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Development of a fuzzy ANP based SWOT analysis for the airline industry in Turkey

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ABSTRACT

Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis has been widely used to evaluate alternative strategies in order to determine the best one for given business setting. This study aims at providing a quantitative basis to analytically determine the ranking of the factors in SWOT analysis via a conventional multi-criteria decision making method, Analytic Network Process (ANP). The ANP method is preferred in this study because of its capability to model potential dependencies among the SWOT factors. The study presents uniqueness in the way it incorporates inherent vagueness and uncertainty of the human decision making process by means of the fuzzy logic. The proposed *SWOT fuzzy ANP* methodology was implemented and tested for the Turkish airline industry. The results showed that the *SWOT fuzzy ANP* is a viable and highly capable methodology that provides invaluable insights for strategic management decisions in the Turkish airline industry, and can also be used as an effective tool for other complex decision making processes.

1. Introduction

Turkey is strategically positioned astride three continents (Europe, Africa and Asia) sharing a border with nine different nations in the region. With a fast growing population, rapid urbanisation, booming tourism industry and an increasing regional commercial base, Turkey is witnessing a need to further develop its civil aviation and airport infrastructure in the near future. As a point of reference, Turkey is larger than any country in the Europe except Russia. Given its large size and growing population, the residents of Turkey have come to rely on domestic and international air service.

The roots of the Turkish airline industry could be traced back to 1933, when the Turkish Airlines (TA) was founded. Between 1933 and 1982, it was the sole player in the Turkish airline industry. In 1982, when the market was deregulated the competitors entered in the airline market and began to operate domestic and international flights. Shortly thereafter, due to fierce competition, many of those new comers into the market went bankrupt (of the 29 airlines established in 1982, 22 went bankrupt in a very short time) (http://www.byegm.gov.tr/, 2009). In 1983, the Turkish Civil Aviation Law was enacted that provided the private sector the right to operate an airline and an airport. A new era began through this legislation for the Turkish Civil Aviation whose activities rapidly grew. In 1980s along with the fast growing tourism industry the air transportation industry in Turkey also showed a fast growing trend. Many charter airlines were founded and started to operate in the Europe–Turkey tourist charter markets. In the second half of the decade both Turkish Airlines and the private charter airlines enlarged their fleets. By the end of 2003, the Turkish government changed its air transportation policy and all restrictions on private airline companies to operate in scheduled domestic routes were lifted, and the domestic routes were opened into the competition. Furthermore, in order to further incentivise companies, the tax reduction was provided for the domestic flights. This was the re-deregulation of the Turkish Air Transportation Industry that gave the private airlines an opportunity to enter the domestic market where they rapidly grew. Taking advantage of the opportunity, the airline carriers offered 30–35% lower prices compared to their largest competitor, Turkish Airlines. This led to a huge demand for air transportation and the growth of the market (Sengur & Sarilgan, 2005). As of now, there are 14 private airline companies in Turkey whose fleets comprise 100s of aircrafts. The number of seats in private airline companies is in excess of 21,000 (Atalık & Arslan, 2009).

This paper is divided into seven parts, including introduction. The second part (called literature review) reviews published literature to succinctly describe Strengths, Weaknesses, Opportunities and Threats (SWOT) method, to reveal its major drawbacks, and offer a multi-methodology approach to overcome those drawbacks. The third part (called background information) briefly describes

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Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), fuzzy AHP, and fuzzy ANP. The fourth part (called proposed SWOT fuzzy ANP methodology) explains the proposed multi-methodological approach in a step-by-step fashion. The fifth part (called the application of SWOT fuzzy ANP methodology in the Turkish domestic airline industry) employs the proposed multi-methodology approach to analyse the Turkish Airlines industry so as to provide decision aid to airline companies in developing their strategies for their domestic operations. The sixth part (called comparing AHP, ANP, FAHP, and FANP results) compares and contrasts outcomes of these approaches. The seventh (and the last) part (called conclusion) summarises the study, restates the empirical findings and provide future research directions.

2. Literature review

SWOT analysis was popularised by Andrews (1965) who combined the ideas of Peter Drucker, Philip Selznick and Alfred Chandler. Drucker (1946) searched for the source of the company's success. He found out that successful organisations should have external purposes and objectives that were directed to determining customer needs and satisfying them. Selznick (1957), on the other hand, proposed two terms "distinctive competences" and "environmental uncertainty". The former dealt with unique capabilities and values possessed by particular organisations that put emphasis on giving them a "sustained competitive advantage". The latter pointed out that in early times firms did not necessarily respond rationally to their environments, but rather they internalised cultural norms and values of the wider system or society in which they operate. Chandler (1962) analysed four multinational companies' growth processes and their injection into their managerial structures. He implied the significance of strategic thought and comprehension in organisations. Chandler argued that environmental variables such as aggregate demand, supply resources, economic fluctuations, technological developments and competitors' behaviour will affect an organisation's strategy that includes determination of objectives, environmental domain, market, and allocation of resources and vice versa. An organisation should be aware of developmental opportunities as a consequence of environmental changes and be capable of responding them creatively. In light of these views, Andrews formulated SWOT analysis which proposed that a firm could generate its strategy after cautiously evaluating the components of its internal and external environments. This allowed companies to use long range planning approach based on qualitative analysis rather than quantitative forecast (Barca, 2005; Learned, Christensen, Andrews, & Guth, 1965).

SWOT matrix, in theory, presents a mechanism for facilitating the linkage among company strengths and weaknesses (internal factors), and threats and opportunities (external factors) in the marketplace. It also provides a framework for identifying and formulating strategies. Matching key internal and external factors is the hardest and challenging part of generating a SWOT matrix and requires the discretion of the practitioner. SWOT matrix helps managers develop four types of strategies respectively as illustrated in Fig. 1, namely SO (strengths-opportunities) strategies, WO (weaknesses-opportunities) strategies, ST (strengths-threats) strategies, and WT (weaknesses-threats) strategies. *SO strategies* use a firm's internal strengths to take advantage of external opportunities. *WO strategies* improve internal weaknesses by taking advantage of external opportunities. *ST strategies* use a firm's strengths to avoid or reduce the impact of external threats. *WT strategies* are defensive tactics directed at reducing internal weaknesses and avoiding environmental threats (Weihrich, 1982). There are eight steps involved in constructing a SWOT matrix: (1) list the firm's key external opportunities, (2) list the firm's key external threats, (3) list the firm's key internal strengths, (4) list the firm's key internal weaknesses, (5) match internal strengths with external opportunities and record the resultant SO strategies, (6) match internal weaknesses with external opportunities and record the resultant WO strategies, (7) match internal strengths with external threats and record the resultant ST strategies, and (8) match internal weaknesses with external threats and record the resultant WT strategies (David, 2007).

