Integration of FPM, fuzzy AHP and ANP Methods in Formulation of Software Industry Strategy (Case study: System Group Company)

1Ahmad Jafarnejad Chaghooshi, 2Mohammad Reza Fathi, 3Asie Omidian and 2Mohammad Karimi Zarchi

1Professor, Department of Management, University of Tehran, Tehran, Iran
2M.S. Candidates of Industrial Management, University of Tehran, Tehran, Iran
3M.S. Candidates of business Management, University of Tehran, Tehran, Iran

Abstract: Nowadays, Due to the accelerated environment changes and organizational decisions have become complex, the need for using strategic programs to face this kind of problems is more tangible. In this paper, at first, the most influential internal and external elements were detected with the help of the techniques of strategy formulation. Then having used the Strengths, Weaknesses, Opportunities and Threats (SWOT) matrix, we formulated the primary strategies. This research uses the analytic network process (ANP), which allows the quantitative analysis of SWOT and measurement of the dependency among the factors. Dependency among the SWOT factors is observed to effect the strategic and sub-factor weights, as well as to change the strategy priorities. Then using of fuzzy AHP and FPM techniques, Software Industry strategies will be prioritized.

Key words: Fuzzy prioritization method (FPM), Software industry, SWOT Matrix, Analytic network process, Fuzzy AHP, Strategic planning.

INTRODUCTION

Increasing complexity of environmental activities and turbulent world has caused managers realize that other traditional form of planning cannot solve their problems. Hence, strategic planning as a necessity in the governments, organizations and communities has been raised. After the environmental analysis, managers determine the orientation and definition of organizational mission, values, vision and organizational objectives are prepared to determine organizational strategies. Strategy formulation is the process of determining areas of good performance to achieve organizational goals in line with organization mission and philosophy of existence. In other words, strategies should reflect environmental analysis and results in achieving the organizational mission and goals. SWOT analysis, is an important support tool for decision making and used as a tool for systematic analysis of internal and external environment organization. SWOT analysis, analysis model that is concise and useful form of any of the factors system has strengths and weaknesses and identifies opportunities and threats by appropriate strategy. In this way, tries to analyze the internal situation and external conditions and based on this, strategies are design for companies. Resource constraints, which makes that all organizations are not able to be follow strategies.

Strategy Formulation Framework:

Strategy formulation includes three-step decision-making. Tools or methods presented in this study is suitable for various organizations and help strategists to identify strategies, evaluation and selection them. First phase includes internal factors evaluation matrix (IFE), external factors evaluation matrix (EFE) and competition Profile matrix (CPM). In the first stage is called input stage, the main information needed to develop strategies is determined. Internal Factors Evaluation Matrix, evaluate strengths and weaknesses of the organization. External factors evaluation matrix and competition Profile matrix, identify external key factors. Methods or tools in the second stage are used as follows: threats Matrix, opportunities, weaknesses and strengths (SWOT) Matrix; Boston Consultants Group (BCG) Matrix; internal and external factors (IE) matrix and the main strategy matrix , which in this study, the matrix of strengths, opportunities, weaknesses and threats are used. The third stage is that decision stages that strategies derived from the previous steps will evaluate to the best strategies are selected (khodadad hoseyni et al, 2009).

Research Methodology:

This research in terms of objective is a practical and in terms of methods is descriptive. For gathering data, both library and field methods are used. For writing literature, library techniques including scientific journals and databases are used. But the main data has been gathered by interview with experts and managers of System Group Company and distributed questionnaires among them. To measure the validity, the opinions of teachers and experts were used.

Various stages of research and data analysis are shown in Fig. 1.

Corresponding Author: Mohammad Reza Fathi, University of Tehran, Tehran, Iran
E-mail: reza.fathi@ut.ac.ir
SWOT Analysis:

SWOT analysis is an important support tool for decision-making, and is commonly used as a means to systematically analyze an organization's internal and external environments (Kangas and Kurtila, 2003). By identifying its strengths, weaknesses, opportunities, and threats, the organization can build strategies upon its strengths, eliminate its weaknesses, and exploit its opportunities or use them to counter the threats. The strengths and weaknesses are identified by an internal environment appraisal while the opportunities and threats are identified by an external environment appraisal (Dyson, 2004). SWOT analysis summarizes the most important internal and external factors that may affect the organization’s future, which are referred to as strategic factors (Kangas and Kurtila, 2003). The external and internal environments consist of variables which are outside and inside the organization, respectively. The organization’s management has no short-term effect on either type of variable (Houben and Lenie, 1999). Comprehensive environmental analysis is important in recognition of the variety of internal and external forces with which an organization is confronted. On the one hand these forces may comprise potential stimulants, and on the other hand, they may consist of potential limitations regarding the performance of the organization or the objectives that the organization wishes to achieve (Houben and Lenie, 1999). The obtained information can be systematically represented in a matrix; different combinations of the four factors from the matrix (Houben and Lenie, 1999) can aid in determination of strategies for long-term progress.

When used properly, SWOT can provide a good basis for strategy formulation (Kangas and Kurtila, 2003). However, SWOT analysis is not without weaknesses in the measurement and evaluation steps. In conventional SWOT analysis, the magnitude of the factors is not quantified to determine the effect of each factor on the proposed plan or strategy (Kuo-liang and Lin Shu-chen, 2008). In other words, SWOT analysis does not provide an analytical means to determine the relative importance of the factors, or the ability to assess the appropriateness of decision alternatives based on these factors (Kangas and Kurtila, 2003). While it does pinpoint the factors in the analysis, individual factors are usually described briefly and very generally (Hill and
Westbrook, 1997). More specifically, SWOT allows analysts to categorize factors as being internal (Strengths, Weaknesses) or external (Opportunities, Threats) in relation to a given decision, and thus enables them to compare opportunities and threats with strengths and weaknesses (Shrestha and Alavalapati, 2004). However, the result of SWOT analysis is often merely a listing or an incomplete qualitative examination of the internal and external factors (Kangas and Kurttila, 2003). For this reason, SWOT analysis cannot comprehensively appraise the strategic decision-making process (Hill and Westbrook, 1997).

