Development of a Hybrid Method Based on Fuzzy PROMETHEE and ANP in the Framework of SWOT Analysis For Strategic Decisions

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ABSTRACT: Nowadays, organizations could not be imagined without enjoying strategy, and the existence of an appropriate strategy is a requirement for a successful organization. On this basis, in the recent years, a considerable amount of research has been done in regard to strategic planning for different organizations by means of MADM methods, especially in a combinational and merging manner. In the same course, in this study, we have also supposed the combinational method of FANP and PROMETHEE in the framework of the SWOT analysis for the strategic planning of organizations, which ultimately prioritizes strategies for organizations which apart from using the strengths and opportunities available in the outside environment of organizations, are also active in the obviation of external weaknesses and threats. This combinational method by using the advantages and assumptions of each of the FANP and FPROMETHEE methods in its appropriate place and within the SWOT analysis framework, results in the reduction of complexity and the simultaneous increase of the desire and accuracy of evaluators for participation in decision making processes.

Keywords: ANP, PROMETHEE, SWOT, Strategy

INTRODUCTION AND STATEMENT OF PROBLEM

In the management modern literature, organizations lacking strategy are like ships that sooner or later will sink in the choppy ocean of competition. Therefore, enjoyment of proper and long term strategies is necessary for an organization. Also, it is apparent that for the fast and considerable success of an organization and for budgeting, these strategies also need to be prioritized and ranked. Nowadays, in spite of the high amount of attention that is paid to long term and strategic decisions in every organization, unfortunately still there are a considerable number of companies that because of wrong, unprofessional, and inoperable decisions have perverted or collapsed.

In the present study, we have tried to increase the accuracy and the correctness of strategic decisions by presenting a new method combined of the two methods of the fuzzy PROMETHEE and ANP, by using the advantages of these two methods together, and using each one in its appropriate place; so that the trustability of these decisions for planning a more clear future goes up. It should be mentioned that for this purpose the SWOT analysis was exploited as the framework and axis of decision making processes so that decisions enjoyed more generality. In fact, it could be said that the main property of this study is the use of a combined method of the fuzzy PROMETHEE and ANP together in the framework of the SWOT analysis for making correct strategic decisions, which has not been mentioned in similar studies this way; and on the other hand the combinational method used here helps to reduce complexity, make relationships more tangible, and increase the correctness, accuracy, and easiness of obtained results. It is evident that when the obtained strategies get more tangible, the specification of operational programs to attain these strategies also get easier. PROMETHEE method, given its paired comparisons for every two choices in relation to all criteria and also high accuracy in decision makings, in combination with the fuzzy ANP method (and using the weights and strategies resulted through this method) has proved to be efficient for proper prioritization of obtained strategies. It is necessary to mention that in this study, considering the fuzzy state of decision making methods, the ambiguities of strategic decision making will be analyzed.
MATERIALS AND METHODS

Fuzzy Promethee

The PROMETHEE method has been developed by Brans et al. based on the fuzzy logic presented by Lotfizadeh and has been named fuzzy PROMETHEE method. The fuzzy PROMETHEE method includes the following stages:

Stage 1: Production of flexible choices, specification of evaluation criteria, and constitution of a group of decision makers. Suppose there are m choices, K criteria, and n decision makers.

Stage 2: Define linguistic variables and specify their equivalent triangular fuzzy numbers. Different scales of linguistic variables are used for evaluating the importance of criteria and choices. As in Chen & Hwang’s study, Fuzzy numbers with 5-scale linguistic variables are used for evaluating the importance of criteria with a fuzzy set. As a recommendation, the following table that shows linguistic scales and triangular fuzzy numbers in order can be used for the evaluation of criteria and the prioritization of choices.

