Knowledge-Based Systems 163 (2019) 581–594

Contents lists available at ScienceDirect

Knowledge-Based Systems

journal homepage: www.elsevier.com/locate/knosys

An application of fuzzy-logic and grey-relational ANP-based SWOT in the ceramic and tile industry

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ARTICLE INFO

Article history:
Received 7 November 2017
Received in revised form 8 August 2018
Accepted 11 September 2018
Available online 27 September 2018

Keywords:
SWOT analysis
Fuzzy logic
Grey relational
Analytical network process
Ceramic and tile industry
Multi-criteria decision making

ABSTRACT

This paper presents a quantitative basis to analytically determine the ranking of factors through strengths, weaknesses, opportunities, and threats (SWOT) analysis using a fuzzy multi-criteria decision-making method known as analytic network process (ANP). The ANP approach is chosen due to its promising capability in modelling potential dependencies among SWOT factors. This study is conducted for the first time in a ceramic and tile industry to determine the most important influential factors affecting the performance. Moreover, the prior mentioned presents unique factors to take into account the inherent uncertainty of human decision making processes via fuzzy logic. The possible benefits of the presented study are: (1) an increased level of exports in the tile and ceramic industry, (2) selecting the best investment opportunities on valuable, inimitable, and irreplaceable resource, and (3) the formulation of a competitive strategy on the basis of existing potentials in the company and throughout the industry. To achieve these aims, grey-relational and fuzzy logic are utilized as well. The proposed approaches are applied and tested for the first time on an Iranian ceramic and tile company as a case study. Finally, the applicability of the proposed approach is investigated by obtaining and identifying the most and the least important strategies. The results indicate that the proposed fuzzy logic and grey relational ANP-based SWOT are highly capable and applicable approaches in providing valuable insights for strategic decisions in the ceramic and tile industries.

1. Introduction

Iran is among a few number of countries that naturally enjoy the support of many mineral and valuable resources. For instance, Iran is considered as one of the countries having considerable mining capabilities in the field of decorative and façade stone [1]. Iran has been ranked the second in terms of proved reserves of decorative stones. Iran is also ranked the first in the world in terms of stone diversity. However, while there are 14 private ceramic and tile manufacturing companies in Iran that make this country as the world's third biggest manufacturer of construction stones and decorative after China and India, it also ranks as the 12th global exporter in this area [2].

The lack of a special export programme and its proper use is one of the primary problems of the tile and ceramic industry in Iran. The development of this industry in the world, otherwise known as the ceramic industry revolution, was primarily due to its wide applications in various industries. However, the Iranian tile and ceramic industries have failed to develop and provide sufficient export figures (The Office of Production Cooperatives, Ministry of Cooperation, Islamic Republic of Iran, 2015). As such, in this paper, the authors attempted to identify the main reasons for poor export in this industry by focusing on the main variables of the proposed model, demonstrated in Table 1, where the internal factors of the company that subsequently influence the export value are identified. Table 1 demonstrates that the ceramic and tile industry has great potential for development at the global level in terms of production and exporting products.

According to the information obtained in 2015, Iran's production in the tile and ceramic industry accounts for 4.2% of the world production. In Asia, after China and India, Iran is the third largest exporter of tile and ceramic products. However, Iran's share of export is only 2.3% of the world (The Office of Production Cooperatives, Ministry of Cooperation, 2015). Nevertheless, according to the macroeconomic indicators of industry and its comparative advantages, one question is raised. What is the reason for Iran's weakness in the exports of ceramic tile products? Or in other words, why does not the exportation of tile and ceramic products provide competitive advantages?

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https://doi.org/10.1016/j.knosys.2018.09.020
0950-7051/

Table 1
World indices of ceramic and tile industry (million square metres).
Source: The office of production cooperatives, Ministry of cooperation, 2015: 6

Year	World production	World export	The export share of world production	Iran's production	Iran's export	Iran's share of export	Iran's export share of world exports
2015	8515	1735	20.4%	350	40	11.5%	2.3%

1.1. Significance and importance of the current study

Given the great potential and capabilities provided by Iran's tile and ceramic industry, also considering the amount of transactions made in this industry until 2015 (based on the report of the Islamic Republic of Iran Customs Administration), the necessity of giving much attention to this industry and its export have been investigated closely in this paper. In this regard and, to improve the structure of the industry's export performance, special attention should be given to the resources and reserves of the industry within Iran. Accordingly, based on the existing approaches for identifying factors affecting export performance, a resource-based approach is taken in this study.