According to table 1, SWOT analysis matrix offers four types of strategies.

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<th>Table 1: SWOT matrix</th>
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SO strategies: Using the internal strengths and external opportunities will be determined.
WO strategies: Use of external opportunities, internal weaknesses can be reduced or eliminated.
ST strategies: Using internal strengths, external threats reduced or be removed.
WT strategies: Decreases the internal weaknesses and external threats are avoided.

For the preparation of SWOT Matrix, six steps must be passed:

1. Preparing a list of major opportunities and threats external environment organizations using PEST, Porter Five Forces Competitive models.
2. Prepare a list of the major strengths and weaknesses within the organization using the Porter value chain, EFQM, BSC models.
3. Compared to internal strengths with external opportunities and determining SO strategies
4. Compared to the internal weaknesses with external opportunities and determining WO strategies
5. Compared to internal strengths and external threats and determining ST strategies
6. Reducing internal weaknesses and avoiding external threats

Analytic Network Process:

An initial study identified the multi-criteria decision technique, known as the AHP, to be the most appropriate for solving complicated problems (Saaty, 1978). AHP was proposed by Saaty in 1980 as a method of solving socio-economic decision-making problems, and has been used to solve a wide range of decision-making problems (Chang, 1992).

AHP is a comprehensive framework which is designed to cope with the intuitive, the rational, and the irrational when multi-objective, multi-criterion, and multi-actor decisions are made, with or without certainty, for any number of alternatives. The basic assumption of AHP is the condition of functional independence of the upper part, or cluster (see Fig. 3), of the hierarchy, from all its lower parts, and from the criteria or items in each level (Kulak and Kahraman, 2005). Many decision-making problems cannot be structured hierarchically because they involve interaction of various factors, with high-level factors occasionally depending on low-level factors (Saaty, 1978). Structuring a problem with functional dependencies that allows for feedback among clusters is considered to be a network system. Saaty suggested the use of AHP to solve the problem of independence among alternatives or criteria, and the use of ANP to solve the problem of dependence among alternatives or criteria (Saaty, 1978). The ANP, also introduced by Saaty, is a generalization of the AHP (Chang and Huang, 2006). While the AHP represents a framework with a un-directional hierarchical AHP relationship, the ANP allows for complex interrelationships among decision levels and attributes. The ANP feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominant or subordinate, direct or indirect.

For instance, not only does the importance of the criteria determine the importance of the alternatives, as in a hierarchy, but the importance of the alternatives may also have an impact on the importance of the criteria (Kuo-liang and Lin Shu-chen, 2008). Therefore, a hierarchical representation with a linear top-to-bottom structure is not suitable for a complex system (Chang and Huang, 2006).

A system with feedback can be represented by a network. The structural differences between a hierarchy and a network are depicted in Fig. 2. The elements of a cluster may influence some or all the elements of any other cluster. A network can be organized to include source clusters, intermediate clusters and sink clusters. Relationships in a network are represented by arcs, where the directions of arcs signify directional dependence (Chang and Huang, 2006). Interdependency between two clusters, termed outer dependence, is represented by a two-way arrow. Inner dependencies among the elements of a cluster are represented by looped arcs (Chang and Huang, 2006).

The ANP is composed of four major steps (Chang and Huang, 2006):
Fig. 2: Structural difference between a hierarchy and a network: (a) a hierarchy; (b) a network

**Step 1:**
Model construction and problem structuring: The problem should be stated clearly and be decomposed into a rational system, like a network. This network structure can be obtained by decision-makers through brainstorming or other appropriate methods. An example of the format of a network is shown in Fig. 2b.

**Step 2:**
Pairwise comparison matrices and priority vectors: Similar to the comparisons performed in AHP, pairs of decision elements at each cluster are compared with respect to their importance towards their control criteria. The clusters themselves are also compared pairwise with respect to their contribution to the objective. Decision-makers are asked to respond to a series of pairwise comparisons of two elements or two clusters to be evaluated in terms of their contribution to their particular upper level criteria. In addition, interdependencies among elements of a cluster must also be examined pairwise; the influence of each element on other elements can be represented by an eigenvector. The relative importance values are determined with Saaty’s 1–9 scale (Table 2), where a score of 1 represents equal importance between the two elements and a score of 9 indicates the extreme importance of one element (row cluster in the matrix) compared to the other one (column cluster in the matrix). A reciprocal value is assigned to the inverse comparison, that is, $a_{ij} = 1/a_{ji}$, $a_{ij}$ ($a_{ji}$) denotes the importance of the $i$th ($j$th) element. Like with AHP, pairwise comparison in ANP is performed in the framework of a matrix, and a local priority vector can be derived as an estimate of the relative importance associated with the elements (or clusters) being compared by solving the following equation:

$$A \times w = \lambda_{\text{max}} \times w$$

Where $A$ is the matrix of pairwise comparison, $w$ is the eigenvector, and $\lambda_{\text{max}}$ is the largest eigenvalue of $A$. Saaty (1986) proposes several algorithms to approximate $w$. In this paper, Expert Choice is used to compute the eigenvectors from the pairwise comparison matrices and to determine the consistency ratios.

**Step 3:**
Supermatrix formation: The supermatrix concept is similar to the Markov chain process (Saaty, 1980). To obtains global priorities in a system with interdependent influences, the local priority vectors are entered in the appropriate columns of a matrix.

<table>
<thead>
<tr>
<th>Table 2: Saaty’s 1–9 scale for AHP preference.</th>
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<tr>
<td>Intensity of importance</td>
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<td>--------------------------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>7</td>
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<tr>
<td>9</td>
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<td>2,4,6,8</td>
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As a result, a supermatrix is actually a partitioned matrix, where each matrix segment represents a relationship between two clusters in a system. Let the clusters of a decision system be $C_k$, $k=1,2,\ldots,n$, and each cluster $K$ has $m_k$ elements, denoted by $e_{k1}, e_{k2}, \ldots, e_{kmk}$. 