<table>
<thead>
<tr>
<th>Linguistic variables</th>
<th>Fuzzy number</th>
<th>Ratings of alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low (VL)</td>
<td>(0.00, 0.00, 0.25)</td>
<td>Worst (W)</td>
</tr>
<tr>
<td>Low (L)</td>
<td>(0.00, 0.25, 0.50)</td>
<td>Poor (P)</td>
</tr>
<tr>
<td>Medium (M)</td>
<td>(0.25, 0.50, 0.75)</td>
<td>Fair (F)</td>
</tr>
<tr>
<td>High (H)</td>
<td>(0.50, 0.75, 1.00)</td>
<td>Good (G)</td>
</tr>
<tr>
<td>Very High (VH)</td>
<td>(0.75, 1.00, 1.00)</td>
<td>Best (B)</td>
</tr>
</tbody>
</table>

Stage 3: Collect the evaluated ideas from decision makers. A decision is obtained by summing up the fuzzy weights of criteria and the fuzzy rate of choices from n decision makers. The ideas of n experts about the criterion j are extracted in order to weigh and evaluate the importance of each criterion according to equation (1). In addition, the preferences of n decision makers about the fuzzy rate of each choice in the i th choice could be obtained by using equation (2):

\[
\bar{x}_i = \frac{1}{n} \sum_{m=1}^{n} x_{ij} = \frac{1}{n} \left( \bar{w}_j (+ \bar{x}_1 ^j (+ ... + \bar{x}_m ^j) \right)
\]

Stage 4: Make a fuzzy decision matrix and calculate the average fuzzy weight of criteria:

\[
\tilde{D} = \left[ \begin{array}{cccc} C_1 & C_2 & \ldots & C_k \\ \tilde{x}_{i1} & \tilde{x}_{i2} & \ldots & \tilde{x}_{ik} \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \ldots & \tilde{x}_{mk} \end{array} \right] \\
W = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_k]
\]

Stage 5: Make a fuzzy preference function, where A is a set of choices, and a and b are two choices of set A. Thus, the selection and preference function of \( \tilde{P}_j(a, b) \) could be defined as the following:
\[
\tilde{P}_j(a,b) = \begin{cases} 
0, & \tilde{x}_{aj} \leq \tilde{x}_{bj}, \\
\frac{\tilde{x}_{aj} - \tilde{x}_{bj}}{\tilde{x}_{aj}}, & j=1,2,\ldots,K
\end{cases}
\]

where the preference function of \( \tilde{P}_j(a,b) \) is the intensity of external ranking, showing a is superior to b. The preference function \( \tilde{P}_j(a,b) \) for a scale of j is produced for a difference between two evaluations at that scale. External ranking structures are produced through the paired comparison of choices proportions:

\[
\begin{align*}
(\tilde{x}_{aj})_j & \iff apb \ (a \ outranks \ b), \\
\tilde{x}_{aj} = \tilde{x}_{bj} & \iff alb \ (a \ is \ indifferent \ to \ b).
\end{align*}
\]

Also, the PROMETHEE method presents six generalized criteria for the definition of superiority (preference) function to the decision maker. The mathematical relations of each function and its diagram have been shown in the table below. Data type and the decision maker idea are determinants of the type of the generalized criterion.

<table>
<thead>
<tr>
<th>criterion name</th>
<th>parameter</th>
<th>relation</th>
<th>diagram</th>
<th>description</th>
</tr>
</thead>
</table>
| Type I: Usual criterion | - | \( P(d) = \begin{cases} 
0, & d = 0 \\
1, & d \neq 0
\end{cases} \) | ![Diagram](source: Chou et al., 2004) | If the scores of both choices are equal, there will be no difference |
| Type II: U-shape criterion | q | \( P(d) = \begin{cases} 
0, & d \leq q \\
1, & d > q
\end{cases} \) | ![Diagram](source: Chou et al., 2004) | As long as the score difference between two choices is less than q, there will be no difference |
| Type III: V-shape criterion | p | \( P(d) = \begin{cases} 
\frac{d}{p}, & d \leq p \\
1, & d > p
\end{cases} \) | ![Diagram](source: Chou et al., 2004) | With the oscillation of scores between zero and 9 the amount of linear priority changes. If the difference is more than p, the choice has a complete priority |
| Type IV: Level criterion | q,p | \( P(d) = \begin{cases} 
0, & d \leq q \\
\frac{1}{2}, & q < d \leq p \\
1, & d > p
\end{cases} \) | ![Diagram](source: Chou et al., 2004) | If the score difference between two choices is less than q, there is no difference. If the difference is between q and p, there is a relative difference. If the difference is more than p, there is a complete priority |
| Type V: V-shape criterion with indifference criterion | q,p | \( P(d) = \begin{cases} 
0, & d \leq q \\
\frac{d - q}{p - q}, & q < d \leq p \\
1, & d > p
\end{cases} \) | ![Diagram](source: Chou et al., 2004) | If the score difference between two choices is less than q, there is no difference. With the change of scores in the interval between q and p, the amount of priority changes linearly. If the difference is more than p, there is a complete priority |
| Type VI: Gaussian criterion | \( \delta \) | \( P(d) = 1 - e^{-\frac{d^2}{2\delta^2}} \) | ![Diagram](source: Chou et al., 2004) | The amount of priority increases with the difference amount between the choices scores |

