_j. The measurement of a_{ij}^k can be described using a ratio scale, and in particular, Saaty's ratio scale is used, $a_{ij} \in [\frac{1}{9},...,\frac{1}{2},1,2,...,9]$: $a_{ij}^k = 1$ denotes indifference between x_i and x_j ; $a_{ij}^k = 9$ denotes that x_i is predominantly preferred to x_j ; and $a_{ij}^k \in \{2,3,...,8\}$ denotes intermediate preferences. They are usually assumed to be multiplicative reciprocal, i.e., $a_{ij}^k a_{ji}^k = 1,\ \forall i,\ j \in \{1,...,\ n\}$ and, particularly, $a_{ii}^k = 1,\ \forall i \in \{1,...,\ n\}$ (Saaty, 1980).

4. Fuzzy preference relations In the case, a expert, DM_k, provides his/her preferences on X is described by a fuzzy preference relation $R^k \subset X \times X$ with membership function $\mu_{R^k} : X \times X \to [0,\ 1]$, where $\mu_{R^K}(x_i,\ x_j) = R_{ij}^k$ denotes the preference degree of the alternative x_i over x_j provided by the expert DM_k : $R_{ij}^k = 0.5$ denotes indifference between x_i and x_j ; $R_{ij}^k = 1$ denotes that x_i is predominantly preferred to x_j ; and $R_{ij}^k > 0.5$ denotes that x_i is preferred to x_j (Tanino, 1984). They are usually assumed to be additive reciprocal (Orlovski, 1978 ; Tanino, 1984), i.e., $R_{ij}^k + R_{ji}^k = 1\ \forall i, j \in \{1,...,n\}$ and, particularly, $R_{ii}^k = 0.5\ \forall i \in \{1,...,n\}$.

PREFERENCE UNIFORM

Due to different experts give their preferences in different formats, the first step should be done is to obtain a uniform representation of the preferences. Since its apparent merits, fuzzy preference relation is commonly used as the base element of the uniform representation (Chiclana et al., 1998), we select fuzzy preference relations as the main element of the uniform representation of the preferences. According to (Chiclana et al., 1998; 2001; Tanino, 1984), the transformation functions of preference ordering, utility function and multiplicative preference relation to fuzzy preference relation are defined as follow:

(1) The preference ordering can be transformed into the fuzzy preference relation by the following function (Chiclana et al., 1998).

$$r_{ij} = \tfrac{1}{2}\left(1 + \tfrac{o(j)-o(i)}{n-1}\right),\ i, j = 1,...,n \quad (1)$$

(2) The utility function can be transformed into the fuzzy preference relation by the following function (Tanino, 1984).

$$r_{ij} = \tfrac{1}{2}(1 + u_i - u_j),\ i, j = 1,...,n \quad (2)$$

(3) The multiplicative preference relation can be transformed into the fuzzy preference relation by the following function (Chiclana et al., 2001).

$$r_{ij} = \tfrac{1}{2}(1 + \log_9 a_{ij}),\ i, j = 1,...,n \quad (3)$$

The previous definitions of preference relations assume that preferences given by experts are perfectly consistent. In fact, however, due to the complexity of decision-making problems, preferences expressed in or transformed into the fuzzy preference relation can be contradictory and not be completely consistent. To make a rational decision, it is inevitable to measure the consistency of fuzzy preference relations.

ADDITIVE CONSISTENCY

Definition 1. A fuzzy preference relation $R = (r_{ij})_{n\times n}$ is additive consistent, if the additive transitivity is satisfied (Tanino, 1984):

$$(r_{ik} - 0.5) + (r_{kj} - 0.5) = (r_{ij} - 0.5),\ \forall i, j, k \in \{1,...,n\} \quad (4)$$

Or

$$r_{ij} = r_{ik} + r_{kj} - 0.5,\ \forall i, j, k \in \{1,...,n\} \quad (5)$$

By expression (5), we can use it to calculate a preference value by other preference values in a fuzzy preference relation. Indeed, the preference value r_{ij} can be estimated using an intermediate alternative x_k.

$$cr_{ij}^{k} = r_{ik} + r_{kj} - 0.5,\ \forall i, j, k \in \{1,...,n\} \quad (6)$$

where cr_{ij}^{k} means the calculated value of r_{ij} via an intermediate alternative x_k, that is, using r_{ik} and r_{kj}. Obviously, if the information provided in a fuzzy preference relation is completely consistent then $cr_{ij}^{k} = r_{ij}\ \forall k$. However, the information given by an expert usually does not satisfy (6), because the information provided by an expert usually suffers from a certain degree of inconsistency. In these cases, the value

$$\varepsilon r_{ij} = \frac{\sum_{h=1,h\neq i,j}^{n} \left| cr_{ij}^{h} - r_{ij} \right|}{n-2} \quad (7)$$

can be used to measure the error of a preference value between two options. This error indicates the consistency level between the preference value r_{ij} and the rest of the preference values of the fuzzy preference relation. Clearly, when $\varepsilon r_{ij} = 0$ then there is no inconsistency at all between r_{ij} and the other preference values, and the higher the value of εr_{ij} the more inconsistent is r_{ij} with respect to the rest of information.

Definition 2. The consistency level associated with a preference value r_{ij} is defined as:

$$CL_{ij} = 1 - \varepsilon r_{ij} \quad (8)$$

when $CL_{ij} = 1$ then the r_{ij} is perfectly consistent. The lower the value of CL_{ij}, the more inconsistent is r_{ij} with respect to the rest of information.