Due to its abovementioned capabilities in strategic management, SWOT analysis has been widely utilised in various business settings to make effective decisions. However, it possesses a major drawback: the lack of the identification of the importance ranking for the SWOT factors/criteria. Therefore, researchers developed models which incorporate Analytic Hierarchy Process (AHP) in SWOT and named their approaches "SWOT-AHP method (or analysis)" which can determine the priorities for the SWOT factors (Kahraman, Demirel, & Demirel, 2007; Kurttila, Pesonen, Kangas, & Kajanus, 2000; Shrestha, Alavalapati, & Kalmbacher, 2004). Moreover, Yuksel and Dagdeviren have recently developed a more sophisticated model with Analytic Network Process to capture *potential interactions, interdependences*, and *feedbacks* amongst the SWOT matrix factors (Yuksel & Dagdeviren, 2007). Although these approaches have brought new insights into the scene and deserve merit in terms of analytical foundation to determine the

	STRENGTHS-S 1. 2. . . . n List of Strengths	WEAKNESSES-W 1. 2. . . . n List of Weaknesses
OPPORTUNITIES-O 1. 2. . . . n List of Opportunities	SO STRATEGIES 1. 2. . . . n Use strengths to take advantage of opportunities	WO STRATEGIES 1. 2. . . . n Overcome weaknesses by taking advantage of opportunities
THREATS-T 1. 2. . . . n List of Threats	ST STRATEGIES 1. 2. . . . n Use strengths to avoid threats	WT STRATEGIES 1. 2. . . . n Minimize weaknesses to avoid threats

Fig. 1. A generic presentation of the SWOT matrix.

importance ranking of SWOT factors, they still have a major limitation: ignoring the imprecision in human decision making processes. To simultaneously overcome these limitations, we propose an integrated *SWOT fuzzy ANP* methodology, which would hypothetically handle the *interactions, interdependences*, and *feedbacks* amongst the SWOT matrix factors and also the *vagueness* in multi-criteria decision making.

3. Background Information on AHP, ANP, fuzzy AHP, and fuzzy ANP methods

What follows are sub-sections aim to briefly describe the conventional AHP, ANP, fuzzy AHP, and fuzzy ANP methods.

3.1. The Analytic Hierarchy Process (AHP) method

The Analytic Hierarchy Process (AHP) method, which was developed by Saaty (1980), is a powerful tool in solving complex decision problems. The AHP helps the analysts organise the critical aspects of a problem into a hierarchical structure similar to a family tree. By reducing complex decisions to a series of simple comparisons and rankings, then synthesizing the results, the AHP not only helps the analysts arrive at the best decision, but also provides a clear rationale for the choices made (Chin et al., 1999).

In the AHP approach, the decision problem is structured hierarchically at different levels with each level consisting of a finite number of decision elements. The upper level of the hierarchy represents the overall goal, while the lower level consists of all possible alternatives. One or more intermediate levels embody the decision criteria and sub-criteria (Partovi, 1994).

The weights of the criteria and the scores of the alternatives, which are called local priorities, are considered as decision elements in the second step of the decision process. The decision-maker is required to provide his preferences by pair-wise comparisons, with respect to the weights and scores. The values of the weights v_i and scores r_{ij} are elicited from these comparisons and represented in a decision table. The last step of the AHP aggregates all local priorities from the decision table by a weighted sum of the type, as shown in Eq. (1).

$$R_j = \sum_i v_i * r_{ij} \tag{1}$$

The global priorities R_j thus obtained are finally used for ranking of the alternatives and selection of the best alternative. The first and the last steps of the AHP are relatively simple and straightforward, while the assessment of local priorities, based on pair-wise comparisons is the main constituent of this method. The pair-wise comparison in the AHP assumes that the decision maker can compare any two elements E_i and E_j at the same level of the hierarchy and provide a numerical value a_{ij} of the ratio of their importance. If the element E_i is preferred to E_j, then $a_{ij} > 1$. Correspondingly, the reciprocal property $a_{ji} = 1/a_{ij}$, $j = 1,2,3,\ldots,n$ and $i = 1,2,3,\ldots,n$ always holds. Each set of comparisons for a level with n elements requires $[n \times (n-1)]/2$ judgments. The second half of the comparison matrix is the reciprocals of those judgments lying above the diagonals, and is usually omitted. Judgments are provided by means of a nine point ratio scale that ranges from two factors being equally important to one of the factors being absolutely more important than the others. After the expert supplies the ratings, local priorities of each element are calculated (Tung & Tang, 1998). A local priority vector $w = (w_1, w_2, w_3, \ldots, w_n)T$ may be obtained from the comparison matrix by applying some prioritization techniques, such as the Eigenvalue method or the Logarithmic Least Squares method (Udo, 2000). The set of n relative priorities should be normalised to sum of one as in Eq. (2)

$$\sum_{i=1}^{n} w_i = 1, \; w_i > 1 \quad \text{and} \quad i = 1,2,3,\ldots,n \tag{2}$$

Hence, the number of independent local priorities would be $(n-1)$. When the decision-maker is perfectly consistent in his answers to pair-wise comparison questions then all elements a_{ij} have perfect values, $a_{ij} = w_i/w_j$. In this case $a_{ij} = a_{ik} * a_{kj}$ for all $i,j,k = 1,2,3,\ldots,n$.

In most practical situations the decision-maker's evaluations (a_{ij}) are not consistent, since they are only estimations of the exact but unknown ratios w_i/w_j. The Eigenvalue method gives good approximation of the preference vector, but when the inconsistency of the decision-maker preferences is substantial then the solutions are not satisfactory. Saaty (1980) states that in many practical cases the pair-wise judgments of decision-makers would contain some degree of uncertainty. It is frequently the case that the decision-maker is certain about the ranking order of the comparison elements but uncertain about the precise numerical values of his judgments. The classical AHP attempts to overcome this problem by introducing a discrete linguistic set of comparison judgments. Instead of directly assigning numerical values to the comparison ratios, the decision-maker chooses an appropriate linguistic phrase, which is the best corresponding to his comparison preferences.

3.2. The Analytic Network Process (ANP) method

ANP method is an improved version of the AHP method and it is more accurate for many complicated models in which many criteria feedback and interrelations among criteria are used. The ANP method evaluates all relationships systematically by adding potential interactions, interdependences, and feedbacks in the decision making system. The powerful side of this method is to easily represent the decision making problem which involves many complicated relationships. This technique is not only enables the pair-wise comparisons of the sub-criteria under main criteria, but also provides the decision maker to independently compare all the sub-criteria which lies in interactions. A comparison of AHP and ANP methods is presented in Fig. 2.

Decision making problems that occur in firms cannot be explained by only hierarchical structure. The criteria and alternatives in a problem can be in interactions. At that circumstance, to find out the weights of all components a complicated analysis would be necessary. The ANP method is used for such kind of problems and is based on the same pair-wise comparisons as in the AHP. For pair-wise comparisons the 1–9 scale of Saaty (1980) is used as tabulated in Table 1. In the ANP model, all the components and relationships are defined and the relationships are determined as two-way interactions. In the model, the network structure is used and all the relationships in a cluster (namely, relationships among sub-criteria in a cluster and relationships between sub-criteria under different clusters) are considered. Because of the involvement of relationships among sub-criteria under a cluster and interactions among different criteria, the ANP method is useful for getting more accurate and effective results in such as a complex and crucial decision making problem.

In the ANP method, there are three matrix analyses such as *super matrix, weighted super matrix* and *limit matrix*. The super matrix provides relative importance of all components and weighted super matrix is used to find out of the value that is obtained by the super matrix values and the value of each cluster. In the limit matrix, the constant values of each value are determined by taking the necessary limit of the weighted super matrix. The results of the decision making problem is gained from the limit matrix scores. It is important to value of the criteria and alternatives by the experts and experienced people in order to get more consistent and

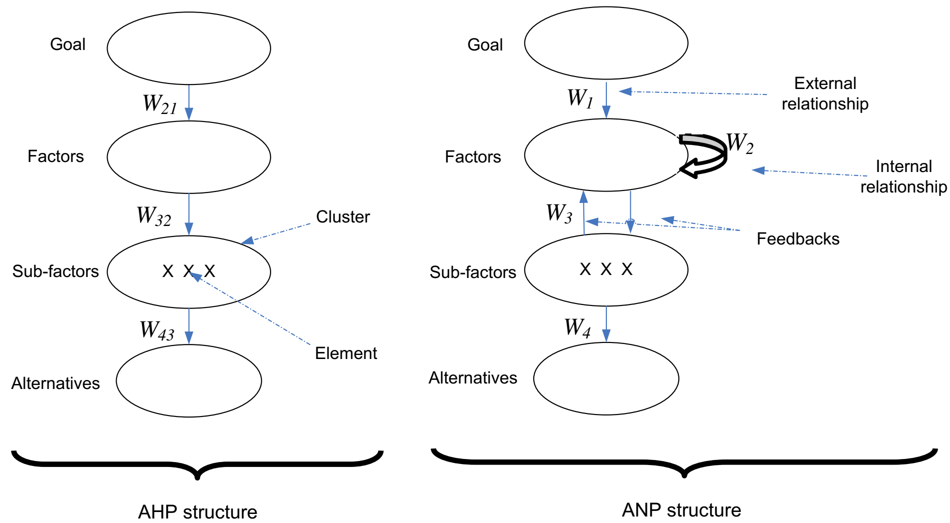

Fig. 2. A high-level comparison of AHP and ANP.

reliable results. The ANP method can be summarised as follows (Saaty, 1999; Saaty, 2003).