[506]
Stage 6: Produce a fuzzy multi-criterion preference index for the determination of the amount of external ranking relation. If every scale Cj(i=1,2,...,k) with a preference function of $\tilde{P}_j$ (multi-scale preference index of $(\tilde{\pi}(a, b)$ could be obtained as follows:

$$\tilde{\pi}(a, b) = \sum_{j=1}^{k} \left[ \widetilde{w}_j \tilde{P}_j(a, b) \right] \sum_{i=1}^{k} \widetilde{w}_j$$

$$\Phi(a, b) = \frac{1}{k} \sum_{j=1}^{k} \tilde{P}_j(a, b)$$

When the priority weights of scales are equal, then equation (7) or the average weight should be used as equation (8).

Stage 7: Calculate the current in choices:

**fuzzy promethee i**

The use of relative pre-order shows a message that can not reflect the comparison between some substitutes.

9) output current:

$$\tilde{\phi}^+(a) = \frac{1}{n-1} \sum_{y \neq a} \tilde{\pi}(a, y), \quad \forall a, y \in A$$

where $\tilde{\phi}^+(a)$ is the sum of choices, showing a is superior compared with other choices. With increase in $\tilde{\phi}^+(a)$ amount the proportion of choice a also increases.

10) Input current:

$$\tilde{\phi}^-(a) = \frac{1}{n-1} \sum_{y \neq a} \tilde{\pi}(y, a), \quad \forall a, y \in A,$$

Where $\tilde{\phi}^-(a)$ is the sum total of choices, showing other choices are superior to a. Where the amount of $\tilde{\phi}^-(a)$ is smaller, the proportion of choice a increases, then the relation of selection to the relative pre-orders of $P^{(i)}, I^{(i)}, R$ is produced as the following:

$$(11) \begin{cases} p \cdot b: \begin{cases} P \text{ iff } \tilde{\phi}^+(a) > \tilde{\phi}^+(b), & \forall a, b \in A \\ \quad 1 \text{ iff } \tilde{\phi}^+(a) = \tilde{\phi}^+(b), & \forall a, b \in A \\ \quad 0 \text{ iff } \tilde{\phi}^{-}(a) > \tilde{\phi}^-(b), & \forall a, b \in A \\ \quad 1 \text{ iff } \tilde{\phi}^{-}(a) = \tilde{\phi}^-(b), & \forall a, b \in A \end{cases} \end{cases}$$

According to the section between chapters (11) and (12), the relation between external ranking and relative prioritization could be obtained as follows:

$$(13) \begin{cases} ap^{(i)}, \begin{cases} (a \text{ outranks } b), & \begin{cases} ap^+b: P \text{ and } \tilde{a}P^-b: \tilde{b}: P \\ \quad aP^+b: I \text{ and } \tilde{a}P^-b: I \end{cases} \end{cases} \\ aI^{(i)}b \text{ (a is indifferent to b),} & \begin{cases} ap^+b: P \text{ and } \tilde{a}P^-b: \tilde{b}: P \\ \quad aP^+b: I \text{ and } \tilde{a}P^-b: I \end{cases} \end{cases}$$