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The local priority vectors obtained in Step 2 are grouped and placed in the appropriate positions in a supermatrix based on the flow of influence from one cluster to another, or from a cluster to itself, as in the loop. A standard form for a supermatrix is as shown in expression (2) (Saaty, 1980).

\[
W = \begin{bmatrix}
    c_1 & \cdots & c_k & \cdots & c_n \\
    w_{11} & \cdots & w_{1k} & \cdots & w_{1n} \\
    \vdots & \ddots & \vdots & \ddots & \vdots \\
    \vdots & \ddots & \vdots & \ddots & \vdots \\
    c_n & \cdots & w_{nk} & \cdots & w_{nn}
\end{bmatrix}
\]

As an example, the supermatrix representation for a hierarchy with three levels, as shown in Fig. 3a (Saaty, 1980), is as follows:

\[
W_h = \begin{bmatrix}
    0 & 0 & 0 \\
    W_{21} & 0 & 0 \\
    0 & W_{32} & 1
\end{bmatrix}
\]

In this matrix, \( w_{21} \) is a vector which represents the impact of the goal on the criteria, \( W_{32} \) is a matrix that represents the impact of the criteria on each of the alternatives, I is the identity matrix, and zero entries correspond to those elements having no influence. For the example given above, if the criteria are interrelated, the hierarchy is replaced with the network shown in Fig. 2b. The interdependency is exhibited by the presence of the matrix element \( w_{22} \) of the supermatrix \( W_n \), yielding (Saaty, 1980):

\[
W_n = \begin{bmatrix}
    0 & 0 & 0 \\
    W_{21} & W_{22} & 0 \\
    0 & W_{32} & 1
\end{bmatrix}
\]

Note that any zero value in the supermatrix can be replaced by a matrix if there is an interrelationship of the elements within a cluster or between two clusters. Since there usually is interdependence among clusters in a network, the columns of a supermatrix may sum to more than one. However, the supermatrix must be modified so that each column of the matrix sums to unity. An approach recommended by Saaty (1980) involves determining the relative importance of the clusters in the supermatrix, using the column cluster (see Fig. 3) as the controlling cluster.

![Fig. 3: Hierarchy and network: (a) hierarchy; (b) network.](image)

That is, row clusters with non-zero entries in a given column cluster are compared according to their impact on the cluster of that column cluster. An eigenvector is obtained from the pairwise comparison matrix of the row clusters with respect to the column cluster, which in turn yields an eigenvector for each column cluster. The first entry of the respective eigenvector for each column cluster, is multiplied by all the elements in the first cluster of that column, the second by all the elements in the second cluster of that column and so on. In this way, the cluster in each column of the supermatrix is weighted, and the result, known as the weighted supermatrix, is stochastic.

Raising a matrix to exponential powers gives the long-term relative influences of the elements on each other. To achieve convergence on the importance weights, the weighted supermatrix is raised to the power of \( 2k + 1 \), where \( k \) is an arbitrarily large number; the new matrix is called the limit supermatrix (Saaty, 1980). The limit supermatrix has the same form as the weighted supermatrix, but all the columns of the limit supermatrix...
are the same. The final priorities of all elements in the matrix can be obtained by normalizing each cluster of this supermatrix. Additionally, the final priorities can be calculated using matrix operations, especially where the number of elements in the model is relatively few. Matrix operations are used in order to easily convey the steps of the methodology and how the dependencies are worked out.

**Step 4:**
Selection of the best alternatives: If the supermatrix formed in Step 3 covers the whole network, the priority weights of the alternatives can be found in the column of alternatives in the normalized supermatrix. On the other hand, if a supermatrix only comprises clusters that are interrelated, additional calculations must be made to obtain the overall priorities of the alternatives. The alternative with the largest overall priority should be selected, as it is the best alternative as determined by the calculations made using matrix operations.

**Fuzzy AHP:**
The AHP was developed first by Satty (Zuo, 1991). It is a popular tool for MCDM by structuring a complicated decision problem hierarchically at several different levels. Its main steps include:

1. Organizing problem hierarchically: The problem is structured as a family tree in this step. At the highest level is the overall goal of this decision-making problem, and the alternatives are at the lowest level. Between them are criteria and sub-criteria.
2. Development of judgment matrices by pairwise comparisons: The judgment matrices of criteria or alternatives can be defined from the reciprocal comparisons of criteria at the same level or all possible alternatives. Pairwise comparisons are based on a standardized evaluation schemes (1= equal importance; 3= weak importance; 5=strong importance; 7= demonstrated importance; 9= absolute importance).
3. Calculating local priorities from judgment matrices: Several methods for deriving local priorities (i.e. the local weights of criteria and the local scores of alternatives) from judgment matrices have been developed, such as the eigenvector method (EVM), the logarithmic least squares method (LLSM), the weighted least squares method (WLSM), the goal programming method (GPM) and the Fuzzy prioritization method (FPM), as summarized by Mikhailov (2000). Consistency check should be implemented for each judgment matrix.
4. Alternatives ranking: The final step is to obtain global priorities (including global weights and global scores) by aggregating all local priorities with the application of a simple weighted sum. Then the final ranking of the alternatives are determined on the basis of these global priorities.

The above process of the AHP method is similar to the process of human thinking, and turns the complex decision-making process into simple comparisons and rankings. However, decision makers often face uncertain and fuzzy cases when considering the relative importance of one criterion or alternative in terms of another. Therefore, it is difficult to determine the ratios based on the standard scheme in the second step above. For this reason, the fuzzy AHP was proposed, in which the uncertain comparisons ratios are expressed as fuzzy sets or fuzzy numbers, such as “between three and five times less important” and “about three times more important”. The triangular fuzzy number, because of its popularity, is used to represent the fuzzy relative importance in this paper. The membership function of triangular fuzzy numbers can be described as:

\[
\mu_{\bar{a}}(x) = \begin{cases} 
\frac{x-l}{m-l} & \text{if } l \leq x \leq m \\
\frac{u-x}{u-m} & \text{if } m < x \leq u \\
0 & \text{otherwise}
\end{cases} \quad (5)
\]

Where l, m, and u are also considered as the lower bound, the mean bound, and the upper bound, respectively. The triangular fuzzy number \(\bar{N}\) is often represented as \((l,m,u)\).