Fig. 2 illustrates that all criteria and clusters are connected to each other using one of the potential connections, in other words one-way, two-way, or looping. One-way and two-way dependencies represent the influence between the clusters are represented by one-way directed arrows or by bi-directed arrows, respectively. On the other hand, looping indicates an inner dependence in a cluster. The relative importance of the element i on the element j is represented by $a_{ij} = w_i/w_j$ in the pair-wise comparison matrix. The pair-wise comparison matrix A with n elements to be compared is formed as in Eq. (3)

$$A = \begin{bmatrix} 1 & w_1/w_2 & \cdots & w_1/w_{n-1} & w_1/w_n \\ w_2/w_2 & 1 & & w_2/w_{n-1} & w_2/w_n \\ \vdots & & \ddots & & \vdots \\ w_{n-1}/w_1 & w_{n-1}/w_2 & & 1 & w_{n-1}/w_n \\ w_n/w_1 & w_n/w_2 & \cdots & w_{n-1}/w_n & 1 \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1(n-1)} & a_{1n} \\ 1/a_{12} & 1 & & a_{2(n-1)} & a_{2n} \\ \vdots & & \ddots & & \vdots \\ 1/a_{1(n-1)} & 1/a_{2(n-1)} & & 1 & a_{(n-1)n} \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1/a_{(n-1)n} & 1 \end{bmatrix} \tag{3}$$

After the completion of the matrix A, an estimate of the relative importance of the elements compared is calculated via the solution of Eq. (4)

$$Aw = \lambda_{max} w \tag{4}$$

where λ_{max} is the largest eigenvalue of the matrix A, and w is the desired estimate.

To form the initial super matrix, the w is then normalised to form the local priority vector. The components of the super matrix is created by placing this normalised priority vectors as a hierarchical representation of goal, factors, sub-factors and alternatives (Saaty & Vargas, 2001) as given in Eq. (5) and represented in Fig. 2.

Table 1
Explanation of the pair-wise comparison scale.

Intensity of importance definition	Explanation
1 Equal importance	Two activities equally contribute to the object
3 Moderate importance	Experience and judgment slightly favour one activity over the other
5 Strong importance	Experience and judgment strongly favour one activity over the other
7 Very strong importance	An activity is very strongly favoured over the other, its dominance is demonstrated in practice
9 Extreme importance	The evidence favouring one activity over the other is of the highest possible order of affirmation
2, 4, 6, 8 For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it

$$W = \begin{matrix} Goal(G) \\ Factors(F) \\ Subfactors(SF) \\ Alternatives(A) \end{matrix} \begin{bmatrix} \overbrace{0}^{G} & \overbrace{0}^{F} & \overbrace{0}^{SF} & \overbrace{0}^{A} \\ W_{21} & 0 & 0 & 0 \\ 0 & W_{32} & 0 & 0 \\ 0 & 0 & W_{43} & I \end{bmatrix} \tag{5}$$

where W is the super matrix since its elements are matrices, W_{21} is a vector which represents the impact of the goal on the factors, W_{32} is a matrix that represents the impact of the factors on each of the sub-factor, W_{43} is a matrix that represents the impact of the sub-factors on each of the alternatives, and I is the identity matrix. If there is any dependence amongst the factors of W as shown in Fig. 2, then W_{22} would be a non-zero matrix. In a similar fashion, all interdependences can also be represented in Eq. (5) by changing the corresponding entry of the super matrix W. To form the weighted super matrix, as the first step an eigenvector is computed from the pair-wise comparison matrix of the row clusters with respect to the column cluster. This operation gives 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 super matrix is weighted which results in the *weighted super matrix* (Yuksel & Dagdeviren, 2007).

3.3. The fuzzy theory and fuzzy numbers

Zadeh (1965) introduced the fuzzy set theory to incorporate the uncertainty of human thoughts in modelling. The most critical contribution of fuzzy set theory is its capability of representing imprecise or vague data. A fuzzy set theory is defined to be a class of objects with a continuum of grades of membership. Such a set is specified by a membership (characteristic) function, which assigns a level of membership to each object, ranging between zero and one (Kahraman, Ruan, & Dogan, 2003). A symbol that represents a fuzzy set receives a tilde '∼' above it. A triangular fuzzy number (TFN) $\widetilde{M}$ is shown in Fig. 3.

A TFN is represented by $(l/m,m/u)$ or (l,m,u). The parameters l, m, and u refer to the smallest possible value, the most promising value, and the largest possible value, respectively. Each TFN is denoted by linear representations on its right and left sides such that its membership function μ can be defined as in Eq. (6)

$$\mu\left(\frac{x}{M}\right) = \begin{cases} 0, & x < l \\ \frac{x-l}{m-l} & l \leqslant x \leqslant m \\ \frac{u-x}{u-m}, & m \leqslant x \leqslant u \\ 0, & x > u \end{cases} \tag{6}$$

A fuzzy number can always be written by its corresponding left and right representation if each degree of membership as in Eq. (7)

$$\widetilde{M} = (M^{l(y)}, M^{r(y)}) = (l + (m-l)y, u + (m-u)y), \quad y \in [0,1] \tag{7}$$

where $l(y)$ and $r(y)$ refer to the left side and right side representation of a fuzzy number, respectively.

3.4. The fuzzy AHP method

There are various fuzzy AHP methods in the literature (Buckley, 1985; Dagdeviren, Yuksel, & Kurt, 2008; Deng, 1999; Leung & Cao, 2000; Mikhailov, 2004). In this study, we use Chang's (1992, 1996) extent analysis method, of which steps are summarised as follows. Let $X = \{x_1,x_2,\ldots,x_n\}$ be an object set, and $U = \{u_1,u_2,\ldots,u_n\}$ be a goal set. According to the Chang's method, each object is taken and the extent analysis for each goal, i.e. g_i, is performed respectively. Therefore, m extent analysis values for each object can be obtained with the following signs

$$M^1_{gi}, M^2_{gi}, M^3_{gi}, \ldots, M^m_{gi}, \quad i = 1,2,\ldots,n \tag{8}$$

where all the M^j_{gi} $(j = 1,2,\ldots,m)$ are TFNs. The steps of Chang's extent analysis can be summarized as follows.

Step 1: The value of fuzzy synthetic extent with respect to the ith object is defined as

$$S_i = \sum_{j=1}^{m} M^j_{gi} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M^j_{gi}\right]^{-1} \tag{9}$$

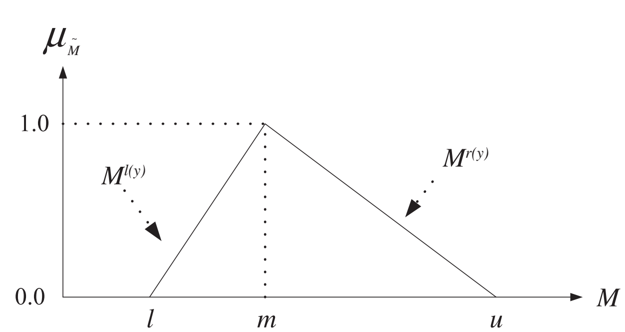

Fig. 3. A triangular fuzzy number.