Fuzzy Promethee ii

compare and rank all of the choices by means of complete prioritization. This model ranks choices according to their pure currents. Pure current is defined like this:

$$\Phi(a) = \tilde{\phi}^+(a) - \tilde{\phi}^-(a), \quad \forall a \in A.$$
The increase of $\hat{\Phi}(a)$ amount also increases the proportion of choice $a$. Finally, for the clarification of prioritization, we can convert the triangular fuzzy amount of $\hat{\Phi}(a)$ with three parameters: $(L,M,U)$ to a definite number, using determination methods. The method used in this study is as below:

$$\hat{\Phi}(a) = \frac{4M + L + U}{6} \quad (15)$$

The preference-selection relation is also defined as the following:

\[
\begin{cases}
(aP^{(i)}(ii)b (a \text{ outranks } b) & \text{iff } \phi(a) > \phi(b), \quad \forall a,b \in A, \\
(aI^{(ii)}b (a \text{ is indifferent to } b) & \text{iff } \phi(a) = \phi(b), \quad \forall a,b \in A.
\end{cases}
\]

As it was shown, in the fuzzy PROMETHEE I, relative prioritization is obtained through input and output currents; while in the fuzzy PROMETHEE II, the results of pure current result in a complete ranking.

Stage 8: Provide an external value ranking diagram for evaluating the selection degree of each choice.

A number of studies that have recently used the PROMETHEE method for strategic evaluating and planning include:

In Asgharizadeh & Nasrollahi’s study (2008), first, the most important excellence models have been investigated briefly and then in the conducted case study 31 auto-parts manufacturers have been ranked according to obtained excellence levels and using the PROMETHEE method with 9 specific criteria (and using the $v$-form preference function). In Anand & Kodali’s research (2008), in order to complete the decision making process, the PROMETHEE method is used for analyzing the effect of the organization shareholders on its profits. In this case study, 3 choices of LMS, CIMS, and TMS are investigated in 38 criteria with different preference functions of "V-form", "U-form", "leveled", and "V-form with indifference zone" (having available the specific and predetermined parameters of $q_i$ and $p_i$) using the PROMETHEE method. Liu & Guan (2009), in their study, first convert specified linguistic variables to triangular fuzzy numbers and in the following exploit the PROMETHEE II method for the evaluation of projects. In this approach, linear criterion (V-form) with the specific and predetermined parameters of $p_i$ has been used for the preference function. Following the positive current of fuzzy, the negative current of fuzzy and the network current of fuzzy are also calculated. Finally, according to the expected value (determination) of triangular fuzzy numbers in the pure current of network, the order of the project is confirmed. Afterwards, this evaluation model is used for evaluating the quality of the service presented to travelers in 3 railway stations in the railway office of Jinan. In this case study, 6 important criteria are also considered. This kind for usage shows that this method (PROMETHEE II) is easy and simple to work with and could be used comprehensively. Study of Vindoh & Girubha (2012) investigates the selection of the concept of storage capability in 3 directions (steps) of ingredients, product, and production process for a specific company. This analysis has been carried out taking account of 16 different and important criteria by using the PROMETHEE method and different preference functions of "V-form", "U-form", and "V-form with indifference zone" (having available the specific and predetermined parameters of $q_i$ and $p_i$). Study Chen, Wang, and Wu (2011) presents the organized method of fuzzy preference ranking for rich evaluation (fuzzy PROMETHEE) in order to evaluate 4 potential suppliers by using 7 scales and 4 decision makers through a real case study (the under study company is a bank in Taiwan). It should be mentioned that in this study the ideas of evaluators have been unified using arithmetic (usual) mean. Ultimately, after the implementation of different steps of the fuzzy PROMETHEE, the ranking of choices is produced. The results of rankings provide a reference that helps decision makers or organizations trying to promote the efficiency of decision making processes regarding the supply of IT/IS resource.