After pairwise comparisons are finished at a level, a fuzzy reciprocal judgment matrix \(\bar{A}\) can be established as

\[
\bar{A} = \{\bar{a}_{ij}\} = \begin{bmatrix} \bar{a}_{11} & \bar{a}_{12} & \ldots & \bar{a}_{1n} \\ \bar{a}_{21} & \bar{a}_{22} & \ldots & \bar{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \bar{a}_{n1} & \bar{a}_{n2} & \ldots & \bar{a}_{nn} \end{bmatrix} \quad (6)
\]

Where n is the number of the related elements at this level, and \(a_{ij}=1/ a_{ji}\).

After constructing \(\bar{A}\), fuzzy priorities \(\bar{w}_i\), \(i=1,2,\ldots,n\), should be calculated in the traditional fuzzy AHP methods. Many fuzzy prioritization approaches have been developed, such as the method based on the fuzzy modification of the LLSM (Boender et al., 1989), the fuzzy geometry mean method (Buckley, 1985), the direct
fuzzification of the \( \lambda_{\text{max}} \) method of Satty (Csutora and Buckley, 2001), and the fuzzy least square method (Xu, 2000). In these methods, global priorities expressed as fuzzy numbers can be determined by aggregating fuzzy local priorities. However, as pointed out by Mikhailov (2003), the global fuzzy priorities often have large supports and overlap a wide range. After the normalization procedure of the fuzzy global scores, the unreasonable conditions where the normalized upper value < the normalized mean value < the normalized lower value may occur. Furthermore, to compare the global fuzzy scores, a fuzzy ranking procedure must be included in the traditional fuzzy AHP methods. But different ranking procedures for fuzzy numbers often give different ranking conclusions (Li, 2002).

To overcome the shortcomings of the fuzzy prioritization methods above, two new approaches that can derive crisp priorities from fuzzy pairwise comparison judgments are proposed (Mikhailov, 2003 and Mikhailov and Tsvetinov, 2004). One is based on \( \alpha \)-cut decomposition of the fuzzy numbers into interval comparisons. In this method, the fuzzy preference programming (FPP) method (Mikhailov, 2000) transforming the prioritization procedure into a fuzzy linear programming problem is used to derive optimized exact priorities, and eventually an aggregation of the optimal priorities derived at the different \( \alpha \)-levels is needed for obtaining overall crisp scores of the prioritization elements. These steps make this method a little complicated. The other is a non-linear modification of the FPP strategy without applying \( \alpha \)-cut transformations. This idea, deriving crisp priorities from fuzzy judgment matrices, shows a new way to deal with the prioritization problem from fuzzy reciprocal comparisons in the fuzzy AHP. A new and simple prioritization method, which can also derive exact priorities from fuzzy pairwise comparisons, is described in the next section.

**Fuzzy Prioritization Method (FPM):**

Suppose that a fuzzy judgment matrix is constructed as Eq. (6) in a prioritization problem, where \( n \) elements are taken into account. Among this judgment matrix \( A \), the triangular fuzzy number \( a_{ij} \) is expressed as \((l_{ij}, m_{ij}, u_{ij})\), \( i \) and \( j = 1, 2, \ldots, n \), where \( l_{ij} \), \( m_{ij} \), and \( u_{ij} \) are the lower bound, the mean bound, and the upper bound of this fuzzy triangular set, respectively. Furthermore, we assume that \( l_{ij} < m_{ij} < u_{ij} \) when \( i \neq j \). If \( i = j \), then \( a_{ij} = a_{ji} = (1, 1, 1) \). Therefore, an exact priority vector \( w = (w_1, w_2, \ldots, w_n)^T \) derived from \( A \) must satisfy the fuzzy inequalities:

\[
I_{ij} \preceq w_i \preceq w_j \preceq m_{ij}
\]

where \( w_i > 0, w_j > 0, i \neq j \), and the symbol \( \preceq \) means “fuzzy less or equal to”.

To measure the degree of satisfaction for different crisp ratios \( w_i / w_j \) with regard to the double side inequality (7), a function can be defined as:

\[
\mu_{ij}(w_i / w_j) = \begin{cases} 
\frac{m_{ij} - (w_i / w_j)}{m_{ij} - l_{ij}} & 0 < \frac{w_i}{w_j} \leq m_{ij} \\
\frac{w_i}{w_j} - m_{ij} & \frac{w_i}{w_j} > m_{ij}
\end{cases}
\]

Where \( i \neq j \). Being different from the membership function (5) of triangular fuzzy numbers, the function value of \( \mu_{ij}(w_i / w_j) \) may be larger than one, and is linearly decreasing over the interval \((0,m_{ij}]\) and linearly increasing over the interval \([m_{ij},\infty)\), as shown in Fig. 4. The less value of \( \mu_{ij}(w_i / w_j) \) indicates that the exact ratio \( w_i / w_j \) is more acceptable.

![Fig. 4: Function for measuring the satisfaction degree of \( w_i / w_j \)](image)

To find the solution of the priority vector \( (w_1, w_2, \ldots, w_n)^T \), the idea is that all exact ratios \( w_i / w_j \) should satisfy \( n(n-1) \) fuzzy comparison judgments \((l_{ij}, m_{ij}, u_{ij})\) as possible as they can, \( i = 1, 2, \ldots, n, i \neq j \). Therefore, in this study, the crisp priorities assessment is formulated as a constrained optimization problem:
Min $J (w_1, w_2, ..., w_n)$

$$= \min \sum_{i=1}^{n} \sum_{j=1}^{n} m_{ij} \left( \frac{w_i}{w_j} \right)^p$$

$$= \min \sum_{i=1}^{n} \sum_{j=1}^{n} \left[ \delta \left( m_{ij} - \frac{w_i}{w_j} \right) \left( \frac{m_{ij} - (w_i/w_j)}{m_{ij} - (w_i/w_j)} \right)^p \right] + \delta \left( \frac{w_i}{w_j} - m_{ij} \right) \left( \frac{(w_i/w_j) - m_{ij}}{w_i/w_j - m_{ij}} \right)^p$$

Subject to

$$\sum_{k=1}^{n} w_k = 1, w_k > 0, k=1,2,\ldots,n.$$  

Where $i \neq j, P \in N$, and

$$\delta(x) = \begin{cases} 
0 & , x < 0 \\
1 & , x \geq 0 
\end{cases} \tag{9}$$

The power index $P$ is fixed, and chosen by decision makers in a specific MCDM problem. A larger $p$ is suggested, e.g. 10, as illustrated briefly in the next section.