Through investigating previous studies in the field of export performance [3], it can be concluded that while in many of these works Porter's view (contingency or environmental view) has been implemented, less attention has been given to the resources and capabilities of the industries. In practice, these studies have concluded that the internal factors of companies can explain changes in profitability better than external (environmental) factors. However, according to the same conclusion, it is evident that the application of a resource-based approach is rarely observed in organizations and companies. Accordingly, this approach has been magnified in this study in order to present a more convincing explanation for its performance. In strategic management, the strengths, weaknesses, opportunities, and threats (SWOT) analysis has been utilized many times in the decision-making processes of different businesses effectively. Nonetheless, it lacks identifying the importance ranking of the SWOT criteria (factors). That is why various models based on the analytic hierarchy process (AHP) were proposed by researchers [4]. However, they do not take into account the interactions between the factors/criteria.

Previous studies have shown that unfortunately, the use of the contingency view provides contradictory results [1,5,6]. Note that the Porter school fans consider the effect of external factors on the performance of organizations at the high level, whereas, fans of the Schumpeterian School believe that this effect is negligible. Note also that the results of studies such as [5] that applied the resource-based approach consider the effect of external factors at the high level. However, the current study intends to investigate the effect of these factors (marketing resources) on the competitive strategy and performance of organizations, with respect to the previous studies conducted in this area.

1.2. Motivation and contribution

A review of the literature in this field reveals that there is no study that explains the flow of "resources of company → competitive strategy → export performance" in an integrated and comprehensive way. The previous studies such as [1,3,7] have only investigated a part of the prior flow. Therefore, this research intends to offer an integrated model to examine the impacts of resources on the strategy and performance of organizations. In short, the significance of the present study can be summarized as follows:

- The importance of a guideline (strategy) in the competitive environment of international markets.
- Increased competition in international markets and the importance of marketing resources.
- The increasing role of marketing resources, especially entrepreneurship-oriented actions in the issue of customers' satisfaction.
- Focusing on the market-oriented approach and avoiding a product-centric perspective to achieve a greater share of the market.

This research is conducted for the first time in the Iranian ceramic and tile industry to investigate the industry's export performance based on a fuzzy logic and grey relational network process (ANP)-based strengths, weaknesses, opportunities, and threats (SWOT) analysis. The possible benefits of the present study are as follows:

- An increased level of non-oil exports in the tile and ceramic industry.
- More investment on valuable, inimitable, and irreplaceable resources for companies.
- Formulation of a competitive strategy based on existing potentials in the company and subsequently, throughout the ceramic and tile industry.

Moreover, the SWOT analysis weighted by the fuzzy ANP that takes into account the inherent uncertainty in the ceramic and tile industry is carried out to evaluate the proposed strategy. On the other hand, while some studies have utilized the traditional SWOT in a deterministic environment, there is no discussion that accounts for the inherent uncertainty in the global ceramic and tile industry.

To address the drawback of the classical SWOT analysis, the problem at hand is enhanced by utilizing fuzzy logic, as well as associating multi-criteria decision-making techniques. In short, the aims of this research can be summarized as the following:

1. Proposing an analytical approach to determine the factor rankings in the SWOT analysis via ANP that incorporates a multi-criteria decision-making method to model the potential dependencies involved among SWOT factors.
2. Considering the inherent uncertainty of human decision making by introducing fuzzy logic. The proposed methodology can also be named SWOT fuzzy ANP, which is further applied and validated in the ceramic and tile industry.

The industrial application of this study provides additional opportunities in identifying critical factors and strategies in the ceramic and tile industrial companies. It also offers cost effectiveness for companies that operate in industrial environments under uncertainty. Moreover, the following points provide further information regarding this research:

✓ **Why is the topic important?** The competition among ceramic and tile industrial companies has been noticeably increasing in Iran.

✓ **What are research questions?**

(1) Identifying significant factors.
(2) Determining the priority among the achieved strategies taken from SWOT.
(3) Demonstrating the most and the least important strategy.

Fig. 1. An instance of the manufactured products.

- ✓ **What has been studied?** The studies and experiments are implemented in Ceramara ceramic and tile Co.
- ✓ **What are the contributions?** A combination of both theory and experimental techniques to investigate quantitative and qualitative critical factors and strategies in a ceramic and tile industrial company.
- ✓ **Why propose this particular method?** The fuzzy logic and grey relational ANP-based SWOT method that considers both quantitative and qualitative critical factors and strategies in a ceramic and tile industrial company is utilized to achieve the aim.