**ANP Technique**

The Analytic Hierarchical Process (AHP) was first developed by Saaty in 1971, the goal of which was creating structure in decision making that are affected by several independent factors. In response to the limits of AHP and the disability of this approach in considering the dependencies between criteria and factors, Saaty in 1996 developed another approach that is well known as the Analytic Network Process (ANP) approach. As the Analytic Network Process is a general and extensive mode of AHP, therefore, it enjoys all the positive properties thereof including simplicity, flexibility, simultaneous use of qualitative and quantitative criteria, and the capability of investigating consistency in judgments; and in addition can consider the complex relationships among and inside decision elements by using a network structure instead of a hierarchical structure. The difference between a hierarchical structure and a network structure is shown in the following diagram:
Analytic Network Process assumes every subject and issue as a network of criteria, sub-criteria, and choices (all of them called elements) that have come together in clusters. All of the elements in a network can be some way in relationship to each other. In other words, in a network, feedback and interaction inside and among clusters is possible (García-Melón, 2008, pp.145). Therefore, ANP could be assumed composed of two parts: control hierarchy and network relationship. Saaty believes that the control hierarchy includes the relationship between goal, criteria, and sub-criteria and is effective on the internal relationship of the system, and the network relationship includes the dependency between elements and clusters. This capability of ANP provides the possibility of the consideration of interdependencies among elements and, in turn, presents a precise attitude towards complex urban issues. The effect of elements on other elements in a network is considered by means of a super-matrix. The classical Analytic Network Process (ANP) could be summarized in four following stages (Carlucci and Schiuma, 2008):

1. Construction of model and conversion of subject/issue to a network structure
2. Formation of binary comparison matrix and specification of priority vectors
3. Formation of super-matrix and its conversion to a limit super-matrix
4. Selection of superior choice.

It needs to be mentioned that in the Analytic Network Process the stages could be proceeded in two ways:

- Choices weights and finally their priority are determined through the formation of great matrix and the normalization thereof.
- Stages are proceeded according to the matrix operation, which is preferred to the previous method in this study.

**SWOT Analysis**

SWOT technique got well known for its evident and reasonable assumptions in the 1970’s so that by means of which managers could plan their internal resources taking account of the external environment. In the 1990’s, Barney refined the SWOT technique by making connections between internal resources and the sustainable competitive advantage (this technique has not lost its reputation and operation even in the new century so that in many companies and organization strategic planning is considered as one of essential techniques). Letters SWOT that are also written in other orders like TOWS, are the first letters of strength, weakness, opportunity, and threat. The essence of strength and weakness is related to the inside of the system, and opportunities and threats are environmental. In the following, a brief description is presented for each factor:

- **Strength: S**: An organizational internal characteristic that is effective for realization of the organization goals.
- **Weakness: W**: An organizational internal characteristic that has a negative effect on its operation.
- **Opportunities: O**: An external fact that if used is, or can be, effective for realization of the organization goals.
- **Threat: T**: An external fact that has, or can have, a negative effect on the organization operation.

From the view point of this model, an appropriate strategy increases strengths and opportunities to their highest extent and decreases weaknesses and threats as low as possible. For this purpose, strengths, weaknesses, opportunities, and threats are connected to each other in four general ways of WT, ST, WO, and SO; and strategy choices are selected among them (Harisson, J. & caron, J., 2004, pp.192).
A. **Strength-Opportunity Approaches (SO)**

This mode is the most appropriate and desirable mode for an organization and means that the company enjoys not only reliable and appropriate capabilities and strengths, but also appropriate and valuable opportunities in its interactive and contextual environment. Therefore, this group of strategies reflect the way of employing the existing capabilities of the organization for maximal exploitation of environmental opportunities.

B. **Strength-Threat Approaches (ST)**

In this mode, although the organization enjoys reliable strengths and capabilities, on the opposite side, it faces different types of threats in its external and interactive environment. Therefore, this group of strategies represents the exploitation of the existing capabilities of the organization for reducing or obviating external threats.

C. **Weakness-Opportunity Approaches (WO)**

In this mode, the organization, using this group of strategies, should do its best for the compensation of weaknesses and inabilities by means of environmental opportunities.