Theorem 1. If fuzzy preference relations $(r_{ij})_{n\times n}$ are additive reciprocal, then

$$CL_{ij} = CL_{ji},\ i, j = 1,...,n \quad (9)$$

Proof:

$$\varepsilon r_{ji} = \frac{\sum_{k=1,k\neq i,j}^{n} \left| r_{jk} + r_{ki} - 0.5 - r_{ji} \right|}{n-2} = \frac{\sum_{k=1,k\neq i,j}^{n} \left| r_{jk} + r_{ki} - r_{ji} - 0.5 \right|}{n-2}$$
$$= \frac{\sum_{k=1,k\neq i,j}^{n} \left| 1 - r_{kj} + 1 - r_{ik} - 1 + r_{ij} - 0.5 \right|}{n-2} = \frac{\sum_{k=1,k\neq i,j}^{n} \left| 0.5 - r_{kj} - r_{ik} + r_{ij} \right|}{n-2}$$
$$\frac{\sum_{k=1,k\neq i,j}^{n} \left| (-1)(r_{ik} + r_{kj} - 0.5 - r_{ij}) \right|}{n-2} = \frac{\sum_{k=1,k\neq i,j}^{n} \left| r_{ik} + r_{kj} - 0.5 - r_{ij} \right|}{n-2} = \varepsilon r_{ij}$$

then $CL_{ij} = CL_{ji}$.

Definition 3. The consistency level for the whole fuzzy preference relation R is defined as follows:

$$CL_R = \frac{\sum_{i,j=1,i\neq j}^{n} CL_{ij}}{n^2 - n} \tag{10}$$

when $CL_R = 1$, then the preference relation R is fully additive consistent, otherwise, the lower CL_R the more inconsistent is R.

PREFERENCE AGGREGATION

After transforming the preference information in multiple formats into one single format, the next step is to obtain collective uniformed preference relations by aggregating the individual ones and then derive the priorities of decision elements. Yager and Filev (1999) proposed the induced OWA (IOWA) operator as an extension of the OWA operator (Yager, 1998) to allow a different reordering of the values to be aggregated. The main difference of the IOWA operator from the OWA operator resides in the order the arguments is not based on their value but the value of an additional inducing variable. Recently, Chiclana et al. (2007), Herrera-Viedma et al. (2007), Peng et al. (2013) introduced the additive consistency induced ordered weighted averaging (AC-IOWA) operator to aggregate fuzzy preference relations, which induces the ordering of the preference values based upon whose consistency.

Definition 4. An AC-IOWA operator of dimension n is a mapping $IOWA_w^{AC} : R^n \to R$ that has an associated weighting vector W of dimension n, such that $\sum_{j=1}^{n} w_j = 1$ and $w_j \in [0,1]$, then

$$IOWA_w^{AC}(<CL_{r_1}, r_1>, \ldots, <CL_{r_n}, r_n>) = \sum_{j=1}^{n} w_j r_{\pi(j)} \tag{11}$$

where $\pi(\cdot)$ is a permutation function over the index set $\{1,2,...,n\}$, such that $CL_{\pi(j-1)} \geq CL_{\pi(j)}$ for all $j=2,...,n$. r_j is the argument variable and CL_{r_j} is consistency level of argument r_j serve as the order-inducing variable.

Obviously, the weights of the aggregation depend on the corresponding the importance of individual arguments, here the consistency levels of the fuzzy preference relations are viewed as the "importance" values associated with the experts or criteria, which implies the aggregation of the preferences in such a way that more importance is given to the most consistent ones. The weighting vector can be elicited and determined by a linguistic quantifier Q (Yager, 1996):

$$w_j = Q\left(\frac{\sum_{k=1}^{j} CL_{\pi(k)}}{T}\right) - Q\left(\frac{\sum_{k=1}^{j-1} CL_{\pi(k)}}{T}\right), \quad j=1,2,...,n \tag{12}$$

being $T=\sum_{j=1}^{n} CL_{ij}$, and $Q(r)=r^{1/2}$ means the quantifier guiding this aggregation to be "most" (Yager, 1996). It can easily be shown that using this the w_j satisfy the conditions: $w_j \in [0,1]$, and $\sum_j w_j = 1$. Note that if the consistency values of arguments are identical, then the orderings of arguments are induced based upon their respective preference values.

In this study, the AC-IOWA aggregation operator can play two roles. When all DMs provide their preference over a set of elements, the AC-IOWA operator is used to obtain a collective preference relation by means of aggregation of the individual opinions. That is, obtain the group opinions from individual ones. The second role, it is used to derive the domination degree of each option over the remaining ones, which utilized to determine the priorities values of option.

The dominance degree for each option, signifying the degree in which each element is dominating the remaining factors, is calculated by using AC-OWA operator.

$$DD_i = IOWA_w^{AC}(< CL_{ij}, r_{ij} >, j=1,...,n, j \neq i) \tag{13}$$

Normalizing the dominance degree for each option, we obtain the priorities SWOT elements with the following expression:

$$\mu_i = \frac{DD_i}{\sum_{i=1}^{n} DD_i}, \text{ for } i=1,2,...,n \tag{14}$$

Obviously, the μ_i satisfy: $\mu_i \in [0,1]$, and $\sum_i \mu_i = 1$.

4. SWOT METHODOLOGY WITH NONHOMOGENEOUS PREFERENCE INFORMATION

Based on the SWOT hierarchy, the MCGDM method with nonhomogeneous preference information and the TOWS matrix, we are now ready to give the quantified SWOT methodology. To facilitate the description of the proposed approach, the following assumptions and notation are used: Let $E=\{e_1,e_2,...,e_K\}$ $K(\geq 2)$ denotes the set of decision makers, $A=\{A_1,...,A_m\}$ as strategic alternatives.

Step 1: Identify all related SWOT factors. Denote $\{S^{(k)},W^{(k)},O^{(k)},T^{(k)}\}$ as SWOT groups, $s^{(k)}=\{s_1^{(k)},s_2^{(k)}, ..., s_i^{(k)}\}$ as Strengths, $w^k=\{w_1^k,w_2^k,...,w_j^k\}$ as Weaknesses, $o^k=\{o_1^k,o_2^k,...,o_p^k\}$ as Opportunities, and $t^k=\{t_1^k,t_2^k,...,t_q^k\}$ as Threats. The key factors of the external and internal environment are identified and then formed the SWOT hierarchy.

