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Application of ANP Network Analysis Process Method in SWOT Model

Fardin Nezafati Namin [a*], Hamid Rez Askari [b], Sirous Ramesh [c], Seyed Masoud Mousavi Hassani [d], Esmat khanmohammadi [e], Heydar Ebrahimi [f]

[a] *Department of Geography, Payame Noor University, Iran.*

[b] *Ph.D. Student of Geography and Urban Planning, Islamic Azad University, Yadegar Imam Khomeini, Tehran, Iran.*

[c] *Master of Geography and Urban Planning, Islamic Azad University, Science and Research Branch of Tehran, Iran.*

[d] *Master of Geography and Urban Planning, Islamic Azad University, Yadegar Imam Khomeini, Tehran, Iran.*

[e] *Ph.D. Student of Geography and Urban Planning, Islamic Azad University, Science and Research Branch of Tehran, Iran.*

[f] *Master of Urban Management, Islamic Azad University, Science and Research Branch of Tehran, Iran.*

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Abstract

Strategy is a comprehensive program for an action which defines the major directions of an organization and provides guidelines for resources allocation on the course to achieve the long-term goals of the organization. Choosing the right strategy is a complex and even risky task. This is because each strategy leads the organization to a specific competitive environment and determines how managers plan to match the strengths and weaknesses of an organization with the environmental opportunities and threats. SWOT analysis alone does not provide an analytical tool for recognizing the importance of identified factors and evaluating various strategic options based on the factors. For this reason, SWOT analysis has some deficiencies and shortcomings in the measurement and evaluation of the factors. Although the Analytical Hierarchy Process (AHP) can overcome these deficiencies, when there is a lack of independency and dependency between factors, the approach loses its efficiency. This is due to the fact that AHP assumes the possibility of factors involved in an independent hierarchy of structure if this assumption cannot be accepted for examining the effects of the internal and external environment. Therefore, a tool to consider and assess the possible dependencies among the factors has been needed. In this paper, an algorithm is presented based on the network analysis process, which can work well even when there is a dependency between the SWOT factors. Then, the green space conditions in Tehran's district 19 are analyzed by SWOT analysis where this algorithm is considered as a real case.

Keywords: Strategic Planning; SWOT Analysis; Multi-criteria Decision Making Techniques (MCDM); AHP and ANP; Green Space; district 19 of Tehran.

1. Introduction

Strategic management is widely used today by most public and private organizations such as the municipality for the integrated and optimal management. The complexity and elegance of decision making in urban management have made strategic management essential. The management of diverse and multi-dimensional internal activities is only part of the modern responsibilities of managers, including city administrators. The immediate external environment of an organization is also a challenging factor [1]. In order to gain effective coverage with all these factors affecting the organization's ability to advance its goals, managers are turning to strategic planning. So far, many quantitative tools and techniques have been used in the field of strategic management. Since decision making is the main component in

* Corresponding author: nazafati2012@yahoo.com

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this area, regarding multiple considerations at the same time, the multi-criteria decision-making techniques (MCDM) have been widely used. SWOT analysis is one of the tools used in the strategy development phase to analyze internal and external strategic issues. This analysis examines the opportunities and threats of the environment and the weaknesses and strengths of the organization. It aims to assess whether the organization is able to seize and exploit the opportunities and to avoid threats in an uncontrolled external environment such as environmental pollution of urban green spaces in a region, lack of balanced distribution of parks, and so on. SWOT summarizes the most important internal and external factors that can affect the future of an organization [2, 3]. If SWOT is well implemented, it could be a very good basis for the strategy development. Looking at the previous documentation available on the SWOT analysis, it is clear that most of the analyses are merely a series of qualitative descriptions less focused on SWOT [4]. Indeed, as planning and decision-making processes become more complex by increasing the number of interdependent criteria, the usefulness of using SWOT is also decreased. In other words, it can be concluded that the SWOT analysis is not perfect and has some limitations. Although some strategic management literatures tried to overcome this shortcoming by providing a quantitative analysis like the one performed by David in his book, such as the Internal Factor Evaluation matrix (IFE), External Factor Evaluation matrix (EFE), or Competitive Profile Matrix (CPM). However, the David's method also has some drawbacks, such as: 1) All the assigned scores are subjectively measured, and 2) when the same question is answered again, lack of uniformity may occur, because the weight of the key factors is subjectively assigned by the assessment team and no compatibility test is performed. It can be concluded that SWOT analysis alone cannot be used for the comprehensive assessment of the strategic decision-making process. In the first section, the efforts made to improve SWOT, and most importantly, multi-criteria decision-making techniques have been used. In this section, special emphasis is placed on the Analytical Hierarchy Process (AHP) technique, which is a multi-criteria decision-making technique. In the second part, the new and more efficient ANP tool in combination with SWOT, which will correct the defects of AHP, along with its application in the green space of Tehran region have been introduced.