D. **Weakness-Threat Approaches (WT)**

This mode draws the worst, most difficult, and most risky conditions for the organization activity. Because, the organization not only is faced with several weaknesses and inabilities, it must also confront different pressures, challenges, and threats in its interactive environments. Thus, making use of WT strategies, it tries to hide its weaknesses, reduce and protect its frailties against environmental threats, and if possible, keep itself away from the danger of such threats and damages.

On the whole, in order to make the matrix of threats, opportunities, weaknesses, and strengths, 8 steps are required to proceed:

- Providing a list of prominent opportunities available in the external environment of the organization.
- Providing a list of prominent threats available in the external environment of the organization.
- Providing a list of the prominent internal strengths of the organization.
- Providing a list of the prominent internal weaknesses of the organization.
- Comparing internal strengths and external opportunities and inserting the result in the related space in the SO strategies group.
- Comparing internal weaknesses with opportunities existing outside and inserting the result in the WO strategies group.
- Comparing internal strengths with external threats and inserting the result in the ST strategies group.
- Comparing internal weaknesses with external threats and inserting the result in the WT strategies group.

A number of articles that have recently been carried out for strategic evaluation and planning in a combinational manner (by means of the mentioned methods) include:

<table>
<thead>
<tr>
<th>combined methods</th>
<th>title of article</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWOT with ANP&amp;AHP</td>
<td>Yuksel&amp;Dagdeviren (2007)</td>
</tr>
<tr>
<td>FAHP with SWOT</td>
<td>Nazemi,Fathi,Didekhani (2011)</td>
</tr>
<tr>
<td>AHP with SWOT</td>
<td>Tahernejad,Khalokakaie,Ataei (2011)</td>
</tr>
<tr>
<td>FANP with SWOT</td>
<td>Sevkli, Oztekin, Uysal, Torlak, Turkylmaz, Delen (2012)</td>
</tr>
<tr>
<td>AHP with SWOT</td>
<td>Gorener,Toker, Ulucay (2012)</td>
</tr>
<tr>
<td>FAHP with SAWTOPSIS&amp;VIKOR</td>
<td>Wua,Tzeng,Chen (2009)</td>
</tr>
<tr>
<td>FANP with DEMATEL&amp;TOPSIS</td>
<td>Kuei Chen, Shuo Chen (2010)</td>
</tr>
<tr>
<td>ANP with ELECTRE</td>
<td>Buyukozkan&amp;Cilgi (2012)</td>
</tr>
<tr>
<td>AHP with DEMATEL &amp; TOPSIS</td>
<td>Kaya&amp;Kahraman (2011)</td>
</tr>
</tbody>
</table>

### METHODOLOGY

The methodology of this study, considering the decision making and analytical methods used in it, could be divided into 4 general parts:

*Drawing the SWOT Model for the Organization (Identification of SWOT Factors)*

In this step, first, using the related literature, taking the ideas of experts, and considering the properties of the organization, the initial SWOT model is defined. Then, using the information obtained from the initial stage and
the collaboration of all of the pundits of that organization (distribution of questionnaire, etc.) we attempt to stabilize the SWOT factors and draw the final SWOT model of the organization (to the level of sub-factors).

**DETERMINING THE WEIGHTS OF SWOT FACTORS AND SUB-FACTORS USING THE FUZZY ANP METHOD**

The recommended algorithm of the fuzzy ANP (FANP) in this article, has been used for determining the importance degree of each of prioritization indices (SWOT factors). In this method, the input of the fuzzy ANP technique is in the form of triangular fuzzy numbers as in the following table:

<table>
<thead>
<tr>
<th>Fuzzy number</th>
<th>TFN</th>
<th>Reciprocal</th>
<th>Reciprocal of a TFN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>~</td>
<td>(1,1,1)</td>
<td>(1,1,1)</td>
</tr>
<tr>
<td>3</td>
<td>~</td>
<td>(1,3,5)</td>
<td>(1/5,1/3,1)</td>
</tr>
<tr>
<td>5</td>
<td>~</td>
<td>(3,5,7)</td>
<td>(1/7,1/5,1/3)</td>
</tr>
<tr>
<td>7</td>
<td>~</td>
<td>(5,7,9)</td>
<td>(1/9,1/7,1/5)</td>
</tr>
<tr>
<td>9</td>
<td>~</td>
<td>(7,9,9)</td>
<td>(1/9,1/9,1/7)</td>
</tr>
</tbody>
</table>