Step 2: Express preference of SWOT elements with different preference formats according to DMs' preference. DMs can express their preference over the SWOT elements in different forms, i.e., preference ordering, utility function, multiplicative preference relations, fuzzy preference relations.

Step 3: Unify nonhomogeneous preference values. Utilize (1), (2) and (3) to transform preference ordering, utility function, multiplicative preference relations into fuzzy preference relation, respectively.

Step 4: Measure the consistent level of the unified fuzzy preference relations by utilizing (8) and (10).

Step 5: Obtain the collective fuzzy preference relations by utilizing (11) and (12) to aggregate individual fuzzy preference relations.

Step 6: Calculate the dominance degrees of the SWOT elements by utilizing (13), then derive their priorities by utilizing (14). The derived priority vectors include $(\mu_S,\mu_W,\mu_O,\mu_T)$, $(\mu_{s_1},\mu_{s_2},...,\mu_{s_p})$, $(\mu_{w_1},\mu_{w_2},...,\mu_{w_q})$, $(\mu_{o_1},\mu_{o_2},...,\mu_{o_f})$, $(\mu_{t_1},\mu_{t_2},...,\mu_{t_e})$ and $(\mu_{s_{ij}}, i=1,2,...,m, j=1,...,p)$, $(\mu_{w_{ij}}, i=1,2...,m, j=1,...,q)$, $(\mu_{o_{ij}}, i=1,2,...,m, j=1,...,f)$, $(\mu_{t_{ij}}, i=1,2,...,m, j=1,...,e)$.

Step 7: Determine the performances of the SWOT factors against each alternative by multiplying the priorities (or dominance degrees) of the alternative strategies with the priorities of the corresponding SWOT factor and group, that are: $\eta_{s_{ij}}=\mu_S\mu_{s_j}\mu_{s_{ij}}\ (j=1,...,p)$, $\eta_{w_{ij}}=\mu_W\mu_{w_j}\mu_{w_{ij}}\ (j=1,...,q)$, $\eta_{o_{ij}}=\mu_O\mu_{o_j}\mu_{o_{ij}}\ (j=1,...,f)$, and $\eta_{t_{ij}}=\mu_T\mu_{t_j}\mu_{t_{ij}}\ (j=1,...,e)$ for all $i=1,2.,...,m$.

Step 8: Calculate the performances of the alternatives' internal factors and external factors.

Due to the positive effects of strengths and opportunities as well as the negative effects of weaknesses and threats for strategic alternatives, according to the ideas of (Saaty and Ozdemir, 2003), the performances I_i of the Alt_i's internal environment and the performances E_i of the external environment are derived by (15) and (16), respectively.

$$I_i = \sum_{j=1}^{p} \eta_{s_{ij}} - \sum_{j=1}^{q} \eta_{w_{ij}}, i = 1, 2, \ldots, m \tag{15}$$

$$E_i = \sum_{j=1}^{f} \eta_{o_{ij}} - \sum_{j=1}^{e} \eta_{t_{ij}}, i = 1, 2., \ldots, m \tag{16}$$

In order to compare the internal and external assessment of the alternatives on the four-quadrant coordinate of SWOT matrix, the performances for internal and external factors of the alternatives are synthesized in a pair of coordinates which will determine the position of a strategic alternative on the four-quadrant coordinate.

Step 9: Calculate the internal and external coordinate values by utilizing (17) and (18) to fix the positions of strategic alternatives on SWOT matrix and compare graphically results.

$$IC_i = I_i - IB,\ i = 1, \ldots, m \tag{17}$$

$$EC_i = E_i - EB,\ i = 1, \ldots, m \tag{18}$$

where $IB = \frac{1}{m}\sum_{i=1}^{m} I_i$ and $EB = \frac{1}{m}\sum_{i=1}^{m} E_i$ represent the internal and external environment performance benchmarking values, respectively. IC_i represents the coordinate value of the Alt_i's internal environment, and EC_i represents the coordinate value of the Alt_i's external environment, and $IC_j, EC_j \in [-1, 1]$.

Now each alternative has a coordinate (x, y), so its position in the four-quadrant coordinate can be clearly realized. It is obvious that the alternatives which possess strengths and opportunities when the coordinate values are larger than the benchmarking values; the alternatives are comparatively weaknesses and face threats when the coordinate values are smaller than the benchmarking values. This can not only help organizations realize their position in the SWOT matrix but also have a reference for developing strategies.

5. NUMERICAL EXAMPLE

In this section, a numerical example of the shareholders of a forest holding owned by a private partnership adapted from (Kangas et al., 2003) is used to illustrate the proposed methodology. The shareholders of a forest holding owned by a private partnership prepared the SWOT analysis. Six alternatives for the management of their forest holding and of old cottage located on the holding were created as follows:

- *Alt*$_1$: Build a new cottage. Finance the investment by utilizing all cutting possibilities.
- *Alt*$_2$: Carry out repair work on the cottage and acquire additional facilities (boat, sauna). Finance the investment by utilizing all cutting possibilities.
- *Alt*$_3$: Carry out repair work on the cottage. Finance this by utilizing less than half of the cutting possibilities.
- *Alt*$_4$: No repairing of the cottage. No cuttings.
- *Alt*$_5$: Sell the cottage. Acquire additional incomes by utilizing cutting possibilities.
- *Alt*$_6$: Utilize first all cutting possibilities. Then sell the cottage and the forestland.

In the following, the SWOT analysis was performed with the proposed quantified SWOT methodology.

Step 1: Identify all related SWOT factors. The SWOT factors concerning these strategic alternatives were adapted from (Kangas et al., 2003) and shown in Table 1.