2. Analytical Hierarchy Process and its Application in SWOT

The Analytic Hierarchy Process (AHP) is a mathematical method for solving complex multi-criteria decision-making problems. This methodology was developed by Professor Clock in 1977. AHP can consider both qualitative and quantitative criteria for evaluating the decision-making options [2]. Here, we will introduce a step-by-step approach for using the AHP in SWOT. It should be noted that the meaning of SWOT groups in the following refers to four strengths, weaknesses, opportunities and threats concepts, and the SWOT factors include the individual factors, which are introduced separately under each SWOT group. However, the steps for using AHP in SWOT are [2]:

- **Step 1:** Create a SWOT matrix, which means identifying the factors for each SWOT group.
- **Step 2:** Make paired comparison between SWOT factors in each group.
- **Step 3:** Make paired comparison between the four SWOT groups, i.e. strengths, weaknesses, opportunities, and threats. After doing the paired comparison and determining the relative weight of each group, the final weights should be determined by multiplying the relative weight of the factors by the relative weight of the groups for the final weights of each factor. In addition, the total weight of all the factors should be unity.
- **Step 4:** Use results in the process of developing and evaluating the strategy. The contribution of this work to the strategic planning process is achieved through the numerical values that indicate the importance of each factor.

3. Analytical Network Process (ANP)

Considering the limitations given in AHP and the inability of this approach to take into account the relationships between the criteria and the factors, Saaty et al. (1996) developed a different approach known as the Analytic Network Process (ANP). This approach has the advantages of AHP in the sense that it considers interdependencies between the criteria [9]. The Analytic Hierarchy Process (AHP) organizes the components of a system into a hierarchy, so that each hierarchical element could depend on its higher-level element and could linearly maintain this dependency to the highest level. In other words, the hierarchy of dependencies should be linear from top to bottom, or vice versa. If the two-way dependency means the weight of the criteria, the weight of the options is also dependent on the criteria. Another issue on the hierarchy is that it provides a "network" or a nonlinear or feedback system [7]. In this case, the hierarchical rules and formulas cannot be used to calculate the weight of elements. In this case, we used the theory of networks to calculate the weight of elements [8].

3.1. Appropriate Network Model for SWOT

The hierarchical model and network proposed here for the SWOT analysis is composed of four levels. The goal (the best strategy) represents the first level, the second level is the SWOT groups, the third level is the factors of each SWOT group, and the fourth level is the options or alternative strategies [6].

In the hierarchical model, W21 is a vector that shows the effect of the goal on the criterion, W32 is a vector that indicates the effect of the criterion on each sub-criterion, and W43 is a vector representing the effect of each sub-criterion

on the options. In the SWOT model, as shown in Figure 1, the internal standard for SWOT groups is considered at the standard level, which refers to what was previously mentioned. For example, there is a dependency between the strengths and the opportunities. In the network model, W1 represents an effective goal vector on SWOT groups, W2 also represents the interdependency vector among SWOT groups, W3 represents the vector of effect of SWOT groups on the group factors, and vector W4 is the effect of factors on the strategic options [10].

3.2. Proposed Algorithm for Using ANP in SWOT

It should be noted in the process of network analysis that the steps can be carried out in two ways: either the process of developing a large matrix of steps, where the ultimate priority is determined based on the evaluation of a large matrix and the normalization of the weight of the options, or that the steps are based on matrix operations, which is preferred to the first one in the proposed algorithm. As a result, in the proposed algorithm, it is not necessary to develop and normalize a large matrix and choose a strategy based on the matrix. Considering the network model developed above and the general principles of ANP, the steps for using the network analysis process in the SWOT analysis are described as follows [6, 11]:

- **Step 1:** Identify the SWOT factors and alternative strategies.
- **Step 2:** Assuming that there is no relationship between the factors, the importance of the SWOT groups can be measured by the pairwise comparisons with the 1-9 scale (calculate W1).
- **Step 3:** As there is a dependency between the SWOT groups, then using the 1-9 scale and the pairwise comparison of the interdependency matrix of the groups (model level 2) (calculate W2).
- **Step 4:** Determine the priority (importance) of each SWOT group by multiplying W1 by W2 (calculate Wf).
- **Step 5:** Determine the relative importance of each SWOT factor with the 1-9 scale and the paired comparisons (calculate W (sub-f (local)).
- **Step 6:** Determine the final degree of importance for each of the SWOT factors by multiplying the result of step 4 by step 5 (W (sub-f (global)).
- **Step 7:** Determine the importance of alternative strategies relative to each of the SWOT factors with the 1-9 scale through paired comparisons (i.e., W4 calculation).
- **Step 8:** Determine the final priorities of each of the strategic options (by multiplying the result of step 6 by step 7).