In this stage, having collected the paired comparison matrices completed by the experts, we unify the ideas with the geometric mean, in the way that a geometric mean is derived for each of the components of triangular fuzzy numbers. For this purpose imagine that $\hat{E}_{ij}^k$ is representative of the fuzzy value given by evaluator $k$ to the $i$th factor of the row in comparison to the $j$th factor of the column, that is shown as follows:

$$ \hat{E}_{ij}^k = \left( LE_{ij}^k, ME_{ij}^k, UE_{ij}^k \right) $$

Now we calculate the geometric mean for any of the components of $\hat{E}_{ij}^k$:

$$ LE_{ij} = \left( \prod_{k=1}^{N} LE_{ij}^{(k)} \right)^{1/N} $$

$$ ME_{ij} = \left( \prod_{k=1}^{N} ME_{ij}^{(k)} \right)^{1/N} $$

$$ UE_{ij} = \left( \prod_{k=1}^{N} UE_{ij}^{(k)} \right)^{1/N} $$

Then, we attempt for their determination through the following formula:

$$ E_{ij} = \frac{4ME_{ij} + LE_{ij} + UE_{ij}}{6} $$

And, by means of this deterministic data we implement the rest of the ANP steps (in this study we use inconsistency rate for measuring the credit of paired comparison matrices). Now, taking account of the network model designed below and the general principles of ANP, different steps of using the Analytic Network Process in the SWOT analysis are defined as following in this study:

![ANP & SWOT network model](image-url)
First step
Assuming that there is no interdependence among the factors, the importance level of SWOT groups is measured through paired comparisons and using the 1-9 scale of the following table (calculation \( W_i \)).

<table>
<thead>
<tr>
<th>importance degree in binary comparison</th>
<th>nonpreferable (equal preference)</th>
<th>almost preferable</th>
<th>preferable</th>
<th>very preferable</th>
<th>completely preferable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numeric code: when the row factor is in preference to the column factor</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Alphabetic code: when the column factor is in preference to the row factor</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
</tr>
</tbody>
</table>

Second Step
As there is dependency among SWOT groups, using the 1-9 scale of the preceding table and the matrix paired comparisons, the interdependencies of groups (second level of the model) are calculated (calculation \( W_{ij} \)).

Third Stage
determination of the preference (importance) of each SWOT group multiplying \( W_i \) \( W_{ij} \) (calculation \( W_{ij} \)).

Fourth Step
determination of the relative importance of each of SWOT sub-factors with the 1-9 scale of the table and paired comparisons \( W_{f(local)} \).

Fifth Step
determination of the final importance of each of SWOT sub-factors by multiplying the result of the third step by the result of the fourth step \( W_{sub-f(local)} \).

Adoption of ST, SO, WO, and WT Strategies:
In this stage, considering the weights resulted from the fuzzy ANP method, ST, SO, WO, and WT combinational strategies, which are derived from the most important strengths, weaknesses, opportunities, and threats of the organization, are adopted. It needs attention that these strategies should be in proportion to the weights obtained for SWOT factors and sub-factors.

STRATEGIES PRIORITIZATION (RANKING) USING THE COMBINATIONAL FUZZY PROMETHEE METHOD

For this purpose the following 3 steps are requires
Putting strategies as the choices of the PROMETHEE method
Specifying the criteria of the PROMETHEE method within the framework of the SWOT analysis (with the assignment of their weights produced in the fuzzy ANP method):
Optimal use of strengths,
Obviation of weaknesses,
Optimal use of opportunities,
Obviation of threats.