Table 1. The key elements of SWOT hierarchy

SWOT group	SWOT factors (and their abbreviations)
Strengths	Good hunting possibilities (S_{-1}) Excellent hiking possibilities (S_{-2}) Possessing share in Kuusamo Common Forest yields income and recreational possibilities (S_{-3}) Future timber cutting possibilities in own forests (S_{-4})
Weaknesses	Great distance from current residences (W_{-1}) Cottage is disrepair (W_{-2}) Cottage is poorly provided as regards facilities (W_{-3}) Costs of maintenance (W_{-4})
Opportunities	Repairing will increase usage (O_{-1}) Additional incomes from renting the cottage to holidaymakers (O_{-2}) New facilities will improve the quality of holidays (O_{-3}) Selling or not repairing the cottage would mean income or saved money (O_{-4})
Threats	Cuttings could spoil the scenery and decrease recreational values (T_{-1}) Social intercourse between partners will fade if the cottage is sold (T_{-2}) Repairing can cost more than expected (T_{-3}) Benefits from Kuusamo Common Forest will be lost (T_{-4})

The strategic alternatives decision is done by a committee of four decision-makers DM_k (k=1,2,3,4). For simplicity and without loss of generality, they provided preference information that is expressed in the following four different formats, where DM_1 provides his preferences over strategic alternatives with respect to internal SWOT factors using preference ordering, DM_2 provides his preferences over strategic alternatives with respect to external SWOT factors using utility function, DM_3 expresses his preferences over SWOT factors with respect to corresponding SWOT groups using fuzzy preference relations, and DM_4 expresses his preferences over SWOT groups using multiplicative preference relations.

Step 2: The preference information of SWOT elements are provided by the four experts and listed in Tables 2 to 4.

Table 2. The preference values of strategic alternatives on each SWOT factor provided by DM1 and DM2 with preference ordering and utility function, respectively

DM_1	Alt $_1$	Alt $_2$	Alt $_3$	Alt $_4$	Alt $_5$	Alt $_6$	DM_2	Alt $_1$	Alt $_2$	Alt $_3$	Alt $_4$	Alt $_5$	Alt $_6$
S_{-1}	3	4	2	1	5	6	O_{-1}	0.9	0.8	0.7	0.5	0.3	0.1
S_{-2}	3	4	2	1	5	6	O_{-2}	0.9	0.8	0.6	0.4	0.3	0.2
S_{-3}	1	2	3	4	5	6	O_{-3}	0.6	0.8	0.7	0.5	0.4	0.3
S_{-4}	3	4	2	1	5	6	O_{-4}	0.1	0.2	0.3	0.5	0.7	0.9
W_{-1}	3	4	5	6	2	1	T_{-5}	0.6	0.5	0.7	0.9	0.3	0.2
W_{-2}	1	2	3	4	5	6	T_{-6}	0.8	0.7	0.7	0.6	0.5	0.3
W_{-3}	2	3	1	4	5	6	T_{-7}	0.5	0.3	0.2	0.9	0.8	0.7
W_{-4}	3	5	6	4	2	1	T_{-8}	0.9	0.8	0.8	0.7	0.6	0.4

Table 3. The preference values of SWOT factors provided by DM3 with fuzzy preference relation

(Strengths)	S_{-1}	S_{-2}	S_{-3}	S_{-4}	(Weaknesses)	W_{-1}	W_{-2}	W_{-3}	W_{-4}
S_{-1}	0.5	0.2	0.6	0.3	W_{-1}	0.5	0.1	0.3	0.6
S_{-2}	0.8	0.5	0.9	0.7	W_{-2}	0.9	0.5	0.7	0.9
S_{-3}	0.4	0.1	0.5	0.4	W_{-3}	0.7	0.3	0.5	0.8
S_{-4}	0.7	0.3	0.6	0.5	W_{-4}	0.4	0.1	0.2	0.5
(Opportunities)	O_{-1}	O_{-2}	O_{-3}	O_{-4}	(Threats)	T_{-1}	T_{-2}	T_{-3}	T_{-4}
O_{-1}	0.5	0.9	0.7	0.9	T_{-1}	0.5	0.6	0.7	0.3
O_{-2}	0.1	0.5	0.3	0.6	T_{-2}	0.4	0.5	0.6	0.2
O_{-3}	0.3	0.7	0.5	0.8	T_{-3}	0.3	0.4	0.5	0.1
O_{-4}	0.1	0.4	0.2	0.5	T_{-4}	0.7	0.8	0.9	0.5

Table 4. The preference values over SWOT groups provided by DM4 with multiplicative preference relation

SWOT Group	Strength	Weaknesses	Opportunities	Threats
Strength	1	3	1/3	2
Weaknesses	1/3	1	1/7	1/2
Opportunities	3	7	1	6
Threats	1/2	2	1/6	1

Step 3: Make the preference information uniform. Utilize (1), (2), and (3) to transform preference ordering, utility function, and multiplicative preference relation into fuzzy preference relation, respectively. The transformed preference information is listed in Tables 5 to 10.

Step 4: Calculate the consistency level of preference relations by (8). The consistency level of preference relations are also listed in Tables 5 to 10. A. For the purpose of brevity, we list here the values of $r_{ij}, (i < j)$ and (the consistency level CL_{ij} of $r_{ij}, (i > j)$), the rest ones can be obtained according to $r_{ji} = 1 - r_{ij}$ and ($CL_{ij} = CL_{ji}$).

Table 5. The unified preference values and the consistency levels over SWOT groups

SWOT Group	Strength	Weaknesses	Opportunities	Threats
Strength	0.5	0.75	0.25	0.66
Weaknesses	(.935)	0.5	0.06	0.34
Opportunities	(.97)	(.9)	0.5	0.91
Threats	(.965)	(.9)	(.935)	0.5

Table 6. The unified preference values and the consistency levels of SWOT factors