To obtain $\sum_{j=1}^{m} M^j_{gi}$ conduct the fuzzy addition operation of extent of m analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M^j_{gi} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \tag{10}$$

and to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M^j_{gi}\right]^{-1}$, conduct the fuzzy addition operation of M^j_{gi}, $j = (1,2,\ldots,m)$ values such that

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M^j_{gi} = \left(\sum_{j=1}^{n} l_j, \sum_{j=1}^{n} m_j, \sum_{j=1}^{n} u_j\right) \tag{11}$$

and then compute the inverse of the matrix $\sum_{i=1}^{n}\sum_{j=1}^{m} M^j_{gi}$ such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M^j_{gi}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{12}$$

Step 2: The degree of possibility of $M_2(l_2,m_2,u_2) \geqslant M_1(l_1,m_1,u_1)$ is defined as

$$V(M_2 \geqslant M_2) = \sup[\min(\mu_{M1}(x), \mu_{M2}(y))] \tag{13}$$

and can also be represented as follows:

$$V(M_2 \geqslant M_1) = hgt(M_1 \cap M_2) = \mu_{M2}(d) = \begin{cases} 1, & \text{if } m_2 \geqslant m_1 \\ 0, & \text{if } l_1 \geqslant u_2 \\ \frac{l_1-u_2}{(m_2-u_2)-(m_1-l_1)}, & \text{otherwise} \end{cases} \tag{14}$$

where d is the ordinate of the highest intersection point D between μ_{M1} and μ_{M2} as shown in Fig. 4. To compare M_1 and M_2 both of the values, i.e. $V(M_1 \geqslant M_2)$ and $V(M_2 \geqslant M_1)$ need to be considered.

Step 3: The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i $(i = 1,2,\ldots,k)$ can be defined by

$$V(M \geqslant M_1, M_2, \ldots, M_k) = V[(M \geqslant M_1) \text{ and } (M \geqslant M_2) \times \text{and } \ldots \text{ and } (M \geqslant M_k)] = \min V(M \geqslant M_i), \quad i = 1,2,\ldots,k \tag{15}$$

Assume that for $k = 1,2,\ldots,n$; $k \neq i$

$$d'(A_i) = \min V(S_i \geqslant S_k) \tag{16}$$

Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T \tag{17}$$

where A_i $(i = 1,2,\ldots,n)$ are n elements.

Step 4: The normalised weight vectors via normalisation would be

$$W = (d(A_1), d(A_2), \ldots, d(A_n))^T \tag{18}$$

where W is a crisp (non-fuzzy) number.

3.5. The fuzzy ANP method

Saaty's discrete scale shown in Table 1 is precise and explicit. However, human perceptions and judgments are mostly uncertain and vague, which requires incorporating fuzziness in modelling. In addition, matching and mapping of the perceptions and judgments

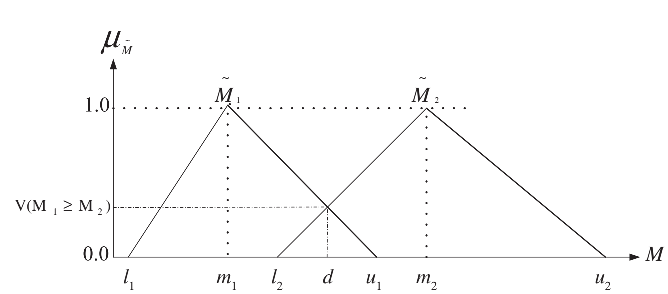

Fig. 4. Comparison of two triangular fuzzy numbers.

to a number cannot be explained by definite numbers. Therefore, fuzzy ANP method has been proposed to be used in such cases (Mohanty, Agarwal, Choudhury, & Tiwari, 2005). Instead of using the discrete scale of 1–9, a triangular fuzzy number (TFN) scale $\tilde{1}-\tilde{9}$ can then be described as in Table 2.

To evaluate the decision maker's judgments, pair-wise comparison matrices are created by using TFNs in Table 2. This comparison fuzzy matrix can be denoted as in Eq. (19) (Ramik, 2006).

$$\widetilde{A} = \begin{pmatrix} (a_{11}^l, a_{11}^m, a_{11}^u) & (a_{12}^l, a_{12}^m, a_{12}^u) & \cdots & (a_{1n}^l, a_{1n}^m, a_{1n}^u) \\ (a_{21}^l, a_{21}^m, a_{21}^u) & (a_{22}^l, a_{22}^m, a_{22}^u) & & (a_{2n}^l, a_{2n}^m, a_{2n}^u) \\ \vdots & & \ddots & \vdots \\ (a_{m1}^l, a_{m1}^m, a_{m1}^u) & (a_{m2}^l, a_{m2}^m, a_{m2}^u) & \cdots & (a_{mm}^l, a_{mm}^m, a_{mm}^u) \end{pmatrix} \quad (19)$$

The element $\tilde{a}_{mn}$ which is given by $(a_{mn}^l, a_{mn}^m, a_{mn}^u)$ represents the comparison of the component m with the component n. Due to the operational laws of fuzzy numbers (Wang & Chang, 2007), the matrix $\widetilde{A}$ can be rewritten as in Eq. (20) by replacing $\tilde{a}_{mn}$ with the corresponding reciprocal values (i.e. $1/a_{mn}$) (Tuzkaya & Onut, 2008)

$$\widetilde{A} = \begin{pmatrix} (1,1,1) & (a_{12}^l, a_{12}^m, a_{12}^u) & \cdots & (a_{1n}^l, a_{1n}^m, a_{1n}^u) \\ \left(\frac{1}{a_{21}^u}, \frac{1}{a_{21}^m}, \frac{1}{a_{21}^l}\right) & (1,1,1) & & (a_{2n}^l, a_{2n}^m, a_{2n}^u) \\ \vdots & & \ddots & \vdots \\ \left(\frac{1}{a_{m1}^u}, \frac{1}{a_{m1}^m}, \frac{1}{a_{m1}^l}\right) & \left(\frac{1}{a_{m2}^u}, \frac{1}{a_{m2}^m}, \frac{1}{a_{m2}^l}\right) & \cdots & (1,1,1) \end{pmatrix} \quad (20)$$

$\widetilde{A}$ is a triangular fuzzy comparison matrix. To compute the estimates of the fuzzy priorities $\tilde{w}_i$, where $\tilde{w}_i = (w_i^l, w_i^m, w_i^u),\ i = 1, 2, \ldots, n$ by means of the judgment matrix which approximates the fuzzy ratios $\tilde{a}_{ij}$ so that $\tilde{a}_{ij} \approx \tilde{w}_i/\tilde{w}_j$. The logarithmic least squares method (Chen, Hwang, & Hwang, 1992) is the most effective and efficient one and was used in our study. In this way, the triangular fuzzy weights for the relative importance of the factors, the feedback of the factors, and alternatives according to the individual factors can be calculated (Ramik, 2006). To compute the triangular fuzzy numbers, the logarithmic least squares method is used as described in Eqs. (21) and (22) (Onut, Kara, & Isik, 2009).

$$\tilde{w}_k = (w_k^l, w_k^m, w_k^u), \quad k = 1, 2, \ldots, n \quad (21)$$

where

$$w_k^s = \frac{\left(\prod_{j=1}^n a_{ij}^s\right)^{1/n}}{\sum_{k=1}^n \left(\prod_{j=1}^n a_{kj}^m\right)^{1/n}}, \quad s \in \{l, m, u\} \quad (22)$$

Following these steps the weights of the alternatives are to be converted to crisp numbers via the extent analysis as described in Section 3.4.