Selecting the Appropriate Preference Function for the Fuzzy PROMETHEE Method:
In this step, according to the ideas of the organization experts and evaluators, we select one of the 6 generalized criteria for the definition of the superiority function. In this study, given the type of the answers, its integrity, and the priority possibility existing in this criterion, the V-form criterion (linear) with parameter P has been selected. The following formula is also used for the selection of the amount of P.

\[
\left( P_i^2 = 1 - \left[ \text{Max}(X_i) - \text{Min}(X_i) \right] \right)
\]
\[
\begin{align*}
\text{Max}(X_i) & \text{Largest weight related to the } i\text{th factor (criterion) of SWOT factors.} \\
\text{Min}(X_i) & \text{Smallest weight related to the } i\text{th factor (criterion) of SWOT factors.}
\end{align*}
\]

The following formula has been provided considering the inverse relation between the dispersion (change range) among the weights of a criterion sub-factors and the possibility of the preference of strategies in that criterion; meaning that if the weights of sub-factors in a criterion are close to each other (the change range of weights is small), the preference of strategies over each other in that criterion is not easily possible, and the preference entails a high difference between those two strategies. On the other hand, if the weights of sub-factors in a criterion have much difference (the change range of weights is large), the preference of strategies over each other in that criterion is more easily possible (specifically for the method used in this article within the framework of the SWOT analysis).

In the following, each of the components of the triangular fuzzy number of are compared with that criterion's special \( P \) number and the amount of \( P(d) \) is obtained according to the following rule:

\[
d = (d_1, d_m, d_u) \quad \text{[if]}
\]

\[
P(d) = \begin{cases} 
\frac{d}{p} & d \leq p \\
1 & d > p
\end{cases}
\]

Now, having the choices, the criteria, and the appropriate preference function; we attempt to evaluate and prioritize the obtained strategies by means of the fuzzy PROMETHEE method (which was completely discussed).

On the whole, the methodology exploited in this study could be represented in the form of the following diagram:

**RESULTS AND DISCUSSION**

In the recent years, several studies and investigations have been carried out by combining the MADM methods, which have tried to simultaneously take advantage of the benefits and assumptions of each of the...
methods. On the other hand, the AWOT analysis in combination with the AHP and ANP hierarchical methods, for the provision of a quantitative aspect and the prioritization of the factors and strategies produced by this method, is abundantly seen in recent studies. On this basis, in order to simultaneously take advantage of the benefits and assumptions of the 3 credible methods of ANP, PROMETHEE, and SWOT analysis, we also exploited the three of them altogether in our study; the way that the two methods of ANP and PROMETHEE (in fuzzy mode) were used in a combinational way within the framework of the SWOT analysis for designing the comprehensive plan and prioritizing the strategies in an organization.

One of the advantages of this combinational method is that it not only provides an appropriate context for ranking and prioritizing the SWOT analysis factors and strategies, but also dispels the ambiguities and complexities encountered at the strategies level in the usual method of fuzzy ANP (given the high amount of paired comparisons), by using the PROMETHEE method at the level of choices (using the information and data obtained through the same fuzzy ANP method at higher levels). In fact, it could be said that the method used in this study not only decreases the amount of complexities and comparisons for evaluators, but also increases the accuracy and speed of their decision making processes (taking into account all of the situations of the organization), that results in more desire and willingness among evaluators for participation in decision-making and, ultimately, coming to more accurate and tangible strategic decisions. It also needs to be said that in the method used in this study, finally some strategies are selected as the most important strategies, which in addition to using the strengths and weaknesses available in the outside environment of the university, are also active in obviating external weaknesses and threats.

A number of suggestions that could be considered for future studies and investigations include:
1) The methodology used in this research is easily executable in all of the country’s organizations. Country’s organizations with the help of multi-index decision making models and taking account of their own operational system and conditions, can attempt to adopt constructive strategies for their organization and prioritize them.
2) Using other combinational MADM methods within the framework of the SWOT analysis with different combinational modes for taking advantage, as appropriately as possible, of the benefits and assumptions of MADM methods for reaching even more accurate and more tangible strategic results for organizations.
3) Theoretic studies about MADM models with the goal of answering questions like:
A) What kind of model is more appropriate for what kind of issue?
B) What are the weaknesses and strengths of a method compared with other methods?
C) Which methods are capable of combination for reaching more complete methods for strategic evaluations?

REFERENCES

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