(Strengths)	S_{-1}	S_{-2}	S_{-3}	S_{-4}	(Weaknesses)	W_{-1}	W_{-2}	W_{-3}	W_{-4}
S_{-1}	0.5	0.2	0.6	0.3	W_{-1}	0.5	0.1	0.3	0.6
S_{-2}	(.95)	0.5	0.9	0.7	W_{-2}	(.95)	0.5	0.7	0.9
S_{-3}	(.9)	(.95)	0.5	0.4	W_{-3}	(1)	(.95)	0.5	0.8
S_{-4}	(.85)	(.9)	(.85)	0.5	W_{-4}	(.95)	(.9)	(.95)	0.5
(Opportunities)	O_{-1}	O_{-2}	O_{-3}	O_{-4}	(Threats)	T_{-1}	T_{-2}	T_{-3}	T_{-4}
O_{-1}	0.5	0.9	0.7	0.9	T_{-1}	0.5	0.6	0.7	0.3
O_{-2}	(.95)	0.5	0.3	0.6	T_{-2}	(1)	0.5	0.6	0.2
O_{-3}	(.95)	(1)	0.5	0.8	T_{-3}	(1)	(1)	0.5	0.1
O_{-4}	(.9)	(.95)	(.95)	0.5	T_{-4}	(1)	(1)	(1)	0.5

Table 7. The unified preference values and the consistency levels of strategic alternatives on each strengths factor

(S_{-1})	Alt_1	Alt_2	Alt_3	Alt_4	Alt_5	Alt_6	(S_{-2})	Alt_1	Alt_2	Alt_3	Alt_4	Alt_5	Alt_6
Alt_1	0.5	0.6	0.4	0.3	0.3	0.2	Alt_1	0.5	0.6	0.4	0.3	0.7	0.8
Alt_2	(.75)	0.5	0.3	0.2	0.6	0.7	Alt_2	(.95)	0.5	0.3	0.2	0.8	0.7
Alt_3	(.75)	(1)	0.5	0.4	0.8	0.9	Alt_3	(1)	(.95)	0.5	0.4	0.8	0.9
Alt_4	(.75)	(1)	(1)	0.5	0.9	1	Alt_4	(1)	(.95)	(1)	0.5	0.9	1
Alt_5	(.65)	(.9)	(.9)	(.9)	0.5	0.6	Alt_5	(.95)	(.8)	(.95)	(.95)	0.5	0.6
Alt_6	(.5)	(.85)	(.85)	(.9)	(.95)	0.5	Alt_6	(1)	(.95)	(1)	(1)	(.95)	0.5
(S_{-3})	Alt_1	Alt_2	Alt_3	Alt_4	Alt_5	Alt_6	(S_{-4})	Alt_1	Alt_2	Alt_3	Alt_4	Alt_5	Alt_6
Alt_1	0.5	0.6	0.7	0.8	0.9	1	Alt_1	0.5	0.6	0.4	0.3	0.7	0.8
Alt_2	(1)	0.5	0.6	0.7	0.8	0.9	Alt_2	(1)	0.5	0.3	0.2	0.6	0.7
Alt_3	(1)	(1)	0.5	0.6	0.7	0.8	Alt_3	(1)	(1)	0.5	0.4	0.8	0.9
Alt_4	(1)	(1)	(1)	0.5	0.6	0.7	Alt_4	(1)	(1)	(1)	0.5	0.9	1
Alt_5	(1)	(1)	(1)	(1)	0.5	0.6	Alt_5	(1)	(1)	(1)	(1)	0.5	0.6
Alt_6	(1)	(1)	(1)	(1)	(1)	0.5	Alt_6	(1)	(1)	(1)	(1)	(1)	0.5

Table 8. The unified preference values and the consistency levels of strategic alternatives on each weaknesses factor

(W$_{-1}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt$_6$	(W$_{-2}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt$_6$
Alt$_1$	0.5	0.6	0.7	0.8	0.4	0.3	Alt$_1$	0.5	0.6	0.7	0.8	0.9	1
Alt$_2$	(1)	0.5	0.6	0.7	0.3	0.2	Alt$_2$	(1)	0.5	0.6	0.7	0.8	0.9
Alt$_3$	(1)	(1)	0.5	0.6	0.2	0.1	Alt$_3$	(1)	(1)	0.5	0.6	0.7	0.8
Alt$_4$	(1)	(1)	(1)	0.5	0.1	0	Alt$_4$	(1)	(1)	(1)	0.5	0.6	0.7
Alt$_5$	(1)	(1)	(1)	(1)	0.5	0.4	Alt$_5$	(1)	(1)	(1)	(1)	0.5	0.6
Alt$_6$	(1)	(1)	(1)	(1)	(1)	0.5	Alt$_6$	(1)	(1)	(1)	(1)	(1)	0.5
(W$_{-3}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt$_6$	(W$_{-4}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt$_6$
Alt$_1$	0.5	0.6	0.4	0.7	0.8	0.9	Alt$_1$	0.5	0.7	0.8	0.6	0.4	0.3
Alt$_2$	(1)	0.5	0.3	0.6	0.7	0.8	Alt$_2$	(1)	0.5	0.6	0.4	0.2	0.1
Alt$_3$	(1)	(1)	0.5	0.8	0.9	1	Alt$_3$	(1)	(1)	0.5	0.3	0.1	0
Alt$_4$	(1)	(1)	(1)	0.5	0.6	0.7	Alt$_4$	(1)	(1)	(1)	0.5	0.3	0.2
Alt$_5$	(1)	(1)	(1)	(1)	0.5	0.6	Alt$_5$	(1)	(1)	(1)	(1)	0.5	0.4
Alt$_6$	(1)	(1)	(1)	(1)	(1)	0.5	Alt$_6$	(1)	(1)	(1)	(1)	(1)	0.5

Table 9. The unified preference values and the consistency levels of strategic alternatives on each opportunities factor