The function $J (w_1, w_2, ..., w_n)$ is non-differentiable. General algorithms for function optimization, limited to convex regular functions, cannot be applied to this optimization problem. Therefore, genetic algorithms, which have great ability to solve difficult optimization problems with discontinuous, multi-modal or non-differentiable objective functions, are chosen in this paper. The genetic algorithm provided by Houck et al. (1995) is utilized in the next section. Because the optimization problem above has non-linear constraints, the penalty techniques (Gen and Cheng, 1996) are combined when employing genetic algorithms for the optimal solution.

In some cases, decision-makers are unable or unwilling to give all pairwise comparison judgments of $n$ elements. However, provided that the known fuzzy set of pairwise comparisons involves $n$ elements, such as $F = \{a_{ij} \} = \{a_{12}, a_{13}, ..., a_{n1}\}$ or $\{a_{21}, a_{31}, ..., a_{n1}\}$, the solution of priority vector $(w_1, w_2, ..., w_n)^T$ will be still able to be derived based on the optimization problem above. Thus, the proposed method can obtain priorities from an incomplete comparison judgment set. Thus, the proposed method can obtain priorities from an incomplete comparison judgment set, which is an interesting advantage comparing with the traditional fuzzy AHP methods.

In order to measure the consistency degree of the fuzzy comparison judgment matrix $A$ as Eq. (6), an index $\gamma$ can be defined after the optimal crisp priority vector $(w_1, w_2, ..., w_n)^T$ is obtained:

$$\gamma = \exp \left\{ - \max \left\{ \mu_{ij} \left( \frac{w_i}{w_j} \right)^p \right\} | i, j = 1,2,\ldots,n, i \neq j \right\} \tag{10}$$

where $\mu_{ij} \left( \frac{w_i}{w_j} \right)^p$ is the function of (8). The value of $\gamma$ satisfies $0 < \gamma \leq 1$ always. If it is larger than $e^{-1} = 0.3679$, all exact ratios satisfy the crisp inequalities $i_{ij} \leq w_i/w_j \leq m_{ij}, i$ and $j=1,2,\ldots,n, i \neq j$, and the corresponding fuzzy judgment matrix has good consistency. $\gamma=1$ indicates that the fuzzy judgment matrix is completely consistent. In conclusion, the fuzzy judgment matrix with a larger $\gamma$ value is more consistent.

**Integration of AHP With Swot Matrix:***

Although the AHP technique removes the deficiencies inherent in the measurement and evaluation steps of SWOT analysis, it does not measure the possible dependencies among factors. The AHP method assumes that the factors presented in the hierarchical structure are independent; however, this is not always a reasonable presumption. The possible dependency among factors can only be determined as a result of internal and external environmental analyses. An organization can make good use of its opportunities if it possesses assets and capabilities in which it can demonstrate superiority, otherwise opportunities are either lost before any benefit can be gained or are used by rivals. A similar relationship exists between threats and strengths. The ability to overcome or resist the effects of threats depends on one’s strengths; a strong organization can use its strengths to either eliminate or minimize the effects of these threats. The relationship between the weaknesses and strengths of an organization are such that an organization with more strength would probably have fewer weaknesses, and therefore would be able to face situations arising from these weaknesses. Among the strategic factors, other two-variable combinations with possible interdependencies are threat-weakness and opportunity-weakness. It can be claimed that organizations with more weaknesses than their rivals are more susceptible to the threats. Thus, organizations should consider the relationship between their threats and weaknesses when establishing their strategies. Similarly, an organization with weaknesses may find it harder to make good use of its opportunities. It would be possible for an organization to benefit from the opportunities if it has sufficient assets and
capabilities, but if not, such opportunities arising from the external environment may otherwise prove not useful (Dincer, 2004). As can be seen, the SWOT factors are not independent of each other, and moreover, there may even be a relationship among some factors. Since the factor weights are traditionally computed by assuming that the factors are independent, it is possible that the weights computed by including the dependent relations could be different. Possible changes in the factor weights can change the priorities of alternative strategies, and these changes, in turn, will affect the strategies chosen. Therefore, it is necessary to employ analyses which measure and take the possible dependencies among factors into account in SWOT analysis.

**Analysis of Data:**

The network model proposed in this study for SWOT analysis is composed of five levels, as shown in Fig. 6. The goal (best strategy) is indicated in the first level, the criteria (SWOT factors) and subcriteria (SWOT sub-factors) are found in the second and third levels respectively, and the last level is composed of the alternatives (alternative strategies). The supermatrix of a SWOT hierarchy with four levels is as follows:

\[
W = \begin{bmatrix}
0 & 0 & 0 & 0 \\
0 & w_{21} & 0 & 0 \\
0 & 0 & w_{32} & 0 \\
0 & 0 & 0 & w_{43}
\end{bmatrix}
\]  

(11)

Fig. 5: (a) The hierarchical representation of the SWOT model. (b) The network representation of the SWOT model.