4. Introduction of Study Scope

Tehran is the capital of Iran, in the north of the country. Tehran currently has 22 municipalities in the study area in the district 19 located southern Tehran (Figure 1). The district 19 of Tehran municipality is located at 51 degrees 6 minutes to 51 degrees and 38 minutes east longitude and 35 degrees 34 minutes to 35 degrees and 51 minutes north latitude and is one of the marginal areas of Tehran metropolitan area. Over the past 30-40 years, it has undergone the development process. The district is bound from the north to the district 17, from the east to the district 16 and from the west to the district 18. The Zamzam and Ayatollah Saidi axes form the common border between the district 19 and the northern and western neighbourhoods. From the eastern side of Bahmanyar Street and the northern section of the Tondgooyan Highway, the boundary is between the districts 19 and 16, and the district 19 is limited to the Azadegan highway on the south. The district 19 of Tehran municipality has a special position in the south-western entrances of Tehran, and incorporates some of the structural elements of the city. The study area is about 2032 hectares, which is about 3.2% of the total area of 22 districts of Tehran (643.96 Km^2) (Department of Municipal Statistics of District 19).

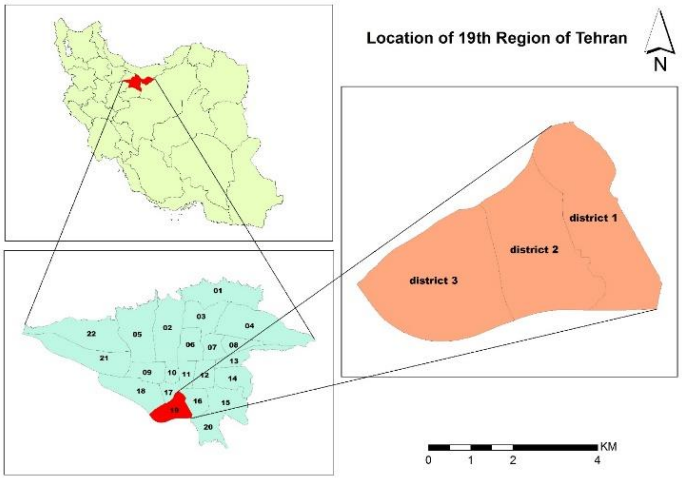

Figure 1. Position of the 19th area in Tehran (Iran)

5. Application of Real Sample of SWOT Analysis Using ANP

In this section, considering the green space of the district 19 of Tehran, the algorithm proposed in the previous section for the strategic analysis has been applied. All public spaces, urban parks and forest parks, gardens and agricultural lands with a total area of 11,000 hectares account for 18% of the area of Tehran. Forest parks consist of the Chitgar, Pardisan and Lavizan forest parks, with a total area of 2,700 hectares. Private Green spaces include all the continuous and scattered gardens and landscapes of Tehran, which are considered a valuable heritage for the city and cover an area of more than 536 hectares. Considering the constructions northern and western Tehran, there are major gardens and agricultural lands in the districts 18 and 20. Among the most important gardens in Tehran are the Ferdows Garden in District 1, Bagh-e Negarestan in the north of Baharestan Square, and Kamrani Garden. The total area of the green space in this area is 3430406 m^2.

Table 1. Current status area of use of green space in region 19 by region (Municipal office of green area 19)

Total area total	Boostan number	The area	Region	Row
1083244	21	District One	19	1
520666	18	District Two	19	2
519692	14	District Three	19	3
61104	7	District Four	19	4
489265	5	District five	19	5
3430406	**65**			**Total area**

Recently, with the changes in the management of the district 19, the senior management has adopted a five-year strategic planning using the network analysis technique with the building of a strategic team. Following extensive studies and regular meetings, the team has completed the analysis of internal and external factors and summarized the key strategic factors in the table, and has identified a number of strategic options according to the identified factors. Now, we intend to use the ANP approach to assess these factors and determine the priority of the strategies.