Table 2
Definition of TFN-linguistic scale for importance.

TFN	Linguistic scale for importance	Triangular fuzzy scale
$\tilde{1}$	Equally preferred	(1,1,1)
$\tilde{2}$	Equally to moderately preferred	(1,3/2,3/2)
$\tilde{3}$	Moderately preferred	(1,2,2)
$\tilde{4}$	Moderately to strongly preferred	(3,7/2,4)
$\tilde{5}$	Strongly preferred	(3,4,9/2)
$\tilde{6}$	Strongly to very strongly preferred	(3,9/2,5)
$\tilde{7}$	Very strongly preferred	(5,11/2,6)
$\tilde{8}$	Very strongly to extremely preferred	(5,6,7)
$\tilde{9}$	Extremely preferred	(5,7,9)

Table 3
Definition of linguistic variables.

Linguistic variables	Bottom	Medium	Top
$\tilde{1}$ Equally preferred	1	1	1
$\tilde{2}$ Equally to moderately preferred	1	1, 5	1, 5
$\tilde{3}$ Moderately preferred	1	2	2
$\tilde{4}$ Moderately to strongly preferred	3	3, 5	4
$\tilde{5}$ Strongly preferred	3	4	4, 5
$\tilde{6}$ Strongly to very strongly preferred	3	4, 5	5
$\tilde{7}$ Very strongly preferred	5	5, 5	6
$\tilde{8}$ Very strongly to extremely preferred	5	6	7
$\tilde{9}$ Extremely preferred	5	7	9

4. The proposed SWOT fuzzy ANP methodology

The main steps of our proposed framework can be summarised 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 Lee and Kim (2000), and Saaty and Takizawa (1986). 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 general sub-matrix notation for the SWOT model used in this study is as follows:

$$W = \begin{matrix} \text{Goal} \\ \text{SWOT factors} \\ \text{SWOT sub-factors} \\ \text{alternatives} \end{matrix} \begin{bmatrix} 0 & 0 & 0 & 0 \\ \tilde{w}_1 & \widetilde{W}_2 & 0 & 0 \\ 0 & \widetilde{W}_3 & 0 & 0 \\ 0 & 0 & \widetilde{W}_4 & I \end{bmatrix}$$

Step 1: Identify SWOT sub-factors and determine the alternative strategies according to SWOT sub-factors.

Step 2: Assume that there is no dependence among the SWOT factors; determine the fuzzy importance degrees of the SWOT factors with a 1–9 scale (i.e. calculate w_1).
The fuzzy pairwise comparisons scale used in this study are as follows:

Step 3: Determine, with a fuzzy $\tilde{1}-\tilde{9}$ scale, the inner dependence matrix of each SWOT factor with respect to the other factors by using the schematic representation of inner dependence among the SWOT factors: (i.e. calculate $\widetilde{W}_2$).

Step 4: Determine the interdependent priorities of the SWOT factors (i.e. calculate $\tilde{w}_{factors} = \widetilde{W}_2 \times \tilde{w}_1$).

Step 5: Determine the local importance degrees of the SWOT sub-factors with a fuzzy $\tilde{1}-\tilde{9}$ scale (i.e. calculate $\tilde{w}_{sub\text{-}fractors(local)}$).

Step 6: Determine the global importance degrees of the SWOT sub-factors (i.e. calculate $\tilde{w}_{sub\text{-}fractors(global)}$).

Step 7: Determine the importance degrees of the alternative strategies with respect to each SWOT sub-factor with a fuzzy $\tilde{1}-\tilde{9}$ scale (i.e. calculate $\widetilde{W}_4$).

Step 8: Determine the overall priorities of the alternative strategies, reflecting the interrelationships within the SWOT factors (i.e. calculate $\tilde{w}_{alternatives} = \widetilde{W}_4 \times \tilde{w}_{sub-factors(global)}$).

5. The application of SWOT fuzzy ANP methodology in the Turkish Domestic Airline Industry

This section presents a case study that was implemented in the Turkish Airlines Company to select the best strategy by using our proposed SWOT fuzzy ANP methodology. As the first step, an external environment analysis was performed by an expert team, familiar with the operation of the organisation. In this way, SWOT sub-factors which affect the success of the organisation but cannot be controlled by the organisation were identified. Based on these analyses, the strategically important sub-factors, i.e. the sub-factors which have very significant effects on the success of the organisation, were determined. Using the SWOT sub-factors, the SWOT matrix and alternative strategies based on these sub-factors were developed as in Table 4.

It can be seen from the Table 4 that the organisation has seven alternative strategies. The strategies identified as:

- Develop Market Penetration Strategy and Segment the Market On The Basis of Short and Long Trip, High and Low Frequency, and Low Ticket Fares (SO1).
- Create A Global Brand Through Adding New Routes to the Network (SO2) .
- Adopt a New ERP Programme (WO1).
- Increasing Brand Recognition and Loyalty (WO2).
- Ensuring Continuity of Growth Potential Through Increasing International Atatürk Airport's Capacity (ST1).
- Provide Effective Training Programmes to the Human Resources of both Turkish Airlines and Other Private Airline Companies Through Building A Training Centre (ST2).
- Developing Core Operations Through Profit-Oriented Improvements and Innovations (WT1).

In this study the aim of the SWOT analysis was to determine the priorities of the strategies.

Step 1: The problem was 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 technique. The schematic structure established is shown in Fig. 5.
The aim of "choosing the best strategy" was placed in the first level of the ANP model and the SWOT factors (Strengths, Weaknesses, Opportunities, Threats) were in the second level. The SWOT sub-factors in the third level

Table 4
SWOT Matrix for the Turkish Airlines Company.

External factors	Internal factors	
	Strengths (S) • Central Geographical Position and Profound Impact of Network (S1) • Modern Aircraft Fleet (S2) • Strong Cash Flow (S3) • Star Alliance Membership (S4) • Cabin Service (S5)	Weaknesses (W) • Failure to focus on core business (W1) • Recognition of TA Brand in the Global Market (W2) • Low Income per Unit (W3) • Insufficient Infrastructure (W4) • Delay in Innovation Applications (W5)
Opportunities (O) • The Percentage of Airline Transportation is Lower than Land and Sea Transportations within the Transportation Business. The Scope of Turkish Domestic Airline Transportation Market is Not As Broad As Those in Europe (O1) • Global Crisis (O2) • The Interaction Between Tourism and Transportation Industries and Airline Transportation Led to An Increase In the Integration Between Airline Network and Recently Developed Tourism Activities. (O3) • An Increase In the Share of In Transit Visitor (O4) • Improvements In Economic and Political Relations (O5)	SO Strategy • Develop Market Penetration Strategy and Segment the Market On The Basis of Short and Long Trip, High and Low Frequency, and Low Ticket Fares (SO1) • Create A Global Brand Through Adding New Routes to the Network (SO2)	WO Strategy • Adopt a New ERP Programme (WO1) • Increasing Brand Recognition and Loyalty (WO2)
Threats (T) • Inadequacy of Atatürk International Airport (T1) • Excessive and Unplanned Increase in Demand in the Airline Industry Gave Rise to A High Need for Competent Employees and Training Companies Cannot Adequately Respond to The Requests of This High Demand (T2) • Increase In Oil Prices In the World and Excessive Taxes On Oil Prices in Turkey: The Cost of Oil Play A Key Role In Determining Ticket Prices. Increase In Oil Prices In The World Have Negatively Affected Airline Transportation Business (T3) • Global Economic Downturn (T4) • An Increase In the Number of Low Cost Carriers In The World (T5)	ST Strategy • Ensuring Continuity of Growth Potential Through Increasing International Atatürk Airport's Capacity (ST1) • Provide Effective Training Programmes to the Human Resources of both Turkish Airlines and Other Private Airline Companies Through Building A Training Centre (ST2)	WT Strategy • Developing Core Operations Through Profit-Oriented Improvements and Innovations (WT1)
	Strengths (S) • Central Geographical Position and Profound Impact of Network (S1) • Modern Aircraft Fleet (S2) • Strong Cash Flow (S3) • Star Alliance Membership (S4) • Cabin Service (S5) Programmes to the Human Resources of both Turkish Airlines and Other Private Airline Companies Through Building A Training Centre (ST2)	Weaknesses (W) • Failure to focus on core business (W1) • Recognition of TA Brand in the Global Market (W2) • Low Income per Unit (W3) • Insufficient Infrastructure (W4) • Delay in Innovation Applications (W5)