Where \(w_{21}\) is a vector which represents the impact of the goal on the criteria, \(W_{12}\) is a matrix that represents the impact of the criteria on each of the sub-criteria, \(W_{34}\) is a matrix that represents the impact of the sub-criteria on each of the alternatives, and \(I\) is the identity matrix. A hierarchical representation of the SWOT model is given in Fig. 5a and its general network representation is presented in Fig. 5b. The network model illustrates the case of a hierarchy with inner dependence within clusters but no feedback. Here, SWOT factors, SWOT sub-factors and strategies are used in place of criteria, sub-criteria and alternatives, respectively, and the SWOT factors have inner dependencies. The main steps of our proposed framework can be summarized as follows. The first step of the study is the identification of the SWOT factors, SWOT sub-factors and alternatives. The importance of the SWOT factor, which corresponds to the first step of the matrix manipulation concept of the ANP, is determined based on the works of Saaty (1980). Then, according to the inner dependencies among the SWOT factors, the inner dependency matrix, weights of SWOT sub-factors and priority vectors for alternative strategies based on the SWOT sub-factors are determined in given order. The letters in parentheses in Fig. 5b represent the relationship that will be signified by sub-matrices for supermatrix evaluation of the relative importance weights. Based on the schematic representation of Fig. 5b, the general sub-matrix notation for the SWOT model used in this study is as follows:
where $w_1$ is a vector that represents the impact of the goal, namely, selecting the best strategy according to SWOT factors, $W_3$ is a matrix that represents the inner dependence of the SWOT factors, $W_4$ is a matrix that denotes the impact of the SWOT factor on each of the SWOT sub-factors, and $W_4$ is a matrix that denotes the impact of the SWOT sub-factors on each of the alternatives. Using matrix operations is preferred in order to show the details of the calculations in this algorithm.

In this study, first an external environment analysis is performed by an expert team familiar with the operation of the organization. In this way, those SWOT sub-factors which affect the success of the organization but cannot be controlled by the organization are identified. In addition, an internal analysis is performed to determine the sub-factors which affect the success of the organization but can be controlled by the organization. In based on these analyses, the strategically important sub-factors, i.e. the sub-factors which have very significant effects on the success of the organization, are determined. Using the SWOT sub-factors, the SWOT matrix and alternative strategies based on these sub-factors are developed (Table 3). In determining SWOT factors and strategies we used some strategies and SWOT factors from khodad hoseyni (2009) that are worked in this industry but with other techniques.

### Table 3: SWOT matrix for System Group Company

<table>
<thead>
<tr>
<th>Internal factors</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opportunities</td>
<td>1. Appropriate structure and effective management system with professional staff 2. High quality and variety of products and services 3. Having a popular brand 4. There are financial resources required to support organization various programs. 5. Being the leading in software industry</td>
<td>1. Lack of appropriate and effective legal system in the organization 2. Lack of effective marketing research 3. Non-compliance production processes with international standards 4. Lack of updated information system data and there is a weak relationship between research and development unit with other units 5. Lack of using information technology to provide comprehensive training in the organization</td>
</tr>
<tr>
<td>Threats</td>
<td>1. Ease of getting into the software industry 2. Difficult to apply copyright law and intellectual property 3. Inflation and economic instability 4. The low penetration of Internet and computer 5. Change norms and values resulting from globalization and the differences between the Islamic religions</td>
<td>1. Use the experiences of other activists in the software industry and do not produce general software 2. Identify active private companies and outsource part of the activities 3. Providing products with an emphasis on simplicity and ease (produce audio and video production)</td>
</tr>
</tbody>
</table>

### Step 1:

The problem is converted into a hierarchical structure in order to transform the sub-factors and alternative strategies into a state in which they can be measured by the ANP and Fuzzy AHP with FPM techniques. The schematic structure established is shown in Fig. 6. The aim of “choosing the best strategy” is placed in the first level of the ANP model and the SWOT factors (Strengths, Weaknesses, Opportunities, Threats) are in the second level. The SWOT sub-factors in the third level include: five sub-factors for the Strengths factor, six sub-factors for the Weaknesses factor, five sub-factors for the Opportunities factor, and five sub-factors for the Threats factor. In the fourth level, the overall weight strategies SO, WO, ST, WT using the ANP method obtains
(The aim of this level is that to determine which one of the strategies are generally more important.) Last level represents final strategies that we prioritize strategies by using the FAHP and FPM methods.

![ANP, FAHP and FPM model for SWOT](image)

**Fig. 6:** ANP, FAHP and FPM model for SWOT.

**Step 2:**

Assuming that there is no dependence among the SWOT factors, pairwise comparison of the SWOT factors using a 1–9 scale is made with respect to the goal. Paired comparisons matrix using Export Choice software, were analyzed and the weight vector is obtained. In paired comparisons, we should pay attention to the compatibility matrix. Matrix \( A = [a_{ij}] \) is consistent, if \( a_{ik} \times a_{kj} = a_{ij} \). Inconsistency rate of less than 0.1 in paired comparisons matrices is acceptable.

<table>
<thead>
<tr>
<th>SWOT factors</th>
<th>S</th>
<th>W</th>
<th>O</th>
<th>T</th>
<th>Importance degrees of SWOT factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strengths</td>
<td>1</td>
<td>2.42</td>
<td>2.31</td>
<td>3.18</td>
<td>0.443</td>
</tr>
<tr>
<td>Weaknesses</td>
<td>0.41</td>
<td>1</td>
<td>2.16</td>
<td>3.14</td>
<td>0.278</td>
</tr>
<tr>
<td>Opportunities</td>
<td>0.43</td>
<td>0.46</td>
<td>1</td>
<td>2.18</td>
<td>0.186</td>
</tr>
<tr>
<td>Threats</td>
<td>0.31</td>
<td>0.32</td>
<td>0.35</td>
<td>1</td>
<td>0.093</td>
</tr>
</tbody>
</table>

CR=0.06

**Step 3:**

Inner dependence among the SWOT factors is determined by analyzing the impact of each factor on every other factor using pairwise comparisons. The introduction section mentioned that it is not always possible to assume the SWOT factors to be independent. More appropriate and realistic results can likely be obtained by using both SWOT analysis and the ANP technique. Using the analysis of both the internal and external environments of the organization, the dependencies among the SWOT factors, which are presented schematically in Fig. 7, are determined. Based on the inner dependencies presented in Fig. 7, pairwise comparison matrices are formed for the factors (Tables 5–7). The following question, “what is the relative importance of strengths when compared with threats on controlling weaknesses?” may arise in pairwise comparisons and lead to a value of 9 (absolute importance) as denoted in Table 6. The resulting eigenvectors are presented in the last column of Tables 5–7. Using the computed relative importance weights, the inner dependence matrix of the SWOT factors (\( W_{2} \)) is formed. As opportunities are affected only by the Strengths, no pairwise comparison matrix is formed for opportunities.
Fig. 7: Inner dependence among SWOT factors.