Table 2. Identification of the important internal and external factors affecting the planning of green space in district 19 of Tehran (Municipality's green space office in Tehran's 19th district)

Strategy	Explanation
SO	Creating a sense of responsibility for people in order to participate in the management and development of green spaces and green parks
ST	Prohibition of changing green space usage into commercial-office spaces
WO	Planning and managing parks and green spaces of the region in an organization to improve the quality of parks and green spaces in the short term and increase the amount of per capita green space in the long term
WT	Preventing the destruction of urban green spaces, the selection of suitable species, observance of scientific principles at the planting and maintenance stage, proper location for the development and development of urban green spaces

Table 3. The most important strategies developed with respect to identified factors and criteria (Municipality's green space office in Tehran's 19th district)

High visibility of green areas and parks by citizens of S1 Proper and optimal location of green area services and parks S3 Quick access to available S3 urban parks and green spaces There are nice and pleasant spaces in the green area and parks S4	**S Strengths**
Uncertainty about the urban landscape for future years W1 Low quality health facilities and services - W2 Decrease the area of parks due to the construction of commercial and service spaces - W3 Per capita of green space relative to the governor designated in Tehran Master Plan - W4	**W Weaknesses**
The role of green spaces and parks on the land market and their neighbourhoods. O1 The favourable psychological and social effects of parks environment on O2 citizens The existence of desert lands needed for the development of green spaces (province boosters) O3	**O Opportunities**
Change the use of urban green space and become residential user-commercial T1 Environmental pollution in urban green spaces in the T2 area Timely and proper irrigation and thus reducing the quality of green areas in some T3 parks The lack of balanced distribution of parks in the city and the non-division of parks at the level of areas in the T4 area	**T Threats**

5.1. Implementation Steps According to Applied Sample

Step 1: First, the hierarchical structure has been addressed, so that it can be assesses by the ANP. Figure 2 shows this hierarchical view. As can be seen in the diagram, the goal of "choosing the best strategy" is at the first level of the ANP model and the SWOT groups (strengths, weaknesses, opportunities, threats) are in the second level, the factors in the third level, and the four strategic alternatives are the fourth level of the model.

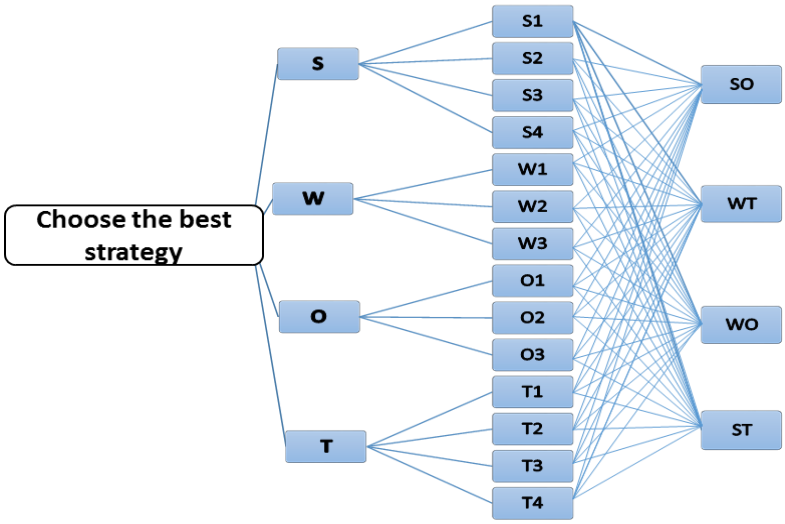

Figure 2. ANP model for SWOT analysis of green space in Tehran's 19th district

Step 2: Assuming now that there is no dependency between SWOT groups, we now make paired comparisons between these groups based on the goal criterion (selecting the best strategy) with the 1-9 scale. Then, we obtain the importance of each group using the Expert Selection software (a software for hierarchical analysis). The chart for the paired comparisons of SWOT groups is presented below as Table 4. The last item in this table is the Compatibility Ratio (CR), which is used to assess the validity of comparisons and, if is more than 0.1, the comparisons should be made again as it is inconsistent. Meanwhile, it should be noted that this software calculates the importance of the value of the special value vector. Our goal is to obtain the vector of each of these pairwise matrices.