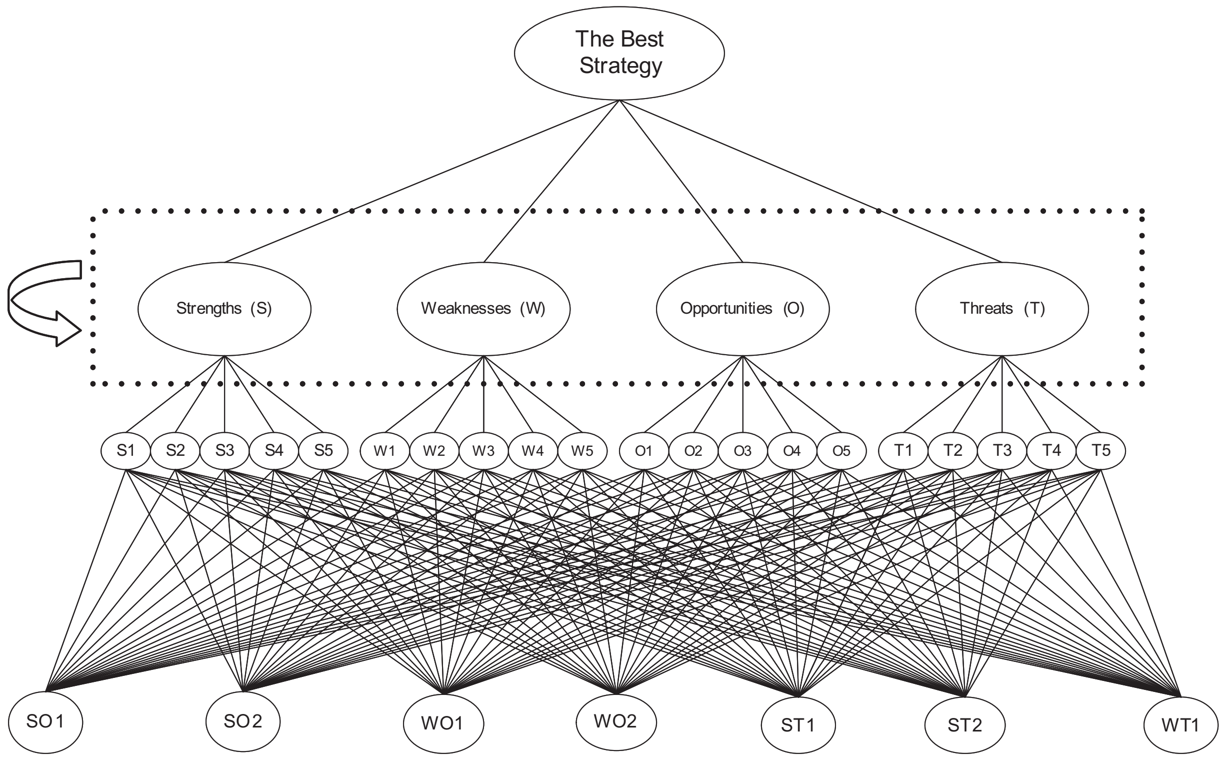

Fig. 5. The ANP model for the case study.

include five sub-factors for the "Strengths" factor, five sub-factors for the "Weaknesses" factor, five sub-factors for the "Opportunities" factor, and five sub-factors for the "Threats" factor. Seven alternative strategies developed for this study were placed in the last level of the model. As presented in the SWOT matrix, these alternatives were SO1, SO2, WO1, WO2, ST1, ST2, and WT1.

Step 2: Assuming that there is no dependence among the SWOT factors, pair-wise comparison of the SWOT factors was conducted with respect to the goal using a triangular fuzzy number (TFN) scale, i.e. $\tilde{1}$–$\tilde{9}$. All pair-wise comparisons in the application were performed by the expert team as mentioned at the beginning of the study.
The pairwise comparison matrix, given in Table 5, is analysed using Microsoft Excel software, and the following fuzzy eigenvector is obtained.

$$\tilde{w}_1 = \begin{bmatrix} S \\ W \\ O \\ T \end{bmatrix} = \begin{bmatrix} 0.250 & 0.370 & 0.370 \\ 0.250 & 0.280 & 0.280 \\ 0.250 & 0.198 & 0.198 \\ 0.250 & 0.152 & 0.152 \end{bmatrix}$$

Step 3: Inner dependence among the SWOT factors is determined by analysing the impact of each factor on every other factor using fuzzy 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 organisation, the dependencies among the SWOT factors are determined.
Based on the inner dependencies, pairwise comparison matrices are formed for the factors (Tables 6–9). 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 $\tilde{9}$ (absolute importance) as denoted in Table 3. The resulting fuzzy eigenvectors are presented in the last column of Tables 6–9.
Using the computed relative fuzzy importance weights, the inner dependence matrix of the SWOT factors (W_2) is formed.

Table 5
Pairwise Comparison of SWOT factors without dependence among them.

SWOT factors	S	W	O	T	Importance degrees of SWOT factors		
					Bottom	Medium	Top
Strengths (S)	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$	$\tilde{3}$	0.250	0.370	0.370
Weaknesses (W)		$\tilde{1}$	$\tilde{2}$	$\tilde{3}$	0.250	0.280	0.280
Opportunities (O)			$\tilde{1}$	$\tilde{2}$	0.250	0.198	0.198
Threats (T)				$\tilde{1}$	0.250	0.152	0.152

Table 6
The inner dependence matrix of the SWOT factors with respect to "strengths".

Strengths	W	O	T	Relative importance weights		
				Bottom	Medium	Top
Weaknesses (W)	$\tilde{1}$	$1/\tilde{9}$	$1/\tilde{4}$	0.115	0.087	0.072
Opportunities (O)		$\tilde{1}$	$\tilde{3}$	0.480	0.609	0.626
Threats (T)			$\tilde{1}$	0.405	0.304	0.301

Table 7
The inner dependence matrix of the SWOT factors with respect to "weaknesses".

Weaknesses	S	T	Relative importance weights		
			Bottom	Medium	Top
Strengths (S)	$\tilde{1}$	$\tilde{9}$	0.833	0.875	0.900
Threats (T)		$\tilde{1}$	0.167	0.125	0.100

Table 8
The inner dependence matrix of the swot factors with respect to "opportunities".