The remainder of this paper is organized as follows: the next section contains some information on the background of the investigated company. Section 3 provides the description of the problem. The solution methodologies are proposed and implemented in Section 4. Finally, Section 5 provides the conclusions.

2. Problem description

Fig. 1 demonstrates some of the manufactured products of the proposed company. The question is how to determine the ranking of the significant factors affecting the exports of the tile and ceramic products of the company through an analytical approach called ANP-based SWOT analysis. In what follows in the next section the implementation of the proposed approach is illustrated.

3. The solution methodology

The majority of multiple-attribute decision making (MADM) methods assume that the criteria are independent of each other; a case that rarely happens in real-world applications. Moreover, the concept of interactions among the criteria has not been discussed much in the existing literature. This paper aims to put a step forward to fill this gap by applying the analytic network process (ANP) method. The fuzzy logic and grey relational ANP-based SWOT method that considers both quantitative and qualitative critical factors and strategies in a ceramic and tile industrial company is utilized to achieve the aim.

To address the drawback of the classical SWOT analysis, the problem at hand is enhanced by utilizing fuzzy logic, as well as associating multi-criteria decision-making techniques. In short, the aims of this research can be summarized as the following:

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The literature on the ANP application is quite reach where there are many works in strategic policy planning [8,9], market and logistics [10], economics and finance [11], civil engineering [12,13], manufacturing systems [6,14], territorial and environmental assessment [7] and transportation problems [7]. Currently, ANP is widely being utilized in territorial decision problems with stakeholders having an active role in decision-making [4]. A broad range of quantitative and qualitative criteria involved in many complex models can be considered in ANP, based on which a multi-criteria decision problem is structured into a network via pair-wise comparisons made to assess the weights and to rank the alternatives [1,3,7]. For instance, Li et al. [15] developed personalized individual semantics to support linguistic group decision making in computing with words. Kou et al. [16] presented a Hadamard model to mitigate judgement contradiction in the decision matrix.

ANP provides an extension to the applications of AHP in cases where there are interdependent relationships between the measured elements and hence generalizes the applications of the super-matrices in AHP [17]. Furthermore, note that the ANP model includes control hierarchies, clusters, and elements, alongside containing the relationships between elements and their ability to connect clusters and elements. The prior mentioned connection capability aims to achieve priorities based on the inherent effects between the elements and the clusters [4]. To summarize, the ANP process involves the following four main phases.

1. Structuring the decision problem and modelling the description;
2. Compilation of pair-wise comparison matrices;
3. Generating a super matrix;
4. Assigning final priorities;

Interested readers are referred to [2,18], and [19] for more details, although none of which considered SWOT in their analyses.

The general form of the super-matrix W^k is depicted in Fig. 2 where C_N denotes the Nth cluster, e_{Nn} shows the nth element in the Nth cluster and W_{ij} is a block matrix that consists of priority weight

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="4">C_1</th><th colspan="4">C_2</th><th colspan="4">C_N</th></tr>
<tr><th>e_{11}</th><th>e_{12}</th><th>...</th><th>e_{1n1}</th><th>e_{21}</th><th>e_{22}</th><th>...</th><th>e_{2n2}</th><th>e_{N1}</th><th>e_{N2}</th><th>...</th><th>e_{NnN}</th></tr>
<tr><td rowspan="4">C_1</td><td>e_{11}</td><td colspan="4" rowspan="4">W_{11}</td><td colspan="4" rowspan="4">W_{12}</td><td colspan="4" rowspan="4">W_{1N}</td></tr>
<tr><td>e_{12}</td></tr>
<tr><td>...</td></tr>
<tr><td>e_{1n1}</td></tr>
<tr><td rowspan="4">C_2</td><td>e_{21}</td><td colspan="4" rowspan="4">W_{21}</td><td colspan="4" rowspan="4">W_{22}</td><td colspan="4" rowspan="4">W_{2N}</td></tr>
<tr><td>e_{12}</td></tr>
<tr><td>...</td></tr>
<tr><td>e_{2n2}</td></tr>
<tr><td>...</td><td>...</td><td colspan="4">...</td><td colspan="4">...</td><td colspan="4">...</td></tr>
<tr><td rowspan="4">C_N</td><td>e_{N1}</td><td colspan="4" rowspan="4">W_{N1}</td><td colspan="4" rowspan="4">W_{N2}</td><td colspan="4" rowspan="4">W_{NN}</td></tr>
<tr><td>e_{N2}</td></tr>
<tr><td>...</td></tr>
<tr><td>e_{NnN}</td></tr>
</table>

Fig. 2. The general form of the super-matrix.

vectors (w) of the influence of the elements in the Ith cluster with respect to the Jth cluster. If the Ith cluster has no influence on the Ith cluster itself, (i.e. a case of inner dependency) W_{ij} becomes zero.