Table 4. SWOT matched pairs of matrices (Experts' opinions of district 19 office of green space)

SWOT	S	W	O	T	Degree of importance of the groups
S	1	2	3	4	0.466
W	1/2	1	2	3	0.277
O	1/3	1/2	1	2	0.161
T	1/4	1/3	1/2	1	0.096
CR					0.01

As can be seen in the table, the importance of the SWOT groups can be summarized as Equation 1:

$$W1 = \begin{bmatrix} S \\ W \\ O \\ T \end{bmatrix} = \begin{bmatrix} 0.466 \\ 0.277 \\ 0.161 \\ 0.096 \end{bmatrix} \quad (1)$$

Step 3: The senior management team of the Municipality of District 19 to find the interdependencies among the SWOT groups after the analysis concluded that among these groups, there are relationships as shown in Figure 3:

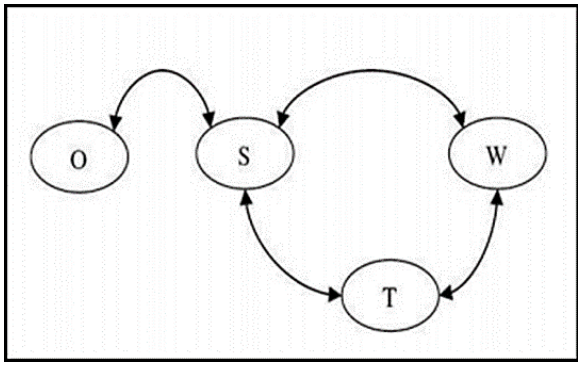

Figure 3. Interdependence between SWOT groups

Now, based on the interdependencies, the matrix of paired comparisons is developed. Based on the tables, the interdependency matrix of SWOT groups is obtained as follows:

$$W2 = \begin{bmatrix} 1 & 0.880 & 1 & 0.875 \\ 0.07 & 1 & 0 & 0.125 \\ 0.604 & 0 & 1 & 0 \\ 0.249 & 0.110 & 0 & 1 \end{bmatrix} \quad (2)$$

It should be noted that since the opportunities (O) only affect S (see Figure 3), a comparison was not made for a separate pair.

Step 4: At this step, the priorities (prefixes) of SWOT groups are calculated by considering the interdependencies (by multiplying W1 by W2).

$$\mathrm{W}_{(\mathrm{SWOT,groups})} = \mathrm{W2} \times \mathrm{W1} = \begin{bmatrix} 0.955 \\ 0.322 \\ 0.442 \\ 0.242 \end{bmatrix} \quad (3)$$

Comparing these priorities with those obtained in step 2 (regardless of dependencies), there is a significant difference.

Step 5: In this step, the relative priorities of each of the SWOT factors are obtained using a pairwise comparison, and the weights are calculated by analysing the pairwise matrices in the Expert Selection software (same as W3).

$$W_{W,factor} = \begin{bmatrix} 0.36 \\ 0.19 \\ 0.35 \\ 0.10 \end{bmatrix} W_{W,factor} = \begin{bmatrix} 0.34 \\ 0.48 \\ 0.18 \end{bmatrix} \quad W_{O,factor} = \begin{bmatrix} 0.29 \\ 0.36 \\ 0.35 \end{bmatrix} W_{T,factor} = \begin{bmatrix} 0.31 \\ 0.23 \\ 0.26 \\ 0.20 \end{bmatrix} \quad (4)$$

Step 6: In this step, the final (total) priorities of the SWOT factors are obtained by multiplying the dependent priorities of the SWOT groups (calculated in step 4) by the relative priorities of the SWOT factors (calculated in step 5). Here, example for the calculation of the final priorities of the strength factors has been presented (Table 5).

Table 5. Calculate the final priorities of SWOT factors

SWOT Groups	Group Priorities	SWOT Factors	The Relative Priority of The Invoices	Final Factor Priority
S	0.955	S1	0.36	0.344
		S2	0.19	0.182
		S3	0.35	0.335
		S4	0.10	0.095

The eigenvectors of the final (total) priorities of the SWOT factors are derived from the tables (W (f, global) (matrix).