**Table 5:** The inner dependence matrix of the SWOT factors with respect to “Strengths”

<table>
<thead>
<tr>
<th>Strengths</th>
<th>W</th>
<th>O</th>
<th>T</th>
<th>Relative weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>1</td>
<td>0.12</td>
<td>0.32</td>
<td>0.078</td>
</tr>
<tr>
<td>O</td>
<td>8.33</td>
<td>1</td>
<td>3.24</td>
<td>0.693</td>
</tr>
<tr>
<td>T</td>
<td>3.13</td>
<td>0.31</td>
<td>1</td>
<td>0.229</td>
</tr>
<tr>
<td>CR = 0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 6:** The inner dependence matrix of the SWOT factors with respect to “Weaknesses”

<table>
<thead>
<tr>
<th>Weaknesses</th>
<th>S</th>
<th>T</th>
<th>Relative weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>1</td>
<td>7.83</td>
<td>0.887</td>
</tr>
<tr>
<td>T</td>
<td>0.13</td>
<td>1</td>
<td>0.113</td>
</tr>
<tr>
<td>CR = 0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 7:** The inner dependence matrix of the SWOT factors with respect to “Threats”

<table>
<thead>
<tr>
<th>Threats</th>
<th>S</th>
<th>W</th>
<th>Relative weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>1</td>
<td>7.14</td>
<td>0.877</td>
</tr>
<tr>
<td>W</td>
<td>0.14</td>
<td>1</td>
<td>0.123</td>
</tr>
<tr>
<td>CR = 0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Step 4:**
In this step, interdependence of the main weights multiplied by the main dependency matrix (relative weights obtained from the third stage) in the main relative weights after normalization is reached. The main factors of weight interdependence are calculated thus:

\[
\begin{bmatrix}
1.000 & 0.887 & 1.000 & 0.877 \\
0.078 & 1.000 & 0 & 0.123 \\
0.693 & 0 & 1.000 & 0.186 \\
0.229 & 0.113 & 0 & 1.000
\end{bmatrix}
\times
\begin{bmatrix}
0.443 \\
0.278 \\
0.186 \\
0.093
\end{bmatrix}
=
\begin{bmatrix}
0.479 \\
0.162 \\
0.247 \\
0.113
\end{bmatrix}
\]

**Step 5:**
In this step, local priorities of the SWOT sub-factors are calculated using the pairwise comparison that their findings are in Table 9. For example, paired comparison matrix for sub-agents strengths is given in Table 8.

**Table 8:** Pairwise comparison matrix for Strengths

<table>
<thead>
<tr>
<th>Strengths</th>
<th>S_1</th>
<th>S_2</th>
<th>S_3</th>
<th>S_4</th>
<th>S_5</th>
<th>Local weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>S_1</td>
<td>1</td>
<td>2.24</td>
<td>2.17</td>
<td>3.69</td>
<td>0.15</td>
<td>0.177349</td>
</tr>
<tr>
<td>S_2</td>
<td>0.446429</td>
<td>1</td>
<td>7.21</td>
<td>1</td>
<td>0.368</td>
<td>0.194842</td>
</tr>
<tr>
<td>S_3</td>
<td>0.460829</td>
<td>2.69</td>
<td>1</td>
<td>4.16</td>
<td>2.5</td>
<td>0.265214</td>
</tr>
<tr>
<td>S_4</td>
<td>0.271003</td>
<td>1</td>
<td>0.240385</td>
<td>1</td>
<td>0.5</td>
<td>0.070233</td>
</tr>
<tr>
<td>S_5</td>
<td>6.666667</td>
<td>2.717391</td>
<td>0.4</td>
<td>2</td>
<td>1</td>
<td>0.292362</td>
</tr>
</tbody>
</table>

**Step 6:**
In this step, the overall priorities of the SWOT sub-factors are calculated by multiplying the interdependent priorities of SWOT factors found in Step 4 with the local priorities of SWOT sub-factors obtained in Step 5. The computations are provided in Table 9.

**Step 7:**
In this step we calculate the importance degrees of the alternative strategies with respect to each SWOT sub-factors. Because of many paired comparisons matrices, four paired comparison matrix is given as an
example and the final results by using Expert Choice software is derived. There is just a table for comparing paired samples, but the final matrix shows the relative weights of these twenty one matrixes. Results using Export Choice software are calculated.

Table 9: Overall priority of the SWOT sub-factors

<table>
<thead>
<tr>
<th>SWOT factors</th>
<th>Priority of the factors</th>
<th>SWOT sub-factors</th>
<th>Priority of the sub-factors</th>
<th>Overall priority of the sub-factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strengths</td>
<td>0.478</td>
<td>Appropriate structure and effective management system with professional staff</td>
<td>0.1773</td>
<td>0.084</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High quality and variety of products and services</td>
<td>0.1948</td>
<td>0.093</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Having a popular brand</td>
<td>0.2652</td>
<td>0.126</td>
</tr>
<tr>
<td></td>
<td></td>
<td>There are financial resources required to support organization various programs</td>
<td>0.0702</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Being the leading in software industry</td>
<td>0.2923</td>
<td>0.139</td>
</tr>
<tr>
<td>Weakness</td>
<td>0.162</td>
<td>Lack of appropriate and effective legal system in the organization</td>
<td>0.279</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lack of effective marketing research</td>
<td>0.138</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-compliance production processes with international standards</td>
<td>0.260</td>
<td>0.042</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lack of updated information system data and there is a weak relationship between</td>
<td>0.187</td>
<td>0.030</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lack of using information technology to provide comprehensive training in the</td>
<td>0.133</td>
<td>0.021</td>
</tr>
<tr>
<td>Opportunities</td>
<td>0.247</td>
<td>Significant internal and external demand for products and services of</td>
<td>0.236</td>
<td>0.058</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Access to educated and professional workforce</td>
<td>0.136</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lack of international competitors</td>
<td>0.277</td>
<td>0.068</td>
</tr>
<tr>
<td></td>
<td></td>
<td>There are protective laws and government support</td>
<td>0.188</td>
<td>0.046</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cultural and religious commonalities with regional states</td>
<td>0.160</td>
<td>0.039</td>
</tr>
<tr>
<td>Threats</td>
<td>0.113</td>
<td>Ease of getting into the software industry</td>
<td>0.150</td>
<td>0.016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Difficult to apply copyright law and intellectual property</td>
<td>0.208</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inflation and economic instability</td>
<td>0.289</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The low penetration of Internet and computer</td>
<td>0.121</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change norms and values resulting from globalization and the differences between</td>
<td>0.230</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Step 8:
Finally, the overall priorities of the alternative strategies are calculated as follows:
The ANP analysis results indicate that SO is the best strategy with an overall priority value of \(0.314\).