During the development of the ANP methodology, three different supermatrices are extracted [18]:

- The un-weighted super-matrix (or initial super-matrix): it includes all eigenvectors that are derived from the pair-wise comparison matrices of the model.
- The weighted super-matrix: A stochastic super-matrix obtained by multiplying the values in un-weighted super-matrix by the weight of each cluster. In this way, it is possible to determine the priority level assigned to each cluster.
- The limited super-matrix: it is the final matrix of the analysis obtained by raising the weighted super-matrix to a limiting power in order to converge and to calculate a long-term stable set of weights that represents the final priority vector.

Moreover, at the final step, the super-matrix is raised to a power limit $\underset{k\to\infty}{Lim}\, W^k$ to achieve a matrix where all columns are identical and each provides the global priority vector. If there are two or more limiting super-matrices, then the Cesaro sum obtained using Eq. (1) is performed to compute the final priorities.

$$\underset{k\to\infty}{Lim}\left(\frac{1}{N}\right)\sum_{r=1}^{N} w_r^k \tag{1}$$

In Eq. (1) N denotes the number of limiting super-matrices, and w_r is the rth limiting priority [19]. The Casero sum can also be used to calculate the average influences of the limiting super-matrix. At the end, the alternative with the largest priority is chosen.

The details of the above-mentioned four main phases are as follows [6].

Step 1 — Network structure formation

Having a comprehensive set of criteria determined by 100 experts, in this step the relationships between/among the criteria, sub-criteria, and alternatives are determined in a graphical network presentation, where both within and between cluster-relationships are captured.

Step 2 — Formation of pair-wise comparisons and obtaining local priority values

Pair-wise comparisons are performed in this step to obtain the priority value of each factor in the network presentation of the first step. Note that during this step, the following operations are performed:

1. Having the values of the pair-wise comparisons in the comparison matrix, a local priority vector is extracted from the eigenvector using Eq. (2), in which A, w, and $\lambda_{\max}$ correspond to the pair-wise comparison matrix, eigenvector, and eigenvalue, respectively.

$$Aw = \lambda_{\max} w \tag{2}$$

2. The matrix A, which demonstrates the pair-wise comparison between the factors, is calculated using Eq. (3).

$$A = \left[a_{ij}\right]_{n\times n};\ i = 1, 2, \ldots, n,\ \ j = 1, 2, \ldots, n, \tag{3}$$

where a_{ij} denotes the pair-wise comparison value in the pair-wise comparison matrix A.

3. Now, the normalized pair-wise comparison matrix B with the elements b_{ij} is calculated using Eq. (4).

$$b_{ij} = \frac{a_{ij}}{\sum_i a_{ij}};\quad i = 1, 2, \ldots, n,\ j = 1, 2, \ldots, n. \tag{4}$$

In addition, the eigenvector (W) is obtained using the eigenvalues shown in Eq. (5).

$$W = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix};\quad w_i = \frac{\sum_i b_{ij}}{n},\quad \text{for } i = 1, 2, \ldots, n. \tag{5}$$

$$W' = AW = \begin{bmatrix} w'_1 \\ w'_2 \\ \vdots \\ w'_n \end{bmatrix},\ \Rightarrow \lambda_{\max} = \frac{1}{n}\left(\frac{w'_1}{w_1} + \frac{w'_2}{w_2} + \cdots + \frac{w'_n}{w_n}\right)$$

Next, $\lambda_{\max}$ is calculated using Eq. (5), while the consistency property is checked after going through Eqs. (6) and (7). In these formulae, CI, RI, and CR are consistency indicator, random indicator, and consistency ratio, respectively. Besides, RI is obtained through a standard random index table showing the random index values for a different number of criteria regarded. Note that the consistency ratio must be smaller than 0.10.