(O$_{-1}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt$_6$	(O$_{-2}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt$_6$
Alt$_1$	0.5	0.55	0.6	0.7	0.8	0.9	Alt$_1$	0.5	0.55	0.65	0.75	0.8	0.85
Alt$_2$	(1)	0.5	0.55	0.65	0.75	0.85	Alt$_2$	(1)	0.5	0.6	0.7	0.75	0.8
Alt$_3$	(1)	(1)	0.5	0.6	0.7	0.8	Alt$_3$	(1)	(1)	0.5	0.6	0.65	0.7
Alt$_4$	(1)	(1)	(1)	0.5	0.6	0.7	Alt$_4$	(1)	(1)	(1)	0.5	0.55	0.6
Alt$_5$	(1)	(1)	(1)	(1)	0.5	0.6	Alt$_5$	(1)	(1)	(1)	(1)	0.5	0.55
Alt$_6$	(1)	(1)	(1)	(1)	(1)	0.5	Alt$_6$	(1)	(1)	(1)	(1)	(1)	0.5
(O$_{-3}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt$_6$	(O$_{-4}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt$_6$
Alt$_1$	0.5	0.4	0.45	0.55	0.6	0.65	Alt$_1$	0.5	0.45	0.4	0.3	0.2	0.1
Alt$_2$	(1)	0.5	0.55	0.65	0.7	0.75	Alt$_2$	(1)	0.5	0.45	0.35	0.25	0.15
Alt$_3$	(1)	(1)	0.5	0.6	0.65	0.7	Alt$_3$	(1)	(1)	0.5	0.4	0.3	0.2
Alt$_4$	(1)	(1)	(1)	0.5	0.55	0.6	Alt$_4$	(1)	(1)	(1)	0.5	0.4	0.3
Alt$_5$	(1)	(1)	(1)	(1)	0.5	0.55	Alt$_5$	(1)	(1)	(1)	(1)	0.5	0.4
Alt$_6$	(1)	(1)	(1)	(1)	(1)	0.5	Alt$_6$	(1)	(1)	(1)	(1)	(1)	0.5

Table 10. The unified preference values and the consistency levels of strategic alternatives on each threat factor

(T$_{-1}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt$_6$	(T$_{-2}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt$_6$
Alt$_1$	0.5	0.55	0.45	0.35	0.65	0.7	Alt$_1$	0.5	0.55	0.55	0.6	0.65	0.75
Alt$_2$	(1)	0.5	0.4	0.3	0.6	0.65	Alt$_2$	(1)	0.5	0.5	0.55	0.6	0.7
Alt$_3$	(1)	(1)	0.5	0.4	0.7	0.75	Alt$_3$	(1)	(1)	0.5	0.55	0.6	0.7
Alt$_4$	(1)	(1)	(1)	0.5	0.8	0.85	Alt$_4$	(.99)	(.99)	(.99)	0.5	0.55	0.7
Alt$_5$	(1)	(1)	(1)	(1)	0.5	0.55	Alt$_5$	(1)	(1)	(1)	(.99)	0.5	0.6
Alt$_6$	(1)	(1)	(1)	(1)	(1)	0.5	Alt$_6$	(.99)	(.99)	(.99)	(.95)	(.99)	0.5
(T$_{-3}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt 6	(T$_{-4}$)	Alt$_1$	Alt$_2$	Alt$_3$	Alt$_4$	Alt$_5$	Alt$_6$
Alt$_1$	0.5	0.6	0.65	0.3	0.35	0.4	Alt$_1$	0.5	0.55	0.55	0.6	0.65	0.75
Alt$_2$	(1)	0.5	0.55	0.2	0.25	0.3	Alt$_2$	(1)	0.5	0.5	0.55	0.6	0.7
Alt$_3$	(1)	(1)	0.5	0.15	0.2	0.25	Alt$_3$	(1)	(1)	0.5	0.55	0.6	0.7
Alt$_4$	(1)	(1)	(1)	0.5	0.55	0.6	Alt$_4$	(1)	(1)	(1)	0.5	0.55	0.65
Alt$_5$	(1)	(1)	(1)	(1)	0.5	0.55	Alt$_5$	(1)	(1)	(1)	(1)	0.5	0.6
Alt$_6$	(1)	(1)	(1)	(1)	(1)	0.5	Alt$_6$	(1)	(1)	(1)	(1)	(1)	0.5

Step 5: Aggregate the individual preference relations. In this case all *DMs* conduct their assessments over different elements sets, so the aggregation is unnecessary.

Step 6: Calculate the dominance degrees of SWOT elements by (12), (13). For example, $DD_S = IOWA_w^{AC}(<0.935, 0.75>, <0.97, 0.25>, <0.965, 0.66>)$, the weights of argument variables are

$$w_1 = \left(\frac{0.97}{2.87}\right)^{1/2} - \left(\frac{0}{2.87}\right)^{1/2} = 0.58,\ w_2 = \left(\frac{1.935}{2.87}\right)^{1/2} - \left(\frac{0.97}{2.87}\right)^{1/2} = 0.24,$$

$$w_3 = \left(\frac{2.87}{2.87}\right)^{1/2} - \left(\frac{1.935}{2.87}\right)^{1/2} = 0.18, \text{ thus}$$

$$DD_S = IOWA_w^{AC}(<0.935, 0.75>, <0.97, 0.25>, <0.965, 0.66>) \\ = 0.18\times 0.75 + 0.58\times 0.25 + 0.24\times 0.66 = 0.1584,$$

Similarly, we can derive the dominance degrees of weakness, opportunity and threat, $DD_W = 0.229$, $DD_O = 0.2093$, $DD_T = 0.3401$. Then, we obtain the priorities of SWOT groups by (14).

$$\mu_S = \frac{0.1584}{0.9368} = 0.17,\ \mu_W = \frac{0.229}{0.9368} = 0.25,\ \mu_O = \frac{0.2093}{0.9368} = 0.22,$$

$$\mu_T = \frac{0.3401}{0.9368} = 0.36.$$

Similarly, we can obtain the priorities of SWOT factors.

$(\mu_{s_1}, \mu_{s_2}, \mu_{s_3}, \mu_{s_4}) =$ (0.15, 0.40, 0.11, 0.34), $(\mu_{w_1}, \mu_{w_2}, \mu_{w_3}, \mu_{w_4}) =$ (0.16, 0.4, 0.31, 0.13), $(\mu_{o_1}, \mu_{o_2}, \mu_{o_3}, \mu_{o_4}) =$ (0.4, 0.16, 0.31, 0.13), $(\mu_{t_1}, \mu_{t_2}, \mu_{t_3}, \mu_{t_4}) =$ (0.27, 0.21, 0.14, 0.38).