Threats	S	W	Relative importance weights		
Strengths (S)	$\tilde{1}$	$\tilde{3}$	0.500	0.667	0.667
Threats (T)		$\tilde{1}$	0.500	0.333	0.333

$$\widetilde{W}_2 = \begin{bmatrix} B & M & T & B & M & T & B & M & T & B & M & T \\ 1.000 & 1.000 & 1.000 & 0.833 & 0.875 & 0.900 & 0.500 & 0.667 & 0.667 & 0.655 & 0.706 & 0.733 \\ 0.115 & 0.087 & 0.072 & 1.000 & 1.000 & 1.000 & 0.000 & 0.000 & 0.000 & 0.158 & 0.118 & 0.106 \\ 0.480 & 0.609 & 0.626 & 0.000 & 0.000 & 0.000 & 1.000 & 1.000 & 1.000 & 0.187 & 0.176 & 0.161 \\ 0.405 & 0.304 & 0.301 & 0.167 & 0.125 & 0.100 & 0.500 & 0.333 & 1.000 & 1.000 & 1.000 & \end{bmatrix}$$

Step 4: In this step, the interdependent fuzzy priorities of the SWOT factors are calculated as follows:

$$\tilde{w}_{factors} = \widetilde{W}_2 \times \tilde{w}_1 = \begin{bmatrix} 0.374 & 0.427 & 0.433 \\ 0.159 & 0.165 & 0.162 \\ 0.208 & 0.225 & 0.227 \\ 0.259 & 0.183 & 0.179 \end{bmatrix}$$

Step 5: In this step, local fuzzy priorities of the SWOT sub-factors are calculated using the pairwise comparison matrix.

Table 9
The inner dependence matrix of the SWOT factors with respect to "threats".

Threats	S	W	O	Relative importance weights		
Strengths (S)	$\tilde{1}$	$\tilde{8}$	$\tilde{5}$	0.655	0.706	0.733
Weaknesses (W)		$\tilde{1}$	$1/\tilde{2}$	0.158	0.118	0.106
Opportunities (O)			$\tilde{1}$	0.187	0.176	0.161

$$\tilde{w}_{sub\text{-}factors(strengths)} = \begin{bmatrix} 0.364 & 0.426 & 0.446 \\ 0.192 & 0.227 & 0.222 \\ 0.148 & 0.124 & 0.118 \\ 0.148 & 0.113 & 0.108 \\ 0.148 & 0.111 & 1.106 \end{bmatrix}$$

$$\tilde{w}_{sub\text{-}factors(weakness)} = \begin{bmatrix} 0.113 & 0.075 & 0.071 \\ 0.319 & 0.392 & 0.401 \\ 0.152 & 0.112 & 0.108 \\ 0.190 & 0.170 & 0.167 \\ 0.226 & 0.250 & 0.253 \end{bmatrix}$$

$$\tilde{w}_{sub\text{-}factors(oppurtunities)} = \begin{bmatrix} 0.306 & 0.358 & 0.373 \\ 0.155 & 0.122 & 0.117 \\ 0.155 & 0.122 & 0.117 \\ 0.192 & 0.199 & 0.196 \\ 0.192 & 0.199 & 0.196 \end{bmatrix}$$

Step 6: In this step, the overall fuzzy priorities of the SWOT sub-factors are calculated by multiplying the interdependent fuzzy priorities of SWOT factors found in Step 4 with the fuzzy local priorities of SWOT sub-factors obtained in Step 5. The computations are provided in Table 10.
The $\tilde{w}_{sub\text{-}factors(global)}$ vector obtained by using the overall priority values of the sub-factors in the last column of Table 10.

Step 7: In this step we calculate the importance degrees of the alternative strategies with respect to each fuzzy SWOT sub-factors. Using Microsoft Excel software, the fuzzy eigenvectors are computed by analysing these matrices and the $\widetilde{W}_4 = \begin{pmatrix} W_4^{Bottom} & W_4^{Medium} & W_4^{Top} \end{pmatrix}$ matrix (Table 11.)

Table 10
The SWOT sub-factors.

SWOT factors	Priority of the factors	SWOT sub-factors	Priority of the sub-factors	Overall priority of the sub-factors
Strengths	(0.374, 0.427, 0.433)	(S1)	(0.364, 0.426, 0.446)	(0.136, 0.182, 0.193)
		(S2)	(0.192, 0.227, 0.222)	(0.072, 0.097, 0.096)
		(S3)	(0.148, 0.124, 0.118)	(0.055, 0.053, 0.051)
		(S4)	(0.148, 0.113, 0.108)	(0.055, 0.048, 0.047)
		(S5)	(0.148, 0.111, 0.106)	(0.055, 0.047, 0.046)
Weakness	(0.159, 0.165, 0.162)	(W1)	(0.113, 0.075, 0.071)	(0.018, 0.012, 0.011)
		(W2)	(0.319, 0.392, 0.401)	(0.051, 0.065, 0.065)
		(W3)	(0.152, 0.112, 0.108)	(0.024, 0.019, 0.017)
		(W4)	(0.190, 0.170, 0.167)	(0.030, 0.028, 0.027)
		(W5)	(0.226, 0.250, 0.253)	(0.036, 0.041, 0.041)
Opportunities	(0.208, 0.225, 0.227)	(O1)	(0.306, 0.358, 0.373)	(0.064, 0.081, 0.085)
		(O2)	(0.155, 0.122, 0.117)	(0.032, 0.027, 0.027)
		(O3)	(0.155, 0.122, 0.117)	(0.032, 0.027, 0.027)
		(O4)	(0.192, 0.199, 0.196)	(0.040, 0.045, 0.045)
		(O5)	(0.192, 0.199, 0.196)	(0.040, 0.045, 0.045)
Threats	(0.259, 0.183, 0.179)	(T1)	(0.306, 0.366, 0.380)	(0.079, 0.067, 0.068)
		(T2)	(0.155, 0.129, 0.124)	(0.040, 0.024, 0.022)
		(T3)	(0.155, 0.093, 0.090)	(0.040, 0.017, 0.016)
		(T4)	(0.192, 0.206, 0.203)	(0.050, 0.038, 0.036)
		(T5)	(0.192, 0.206, 0.203)	(0.050, 0.038, 0.036)

Table 11
Results.