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{6}$$

$$CR = \frac{CI}{RI} \tag{7}$$

Step 3 — Formation of the unweighted, weighted and limiting super-matrices and to obtain final priority values

The super matrix, or the partition matrix, is obtained by locating the local priority vectors on convenient columns. Generally, the sum of one column in the super matrix is greater than 1. The cluster is then weighted and normalized to establish a stochastic matrix, based on which the sum of the elements in a column is 1. The new obtained super matrix is called the weighted supermatrix [20]. If the power limit k displays a big random number, an increase is provided in the super matrix to power $2k+1$, so there becomes an approximation to limit, which is the importance weight. The new matrix is then called the limiting super matrix. Afterward, the priorities of the alternatives can be obtained by normalizing each column in the super matrix [21,22].

In what follows in Sections 3.1 and 3.2, brief backgrounds on the fuzzy analytic hierarchy process and the fuzzy ANP are given.

3.1. The fuzzy AHP

The analytic hierarchy process (AHP) is a decision-making tool utilized by many researchers worldwide. It helps to set priorities when quantitative and qualitative aspects are being considered in the process. Many find it very practical and flexible to use. AHP works by minimizing complex evaluation criteria into a series of one to one comparisons. However, due to lack of certainty on information and difficulty evaluating the strength of preferences, decision makers are unable to set the exact numerical values when conducting the test. Therefore, AHP plays a key role in solving this issue as it enables the users to deal with uncertainties involved in decision-making processes.

On the other hand, fuzzy AHP (FAHP) includes local priorities from the preference ratio, which are combined to obtain the global priorities. FAHP computes fuzzy priorities based on arithmetic operations for trapezoidal or triangular numbers. Although this system is widely known, there are many critics of this theory due to its consistency issue. This is because there is no specific articulation on what would make up an inconsistent comparison matrix and how the information would be handled. Besides, the obtained fuzzy priorities are more likely to be flawed due to its lacking of a mechanism to eliminate inconsistent data. As a remedy, the following steps are carried out in this paper to achieve the normalized weight vectors. As mentioned in Chang's [3] procedure, the extent analysis for each goal is performed after each object is taken.

In this way, Aher et al. [23] tried to study various morphological characteristics and to implement Geographical Information System (GIS) and MCDM through FAHP techniques for identification of critical sub-watersheds situated in transaction zone between mountainous and water scarcity region of Western Part of India. Besides, Agell et al. [24] presented a new approach based upon qualitative reasoning techniques for representing and synthesizing the information given by a group of evaluators. A mathematical formulation was then developed that contributes to decision-making analysis in the context of multi-attribute and group decision-making. Dong et al. [25] presented a review of consensus reaching processes (CRP) in a social network group decision making, and therefore it classified them into two paradigms: (i) the CRP paradigm based on trust relationships, and (ii) the CRP paradigm based on opinion evolution.

Step 1: The value of fuzzy synthetic extent with regard to the ith object is determined using Eq. (8)

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \oplus \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}. \tag{8}$$

To calculate $\sum_{j=1}^{m} M_{gi}^{j}$ in this equation, the fuzzy addition operation of m extent analysis values for the certain matrix is calculated using Eq. (9)

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right). \tag{9}$$

To acquire $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]$, the fuzzy addition operation of M_{gi}^{j} is performed. Hence,

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right] = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right), \tag{10}$$

As a result $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$ can be calculated by the inverse of Eq. (10) as follows [16]:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right). \tag{11}$$

Step 2: as $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $\tilde{M}_2 \geq \tilde{M}_1$ is defined as

$$V\left(\tilde{M}_2 \geq \tilde{M}_1\right) = Sup\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right] \quad \text{for } y \geq x. \tag{12}$$

Eq. (12) can also be equivalently expressed as:

$$V\left(\tilde{M}_2 \geq \tilde{M}_1\right) = hgt\left(\tilde{M}_1 \cap \tilde{M}_2\right) = \mu_{M_2}(d) = \begin{cases} 1 & \text{if } m_2 \geq m_1 \\ 0 & \text{if } l_2 \geq u_2 \\ \frac{(l_1-u_2)}{(m_2-u_2)-(m_1-l_1)} & Otherwise, \end{cases} \tag{13}$$

This is a method for calculating the area of a trapezoid, without using the trapezoid *height* of Fig. 3, where *d,* as shown in Fig. 3, is the ordinate of the highest intersection point between μ_{M_1} and μ_{M_2}. To do this, we drop perpendiculars (called '*hgt*' for height) from the upper base to the lower base.

To better compare $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$, calculating both values of $V\left(\tilde{M}_1 \geq \tilde{M}_2\right)$ and $V\left(\tilde{M}_2 \geq \tilde{M}_1\right)$ is necessary [16].