And the dominance degrees of alternatives with respect to SWOT factors, the results are listed in Tables 11 and 12.

Table 11. The dominance degrees of alternatives with respect to the strength factors and the weakness factors

	S_{-1}	S_{-2}	S_{-3}	S_{-4}	W_{-1}	W_{-2}	W_{-3}	W_{-4}
Alt_1	0.725	1.015	1.401	0.664	0.31	0.417	0.364	0.342
Alt_2	0.6	0.869	1.225	0.548	0.255	0.366	0.311	0.218
Alt_3	1.071	1.210	1.043	0.779	0.2	0.312	0.417	0.145
Alt_4	1.263	1.396	0.861	0.893	0.13	0.258	0.257	0.28
Alt_5	0.729	0.632	0.674	0.474	0.363	0.201	0.2	0.4
Alt_6	0.475	0.306	0.438	0.280	0.415	0.132	0.130	0.458

Table 12. The dominance degrees of alternatives with respect to the opportunity factors and the threat factors

	O_{-1}	O_{-2}	O_{-3}	O_{-4}	T_{-1}	T_{-2}	T_{-3}	T_{-4}
Alt_1	1.577	1.531	1.166	0.776	0.31	0.331	0.296	0.341
Alt_2	1.465	1.415	1.390	0.934	0.281	0.300	0.230	0.312
Alt_3	1.351	1.199	1.279	1.063	0.338	0.300	0.188	0.312
Alt_4	1.120	0.972	1.05	1.315	0.396	0.272	0.421	0.283
Alt_5	0.882	0.855	0.931	1.563	0.220	0.224	0.391	0.253
Alt_6	0.589	0.710	0.783	1.808	0.182	0.18	0.359	0.178

Step 7: Calculate the performances of strategic alternatives with respect to each SWOT factor by multiplying the dominance degree of strategic alternative under SWOT factor with the priorities of the corresponding SWOT factor and group. The results are listed in Tables 13 and 14. In addition, Figure 3 graphically shows the comparison of each strategic alternative with respect to SWOT factors.

Table 13. The performance of strategic alternatives with respect to the strength factors and the weakness factors

	S_{-1}	S_{-2}	S_{-3}	S_{-4}	W_{-1}	W_{-2}	W_{-3}	W_{-4}
Alt_1	0.0185	0.069	0.0262	0.0384	0.0124	0.0417	0.0282	0.0111
Alt_2	0.0153	0.0591	0.0229	0.0317	0.0102	0.0366	0.0241	0.0071
Alt_3	0.0273	0.0823	0.0195	0.045	0.008	0.0312	0.0323	0.0047
Alt_4	0.0322	0.0949	0.0161	0.0516	0.0052	0.0258	0.0199	0.0091
Alt_5	0.0186	0.043	0.0126	0.0274	0.0145	0.0201	0.0155	0.013
Alt_6	0.0121	0.0208	0.0082	0.0162	0.0166	0.0132	0.0101	0.0149

Table 14. The performances of strategic alternatives with respect to the opportunity factors and the threat factors

	O_{-1}	O_{-2}	O_{-3}	O_{-4}	T_{-1}	T_{-2}	T_{-3}	T_{-4}
Alt_1	0.1388	0.0539	0.0795	0.0222	0.0301	0.025	0.0149	0.0466
Alt_2	0.1289	0.0498	0.0948	0.0267	0.0273	0.0227	0.0116	0.0427
Alt_3	0.1189	0.0422	0.0872	0.0304	0.0329	0.0227	0.0095	0.0427
Alt_4	0.0986	0.0342	0.0716	0.0376	0.0385	0.0206	0.0212	0.0387
Alt_5	0.0776	0.0301	0.0635	0.0447	0.0214	0.0169	0.0197	0.0346
Alt_6	0.0518	0.025	0.0534	0.0517	0.0177	0.0136	0.0181	0.0244

From Figure 3, we can visually understand the embodied situations of strategic alternatives under their SWOT factors, and the comparisons of the all alternatives.

Step 8: Calculate the performances of the alternatives' internal factors and external factors by (15) and (16). The performances are listed in Table 15.

Table 15. The performances of alternatives' internal factors and external factors

	Alt_1	Alt_2	Alt_3	Alt_4	Alt_5	Alt_6
Performances of alternatives' internal factors	0.0587	0.051	0.0979	0.1348	0.0385	0.0025
Performances of alternatives' external factors	0.1778	0.1959	0.1709	0.123	0.1233	0.1081

Step 9: Calculate the coordinate values of all alternatives by (17) and (18), the coordinate values of alternatives are listed in the first two rows of Table 16, and the positions of strategic alternatives can be graphically represented on SWOT matrix, as show in Figure 4.

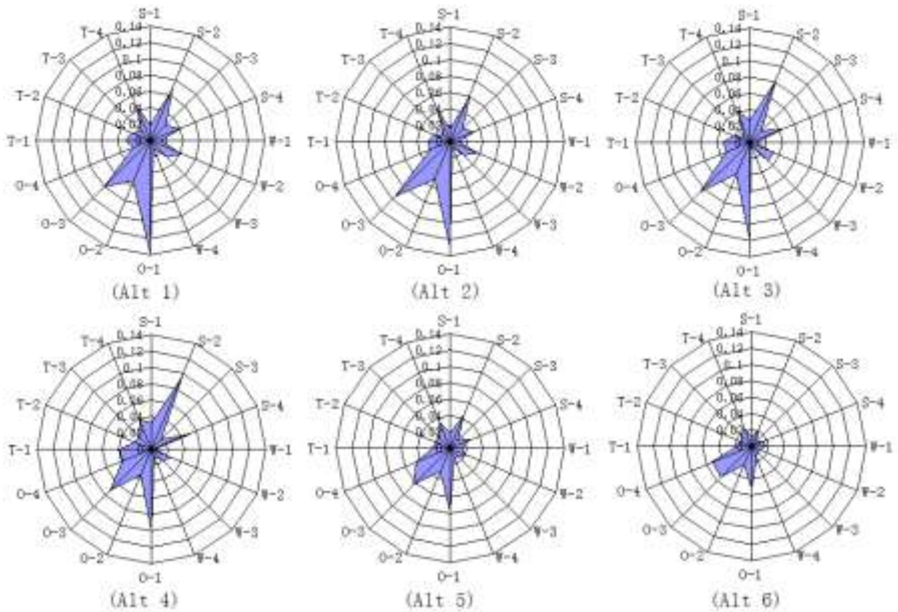

Figure 3. Graphical representations of the performances of each strategic alternative with respect to all SWOT factors