$W_4^{Bottam} =$	0.221	0.249	0.143	0.210	0.150	0.159	0.151	0.155	0.082	0.178	0.249	0.243	0.219	0.169	0.174	0.114	0.095	0.143	0.152	0.155
	0.202	0.249	0.186	0.176	0.093	0.111	0.151	0.155	0.082	0.134	0.249	0.135	0.219	0.229	0.262	0.114	0.095	0.143	0.219	0.249
	0.072	0.068	0.077	0.134	0.076	0.111	0.088	0.083	0.136	0.114	0.068	0.116	0.06	0.071	0.066	0.079	0.095	0.143	0.06	0.068
	0.202	0.155	0.214	0.153	0.151	0.111	0.231	0.136	0.092	0.134	0.155	0.157	0.152	0.229	0.243	0.114	0.095	0.143	0.219	0.249
	0.102	0.093	0.053	0.102	0.081	0.090	0.151	0.117	0.236	0.093	0.093	0.116	0.152	0.136	0.092	0.270	0.095	0.143	0.098	0.093
	0.095	0.093	0.057	0.066	0.215	0.111	0.113	0.117	0.236	0.093	0.093	0.097	0.098	0.071	0.071	0.155	0.393	0.143	0.098	0.093
	0.107	0.093	0.269	0.159	0.233	0.308	0.113	0.238	0.136	0.254	0.093	0.135	0.098	0.096	0.092	0.155	0.133	0.143	0.152	0.093
$W_4^{Medium} =$	0.256	0.285	0.138	0.273	0.136	0.187	0.174	0.174	0.062	0.205	0.284	0.294	0.253	0.174	0.176	0.091	0.073	0.158	0.152	0.151
	0.242	0.285	0.167	0.187	0.066	0.118	0.174	0.174	0.056	0.135	0.284	0.170	0.253	0.275	0.284	0.091	0.073	0.158	0.26	0.276
	0.047	0.046	0.062	0.102	0.069	0.085	0.060	0.052	0.147	0.093	0.044	0.084	0.044	0.048	0.052	0.053	0.073	0.158	0.043	0.050
	0.194	0.157	0.215	0.169	0.150	0.118	0.290	0.125	0.063	0.135	0.157	0.182	0.149	0.265	0.276	0.091	0.073	0.158	0.260	0.276
	0.102	0.067	0.036	0.081	0.053	0.057	0.112	0.103	0.275	0.062	0.073	0.084	0.149	0.115	0.074	0.366	0.073	0.105	0.066	0.083
	0.083	0.093	0.059	0.049	0.258	0.085	0.083	0.078	0.275	0.062	0.079	0.061	0.068	0.054	0.057	0.154	0.474	0.105	0.066	0.083
	0.076	0.067	0.323	0.138	0.269	0.351	0.107	0.295	0.122	0.308	0.079	0.125	0.083	0.070	0.081	0.154	0.160	0.158	0.152	0.083
$W_4^{Top} =$	0.260	0.295	0.137	0.279	0.135	0.186	0.173	0.174	0.058	0.209	0.294	0.304	0.259	0.175	0.178	0.087	0.065	0.158	0.151	0.150
	0.247	0.295	0.169	0.189	0.062	0.113	0.173	0.174	0.052	0.133	0.294	0.168	0.259	0.285	0.292	0.087	0.065	0.158	0.266	0.287
	0.043	0.041	0.058	0.100	0.064	0.081	0.057	0.048	0.143	0.089	0.040	0.082	0.040	0.044	0.048	0.048	0.065	0.158	0.039	0.045
	0.200	0.156	0.219	0.169	0.148	0.113	0.302	0.122	0.060	0.133	0.155	0.183	0.149	0.268	0.285	0.087	0.065	0.158	0.266	0.287
	0.099	0.063	0.032	0.078	0.049	0.053	0.113	0.099	0.283	0.059	0.068	0.082	0.149	0.112	0.069	0.385	0.065	0.105	0.063	0.077
	0.078	0.087	0.053	0.045	0.267	0.081	0.08	0.075	0.283	0.059	0.074	0.058	0.065	0.050	0.053	0.153	0.523	0.105	0.063	0.077
	0.073	0.063	0.332	0.138	0.275	0.375	0.103	0.307	0.121	0.316	0.074	0.123	0.079	0.066	0.075	0.153	0.150	0.158	0.151	0.077

Step 8: Finally, the overall fuzzy priorities of the alternative strategies, reflecting the interrelationships within the SWOT factors, are calculated as follows:

$$\tilde{w}_{alternatives} = \begin{bmatrix} S01 \\ S02 \\ W01 \\ W02 \\ ST1 \\ ST2 \\ WT1 \end{bmatrix} = \widetilde{W}_4 \times \tilde{w}_{sub\text{-}factors(global)} = \begin{bmatrix} 0.177 & 0.204 & 0.208 \\ 0.180 & 0.206 & 0.211 \\ 0.085 & 0.061 & 0.057 \\ 0.172 & 0.184 & 0.186 \\ 0.120 & 0.108 & 0.107 \\ 0.120 & 0.104 & 0.101 \\ 0.145 & 0.134 & 0.131 \end{bmatrix}$$

Step 9: Finally, the overall fuzzy priorities of the alternative strategies are converted crisp values:

$$w_{alternatives} = \begin{bmatrix} S01 \\ S02 \\ W01 \\ W02 \\ ST1 \\ ST2 \\ WT1 \end{bmatrix} = W_4 \times w_{sub\text{-}factors(global)} = \begin{bmatrix} 0.196 \\ 0.199 \\ 0.068 \\ 0.181 \\ 0.112 \\ 0.108 \\ 0.137 \end{bmatrix}$$

The FANP analysis results indicate that SO2 is the best strategy with an overall priority value of 0.199.

6. Comparing the AHP,ANP, FAHP and FANP Results

According to the FANP analysis, alternative strategies are ordered as SO2–SO1–WO2–WT1–ST1–ST2–WO1. The same example is analysed with the AHP and FAHP hierarchical models by assuming there is no dependence among the factors. In addition, the ANP model is applied to the same model. The overall priorities computed for the alternative strategies are presented below. The same pairwise comparison matrices are used to compute the AHP, FAHP and ANP priority values.

In the AHP analysis, the SO1 strategy is found to be the best alternative with an overall priority value of 0.2179. However, the best strategy in FAHP, ANP and FANP is SO2. The results obtained from the AHP, ANP, FAHP and FANP analyses are comparatively listed in Table 12.

In cases where the dependency among SWOT factors and sub-factors is established, ANP analysis can be performed in order to determine the alternative priorities so that firms are able to make strategically correct decisions. AHP analysis can be used in situations where there is no dependency among SWOT factors and sub-factors or where the level of this dependency can be neglected.

7. Conclusions

SWOT analysis has been a widely used tool for evaluating the Strengths, Weaknesses, Opportunities, and Threats involved in business endeavour. Even though it is a well-structured and generally accepted way of evaluating business situations, as is the case in any tools of this kind, the quality and usefulness of its outcome depends upon the data and analysis go into defining its structure. Traditional SWOT analysis method employs arbitrary ranking of factors and assumes independence (ignores the potential interdependencies) of factors to each other. Today's complex business situations fuelled by continuously stringent constraints of the global marketplace demands methods that take into account optimising multiple goals at the same time while taking into account the uncertainty inherent in any real-world situation.

In order to overcome the above mentioned shortcomings of the traditional SWOT analysis, we proposed to enhance it with fuzzy logic and multi-criteria decision making techniques. Our goals were to (1) provide a quantitative basis to analytically determine the ranking of factors in SWOT analysis via a multi-criteria decision making method (i.e., Analytic Network Process [ANP]); the ANP method is preferred in this study because of its capability of modelling the potential dependencies of SWOT factors, and (2) incorporate inherent vagueness and uncertainty of the human decision making process by means of the fuzzy logic. We called the proposed methodology as *SWOT fuzzy ANP*, which was implemented and tested in the Turkish airline industry.

Table 12
Weights and Ranking of the Strategies with AHP and ANP.

	SO1	SO2	WO1	WO2	ST1	ST2	WT1
Weights in AHP	0.2179	0.2122	0.0497	0.1930	0.0961	0.0939	0,1372
Ranking in AHP	1	2	4	7	5	6	3
Weights in ANP	0.2226	0.2252	0.0465	0.1903	0.0987	0.0927	0.1240
Ranking in ANP	2	1	4	7	5	6	3
Weights in FAHP	0.1913	0.1915	0.0704	0.1801	0.1144	0.1092	0.1432
Ranking in FAHP	2	1	4	7	5	6	3
Weights in FANP	0.1962	0.1989	0.0677	0.1807	0.1116	0.1083	0.1366
Ranking in FANP	2	1	4	7	5	6	3

The comparative results of the *SWOT fuzzy ANP* methodology showed that such an enhanced version of SWOT analysis method is capable of providing enriched insights for strategic management in the Turkish airline industry as well as improved effectiveness for other related decision making processes. Main limitation of this study is the fact that it has only been applied to one application domain, the airline industry in Turkey. Our future research directions include applying this methodology to a variety of application areas (business settings that range from traditional manufacturing to service as well as e-commerce) to measure its effectiveness and usability. As per the results obtained from these application cases, we plan to improve and generalise on this overall methodology.

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