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

$$\begin{aligned} &V\left(\tilde{M} \geq \tilde{M}_1, \tilde{M}_2, \ldots, \tilde{M}_k\right) \\ &= v\left(\tilde{M} \geq \tilde{M}_1 \text{ and } \tilde{M} \geq \tilde{M}_2 \text{ and } \cdots \text{ and } \tilde{M} \geq \tilde{M}_k\right) \\ &= \underset{i}{Min}\, v\left(\tilde{M} \geq \tilde{M}_i\right) \end{aligned} \tag{14}$$

If we define

$$d'(A_i) = \underset{i}{Min}\, v\left(\tilde{M}_i \geq \tilde{M}_j\right) \text{ for } i \neq j \tag{15}$$

then the weight vector is obtained by

$$W' = \left(d'(A_1), d'(A_2), \ldots, d'(A_n)\right)^T \tag{16}$$

where A_i; $i = 1, 2, \ldots, n$ are the n elements of the weight vector.

Step 4: Via normalization, the normalized weight vectors are

$$w = \left(d(A_1), d(A_2), \ldots, d(A_n)\right)^T, \tag{17}$$

where w is a non-fuzzy number.

3.2. The fuzzy ANP

AHP is applicable, in particular, for those problems that have no interaction between criteria. Nonetheless, in many real-world situations, interactions between criteria and sub-criteria can be seen; this is the disadvantage of the ordinary AHP. In contrast,

Table 2
Generating parameters.

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight importance	One activity is weaker than the other
3	Moderate importance	Experience and judgement moderately favour one activity over another
4	Moderate plus importance	One activity is more moderate in favour of another
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus importance	Experience and judgement more strongly favour one activity over another
7	Very strong importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong importance	An activity is favoured very-very strong over another
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of the above scales	If activity *i* has one of the above non-zero numbers assigned to it when compared to activity *j*, then *j* has the reciprocal value when compared to *i*	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities

Saaty [18] proposed an ANP that is capable of dealing with nonlinear, i.e. network models. To cope with the interactions between criteria and sub-criteria, ANP adopts the super-matrix calculation to determine factor weights. Nevertheless, as some decision makers are often subjective and imprecise, especially when evaluating the performances, the use of the fuzzy set theory is justified. This theory is cable of describing the ambiguity involved in the decision-making processes. In this regard, Mikhailov & Tsvetinov [9] developed a fuzzy AHP method that utilizes a nonlinear programming based on fuzzy preference programming (FPP). FPP is appropriate to obtain comparison matrices for interval and fuzzy judgements and provides a more efficient way compared to the ones obtained using linear programming models. That is why the FPP approach proposed by Mikhailov & Tsvetinov [9] is adopted in the current work to obtain factor weights.

A triangular fuzzy number (TFN) scale $\tilde{1}$–$\tilde{9}$ as demonstrated further in Table 2 is utilized in this work, where pair-wise comparison matrices are constructed using TFNs regarding the decision maker's judgements. This fuzzy comparison matrix is shown in Eq. (18) [15].

$$\tilde{A} = \begin{pmatrix} (a^l_{11}, a^m_{11}, a^u_{11}) & (a^l_{12}, a^m_{12}, a^u_{12}) & \ldots & (a^l_{1n}, a^m_{1n}, a^u_{1n}) \\ (a^l_{21}, a^m_{21}, a^u_{21}) & (a^l_{22}, a^m_{22}, a^u_{22}) & \ldots & (a^l_{2n}, a^m_{2n}, a^u_{2n}) \\ \vdots & \vdots & \ddots & \vdots \\ (a^l_{m1}, a^m_{m1}, a^u_{m1}) & (a^l_{m2}, a^m_{m2}, a^u_{m2}) & \ldots & (a^l_{mn}, a^m_{mn}, a^u_{mn}) \end{pmatrix}. \quad (18)$$