**Step 9:**
At this stage, we obtain the final weight of each strategy (from St\(_1\) to St\(_{12}\)) by using FAHP and FPM methods after that we prioritize strategies.

Table 10: Fuzzy comparison matrix for SO strategies.

<table>
<thead>
<tr>
<th>SO</th>
<th>St(_1)</th>
<th>St(_2)</th>
<th>Local weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>St(_1)</td>
<td>(1,1,1)</td>
<td>(6,7,8)</td>
<td>0.8750</td>
</tr>
<tr>
<td>St(_2)</td>
<td>(1/8,1/7,1/6)</td>
<td>(1,1,1)</td>
<td>0.1250</td>
</tr>
</tbody>
</table>

Table 11: Fuzzy comparison matrix for WO strategies.

<table>
<thead>
<tr>
<th>WO</th>
<th>St(_3)</th>
<th>St(_4)</th>
<th>St(_5)</th>
<th>Local weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>St(_3)</td>
<td>(1,1,1)</td>
<td>(2,3,4)</td>
<td>(4,5,6)</td>
<td>0.6548</td>
</tr>
<tr>
<td>St(_4)</td>
<td>(1/4,1/3,1/2)</td>
<td>(1,1,1)</td>
<td>(1,2,3)</td>
<td>0.2285</td>
</tr>
<tr>
<td>St(_5)</td>
<td>(1/6,1/5,1/4)</td>
<td>(1/3,1/2,1)</td>
<td>(1,1,1)</td>
<td>0.1258</td>
</tr>
</tbody>
</table>

Table 12: Fuzzy comparison matrix for ST strategies.

<table>
<thead>
<tr>
<th>ST</th>
<th>St(_7)</th>
<th>St(_8)</th>
<th>St(_9)</th>
<th>Local weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>St(_7)</td>
<td>(1,1,1)</td>
<td>(1/8,1/7,1/6)</td>
<td>(1,1,1)</td>
<td>0.8750</td>
</tr>
<tr>
<td>St(_8)</td>
<td>(6,7,8)</td>
<td>(1,1,1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 13: Fuzzy comparison matrix for WT strategies.

<table>
<thead>
<tr>
<th>WT</th>
<th>St(_10)</th>
<th>St(_11)</th>
<th>St(_12)</th>
<th>Local weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>St(_10)</td>
<td>(1,1,1)</td>
<td>(1/3,1/2,1)</td>
<td>(1,1,1)</td>
<td>0.2052</td>
</tr>
<tr>
<td>St(_11)</td>
<td>(1,2,3)</td>
<td>(1/3,1/2,1)</td>
<td>(1,2,3)</td>
<td>0.4808</td>
</tr>
<tr>
<td>St(_12)</td>
<td>(1/3,1/2,1)</td>
<td>(1,1,1)</td>
<td>(1,1,1)</td>
<td></td>
</tr>
</tbody>
</table>

\[
W = W \times W = \begin{bmatrix} 0.314 \\ 0.210 \\ 0.246 \\ 0.230 \end{bmatrix}
\]

Finally, using Fuzzy AHP and FPM, weight of each strategy was determined from st\(_1\) to st\(_{10}\) and strategies to be prioritized as follow:

1- Inform about trademark and product quality level of the organization to develop international markets and increase sales offices in other countries
2- Coordination with other producers to pressure authorities to enact and enforce laws on intellectual property field
3- Using Advanced methods in managing the organization, such as ERP and CRM and marketing innovation methods and emphasis on capabilities of learning organizations
4- Identify active private companies and outsource part of the activities
5- Use the experiences of other activists in the software industry and do not produce general software
6- Cooperation and communication with international organizations to meet Global Standards
7- Providing products with an emphasis on simplicity and ease (produce audio and video production)
8- Development of human resources management activities to attract educated specialists and identifying new technology trends
9- To strengthen research and development unit for producing and using new ideas and presenting flexible products and services with an emphasis on cultural commonalities
10- Development team activities and linking research and development centers with the aim of coordinating research activities.
Conclusions:

Software industry in our country is still new and to achieve excellence and original position is a long road ahead. Due to Lack of government and private sector investment in software field, software development process in Iran has slowed, that if these problems solve we can be hoped that the country's product is competitive with foreign products.

Although the software industry is a new industry in our country, the trained manpower in this field, is an important advantage that there is a general form. Software because of their properties is not similar to other hardware products, such as transforming is easy and short lifetime. One of the main problems of software producers are intellectual property rights.

In this paper, at first, by analysis of internal and external environment, strengths and weaknesses, opportunities and threats identified and SWOT matrix was formed. After formation SWOT matrix, four general strategies SO, WO, ST and WT was found that each weight was obtained by the ANP method .Then, using Fuzzy AHP and FPM, weight of each strategy was determined from st1 to st10 and finally the best strategy is that inform about trademark and product quality level of the organization to develop international markets and increase sales offices in other countries.

REFERENCES