Table 16. The coordinate values and overall performance of alternatives

Alternative	Alt_1	Alt_2	Alt_3	Alt_4	Alt_5	Alt_6
Internal coordinate	-0.0052	-0.0129	0.034	0.0709	-0.0254	-0.0614
External coordinate	0.027967	0.046067	0.021067	-0.02683	-0.02653	-0.04173
Overall performance	0.2365	0.2469	0.2688	0.2578	0.1618	0.1106

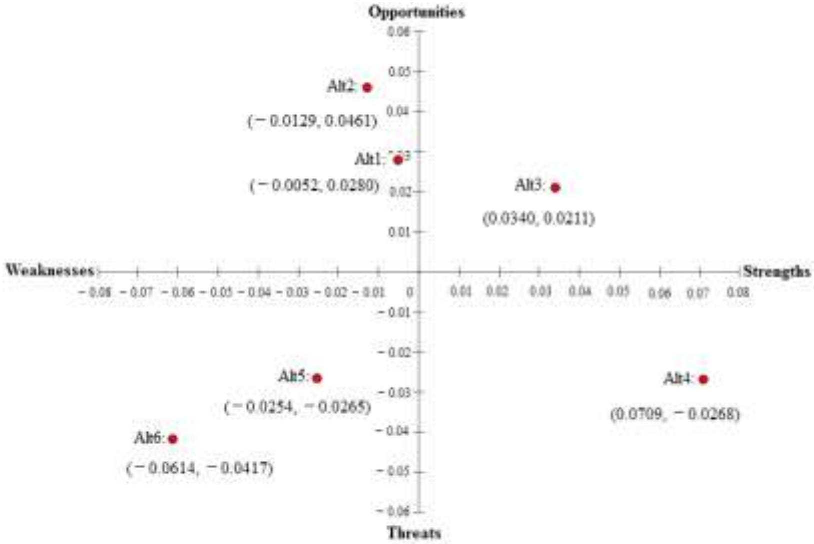

Figure 4. Graphical representation of the situation of the strategic alternatives

Figure 4 shows clearly the positions of strategic alternatives in the SWOT matrix. Alt_3 is in the first quadrant (the value of internal coordinate=0.034, the value of internal coordinate=0.0211), which means that it is in the best position and has external opportunities and internal strengths. So Alt_3 can adopt aggressive strategies to maximize both strengths and opportunities. Alt_1 and Alt_2 are in the second quadrant, their coordinate values are (–0.0052, 0.027967) and (–0.0129, 0.046067), respectively, which indicates that they face opportunities but possess greater weaknesses than strengths. The most urgent issue is to gain benefit from the external opportunities by taking into account the internal weaknesses. Alt_4 is in the forth quadrant (0.0709, –0.02683), which means that it possesses competition strengths but faces greater threats than opportunities. So it should use the internal strengths to remove or reduce the effects of threats of some unfavorable situations. Alt_5 and Alt_6 are parked in the third quadrant, which indicate they are of weaknesses and facing external threats, the positions are unfavorable and one that any alternative will try to avoid. The defensive strategy adopted supposes fight for survival and diminution of losses by minimizing both internal weaknesses and external threats. But, in fact, they are viewed as inefficient alternatives compared with the others.

From the SWOT matrix, we can conclude that Alt_3 is in the first quadrant and is the best alternative of them, Alt_5 and Alt_6 are inefficient alternatives. However, Alt_1 and Alt_2 are in the third quadrant as well as Alt_4 is in the forth quadrant, which is better is indeterminate. In order to rank the alternatives, we further synthesize all performance of SWOT factors against each strategic alternative to get the overall performances of strategic alternatives. The overall performances are listed in the third rows of Table 16. The ranks: $Alt_3 \succ Alt_4 \succ Alt_2 \succ Alt_1 \succ Alt_5 \succ Alt_6$. Hence Alt_3 (Carry out repair work on the cottage and finance this by utilizing less than half of the cutting possibilities) is the most recommendable.

6. CONCLUSIONS

SWOT is a widely used tool for analyzing internal and external environments in order to attain a systematic understanding of a strategic decision situation. This paper proposed a quantified SWOT decision analysis methodology to evaluate and analyze multiple alternatives simultaneously, which consists of three parts: a converted SWOT hierarchy as the general framework is first used to structure the problem and to keep the entire decision-support process under the decision-makers' control, a MCGDM method with multiple preference structures is developed to allow *DMs* not only provide their opinions in a more versatile and free manner to represent their preference of SWOT decision elements, but also forces they to think harder and to analyze the situation more precisely and in more depth. Finally, by using SWOT matrix to holistically analyze and compare of multiple strategic alternatives.

In the proposed MCGDM method, the multiple preference structures are transformed firstly into fuzzy preference relations. The aggregation and exploitation of unified preference information is by utilizing AC-IOWA operator which directly make use of consistency associated with preference to effectively overcome inconsistent judgment and improves the reliability of the aggregation results.

As it can be understood from the illustrative example, the methodology can not only provide effectively decision support evaluation of internal and external environment of individual strategic alternative, but also facilitate holistic analysis and compare multiple strategic alternatives, hence improving the usability of SWOT analysis.

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