As seen above, the element $\tilde{a}_{mn}$, which is derived by $(a^l_{mn}, a^m_{mn}, a^u_{mn})$ denotes the comparison of the component m along with the component n. Because of the operational laws of fuzzy numbers, the matrix $\tilde{A}$ can be rewritten by replacing $\tilde{a}_{mn}$ with its corresponding reciprocal value (i.e. $1/a_{mn}$) as follows:

$$\tilde{A} = \begin{pmatrix} (1,1,1) & (a^l_{12}, a^m_{12}, a^u_{12}) & \ldots & (a^l_{1n}, a^m_{1n}, a^u_{1n}) \\ (\frac{1}{a^l_{21}}, \frac{1}{a^m_{21}}, \frac{1}{a^u_{21}}) & (1,1,1) & \ldots & (a^l_{2n}, a^m_{2n}, a^u_{2n}) \\ \vdots & \vdots & \ddots & \vdots \\ (\frac{1}{a^l_{m1}}, \frac{1}{a^m_{m1}}, \frac{1}{a^u_{m1}}) & (\frac{1}{a^l_{m2}}, \frac{1}{a^m_{m2}}, \frac{1}{a^u_{m2}}) & \ldots & (a^l_{mn}, a^m_{mn}, a^u_{mn}) \end{pmatrix} \quad (19)$$

This matrix is used to estimate the fuzzy priority $\tilde{w}_i$, $\tilde{w}_i = (w^l_i, w^m_i, w^u_i)$, $i = 1, 2, \ldots, n$ by means of the judgement matrix which approximates the fuzzy ratios $\tilde{a}_{ij}$ so that $\tilde{a}_{ij} \approx {}^{\tilde{w}_i}/_{\tilde{w}_j}$. Now, to compute the triangular fuzzy numbers, the logarithmic least squares method is utilized as described in Eqs. (20) and (21).

$$\tilde{w}_k = (w^l_k, w^m_k, w^u_k), \quad k = 1, 2, \ldots, n \quad (20)$$

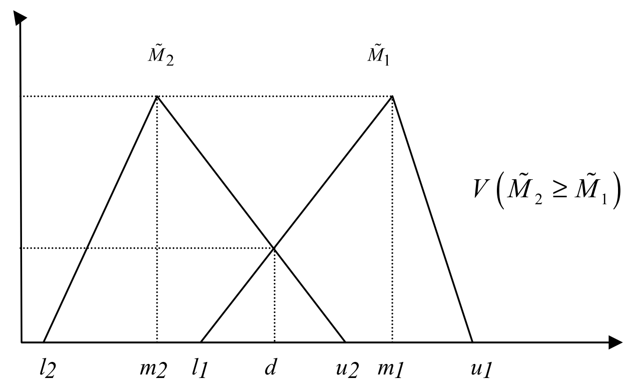


Fig. 3. Intersection between $\tilde{M}_1$ and $\tilde{M}_2$.

$$w^s_k = \frac{\left(\prod_{j=1}^{n} a^s_{ij}\right)^{1/n}}{\sum_{k=1}^{n}\left(\prod_{j=1}^{n} a^m_{ij}\right)^{1/n}}; \quad s \in \{l, m, u\}. \quad (21)$$

3.3. The SWOT fuzzy ANP

Having the background in Section 3, the essential steps involved in the proposed framework can be stated as follows. The first step 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 explored based on the works of Saaty & Takizawa [21]. Afterward, the inner dependencies among the SWOT factors, the inner dependency matrix, the weights of SWOT sub-factors and the priority vectors for alternative strategies are computed. The general sub-matrix for the SWOT model used in this study is as follows:

$$W = \begin{bmatrix} \text{Goal} \\ \text{SWOT factor} \\ \text{SWOT sub-factor} \\ \text{alternative} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ \tilde{w}_1 & \tilde{W}_2 & 0 & 0 \\ & \tilde{W}_3 & 0 & 0 \\ 0 & 0 & \tilde{W}_4 & I \end{bmatrix}, \quad (22)$$

where $\tilde{w}_1$ is (w^l_1, w^m_1, w^u_1). Thus, the proposed SWOT fuzzy ANP approach involves the following steps to perform.

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

Step 2: Assume that there are no dependencies among the SWOT factors; determine the fuzzy importance degrees of the SWOT factors using a 1–9 scale (i.e. obtain $\tilde{w}_1$). The fuzzy pairwise comparisons scale used in this study are further described as follows.

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

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

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

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

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. specify $\tilde{W}_4$).

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

4. A case study

In order to demonstrate the application of the proposed SWOT fuzzy ANP approach, the Ceramara Company case study is presented in this section.

4.1. Generating the SWOT matrix

To initialize, an expert team who is familiar with the operations involved in the company performs the external environmental analysis. Here, the aim is to identify uncontrollable SWOT sub-factors that affect the success of the organization. This leads into identifying the strategically important sub-factors that have significant effects on the success of the organization. Table 3 presents the SWOT matrix and the seven alternative strategies based on these sub-factors.