Step 7: In this step, the importance of the selected strategies for each SWOT factor has been calculated. Following, only eigenvector has been calculated.

$$\boldsymbol{W_{f,global}} = \begin{bmatrix} \mathbf{0.344} \\ \mathbf{0.182} \\ \mathbf{0.335} \\ \mathbf{0.955} \\ \mathbf{0.102} \\ \mathbf{0.155} \\ \mathbf{0.058} \\ \mathbf{0.128} \\ \mathbf{0.160} \\ \mathbf{0.158} \\ \mathbf{0.075} \\ \mathbf{0.056} \\ \mathbf{0.063} \\ \mathbf{0.048} \end{bmatrix} \quad \boldsymbol{W4} = \begin{bmatrix} \mathbf{0.60} & \mathbf{0.59} & \mathbf{0.10} & \mathbf{0.48} & \mathbf{0.30} & \mathbf{0.07} & \mathbf{0.08} & \mathbf{0.12} & \mathbf{0.08} & \mathbf{0.15} & \mathbf{0.57} & \mathbf{0.54} & \mathbf{0.08} & \mathbf{0.54} \\ \mathbf{0.22} & \mathbf{0.10} & \mathbf{0.55} & \mathbf{0.13} & \mathbf{0.13} & \mathbf{0.13} & \mathbf{0.22} & \mathbf{0.64} & \mathbf{0.32} & \mathbf{0.51} & \mathbf{0.23} & \mathbf{0.13} & \mathbf{0.33} & \mathbf{0.13} \\ \mathbf{0.11} & \mathbf{0.24} & \mathbf{0.04} & \mathbf{0.29} & \mathbf{0.49} & \mathbf{0.46} & \mathbf{0.52} & \mathbf{0.16} & \mathbf{0.53} & \mathbf{0.22} & \mathbf{0.13} & \mathbf{0.23} & \mathbf{0.53} & \mathbf{0.24} \\ \mathbf{0.06} & \mathbf{0.05} & \mathbf{0.29} & \mathbf{0.09} & \mathbf{0.07} & \mathbf{0.32} & \mathbf{0.17} & \mathbf{0.06} & \mathbf{0.04} & \mathbf{0.10} & \mathbf{0.05} & \mathbf{0.08} & \mathbf{0.04} & \mathbf{0.06} \end{bmatrix} \quad (6)$$

Step 8: Ultimately, the final priorities of the strategy options are obtained by multiplying the eigenvector of the final priorities of the SWOT factors by the importance of the alternative strategy (W4) matrix.

$$W_{(alternative)} = \begin{bmatrix} SO \\ WO \\ ST \\ WT \end{bmatrix} = W4 \times W_{f,global} = \begin{bmatrix} 1.00758 \\ 0.71371 \\ 0.73089 \\ 0.32295 \end{bmatrix} \quad (7)$$

As shown above, performing the evaluation, the SO strategy finally takes the highest priority, followed by the ST, WO and WT strategies, respectively.

6. Comparison of AHP Results with ANP

The solution to the process of network analysis and the type of prioritization of strategies can be seen. Here, we will see the results obtained from the analytic hierarchy process. The final solution using the AHP is as follows:

$$W_{alternative} = \begin{bmatrix} SO \\ WO \\ ST \\ WT \end{bmatrix} = \begin{bmatrix} 0.365 \\ 0.291 \\ 0.240 \\ 0.100 \end{bmatrix} \quad (8)$$

As can be seen here, the SO strategy was identified as the first choice, but if we carefully take a look, we see that the order of priority of the strategies varies in both ways. In other words, if we do not consider the interdependencies between the SWOT groups (i.e., using AHP), then it poses the threat of falling into the wrong direction.

7. Conclusion

In this paper, a systematic approach for assessing the factors listed in the SWOT matrix has been introduced. In this regard, the efforts made in this regard and mentioned the limitations of each one outlined first. Then, the hierarchical analysis process (AHP) as a suitable approach to this task has been considered. This approach also has deficiencies, and its most important limitation is not to consider possible dependencies between the factors and the options. In order to address this limitation, using a more recent approach, Analytic Network Process (ANP), and illustrated its application for the strategic planning in the green space of the district 19 of Tehran has been suggested. By comparing the results of these two approaches, we concluded that the second approach produces a more accurate solution. The reason for this is that the weight of the SWOT factors is different in the two approaches, which is due to the fact that in the ANP approach, the dependencies between the SWOT factors are considered. In the case study, it was observed that the interdependency between the factors affects both the choice of strategy and the prioritization of strategies. Finally, based on the analysis, it can be stated that the Municipality of District 19 should focus on two strategies: innovation and advertising. In addition, the algorithm developed in this paper was limited to the interdependencies among the SWOT groups (strengths, weaknesses, opportunities, and threats). Future efforts in this field can examine the dependencies and interactions between the factors within each group. Moreover, the combination of fuzzy approaches with this approach can lead to the more accurate solutions in the situations with the high uncertainty.

8. Conflict of Interest

The authors declare no conflict of interest.

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