The aim of using the SWOT analysis in this study is to determine the priorities of the strategies. Export development, achieving the maximum nominal production capacity, and focusing more on the domestic consumer market are among the strategies that should be considered in the short-term by the owners of the Ceramara Industrial Co. These strategies are considered as either stabilization or opportunity creating strategies. The opportunity strengthening or maintaining strategies consist of gaining technical knowledge on designing and manufacturing external enamels, localization (joint venture), providing a systematic plan for export, confidence building and optimal use of BDS that are in line with the research into the industry. The stabilization strategies of creating opportunity include a wide advertisement at the internal and external levels, checking the performance of the domestic and foreign competitors, producing various products with excellent quality, and producing various sets of commodities (Portfolio). The WT avoiding strategies or opportunity seeking strategies include the sales of managers and experts' services in other markets, the general strengthening of the factory for taking advantage of the possible opportunities.

Further investigations in Ceramara Industrial Co. indicate that creating effective mutual trust between the partners and neighbouring units as well as private and state support seem essential. Considering the possibility of raising the level of general knowledge and management along with the inadequacy of the relationships in the private and public sectors, also the need for identifying the financial, credit and educational opportunities and facilities in setting the goals and making the collective policies necessitates providing the possibility of the specialized consultations for the sub-units of the company. Given the formation of the industrial clusters of ceramic tile in Ceramara Industrial Co. and the existence of many possible areas of cooperation between them, a tremendous need for conducting a more comprehensive study on the creation of cooperation networks among the Ceramara Industrial Co. and other active companies operating in this field seems necessary. The following are a number of preliminary suggestions for these cooperation networks in order to expand the tile industry in Ceramara Industrial Co. further.

- Generating a transport corporate in order for the shared use of facilities by the factories to reduce costs.
- Making attempts to encourage investors to invest in areas such as processing raw materials and manufacturing of parts and machinery of tile production in order to localize the industry (considering the appropriate fields and the scattered activities of craftsmen in this field).
- Formation of the corporate commercial companies in order to organize marketing and the possibility of encouraging the competition and gaining access the international markets.
- Effective communication with the builders and contractors in the construction industry.
- Creating a think tank in the Ceramara Industrial Co. to provide more practical solutions in line with the future development of the tile industry.
- Training and reinforcing more teamwork among the owners of the tile industry in Ceramara Industrial Co. to gain great access to the foreign markets.

4.2. The grey relational analysis

In what follows, brief backgrounds on the grey analytic hierarchy process and the grey ANP are given. The major advantage of the grey theory is that it can handle both incomplete information and unclear problems very precisely. As a part of the grey theory, the grey relational analysis (GRA) is a method to analyse the relational degree of every factor in the system. The main function in GRA is used to indicate the relational degree between two measurement sequences via utilizing a discrete measurement method to measure the distances [25].

The whole calculation steps are shown as follows:

Step 1: Five levels of maturity are defined as initial $\in$ [0, 1], repeatable $\in$ (1, 2], standardized $\in$ (2, 3], managed $\in$ (3, 4] and optimizing $\in$ (4, 5].

Step 2: Suppose the number of decision makers is p, which effectively filled in the questionnaire. d_{ijk} means the score of the second-class index. Therefore Sample matrix D can be obtained:

$$D = (d_{ijk})$$

$$i = 1, \dots, m; j = 1, \dots, n; k = 1, \dots, p$$

Step 3: Threshold value $\lambda_g(g = 1, 2, \dots, 5)$ and evaluation grey type $C_e(e = 1, \dots, g)$ are defined, with the purpose of determining the corresponding whitenization weight coefficient $f_g(d_{ijk})$, then grey evaluation weight r_{ij} of each second-class index can be calculated as the following:

$$r_{ij} = \frac{\sum_{k=1}^{p} f_e(d_{ijk})}{\sum_{e=1}^{g} \sum_{k=1}^{p} f_e(d_{ijk})} \quad (23)$$

$$e = 1, \dots, g; k = 1, \dots, p$$

Then, the grey evaluation weight vector of every second-class index X_{ij} can be obtained:

$$r_{ij} = (r_{ij1}, r_{ij2}, \dots, r_{ijp}); i = 1, 2, \dots, m; j = 1, 2, \dots, n. \quad (24)$$

Table 3
SWOT sub-factors.

	Strengths	Weaknesses
SWOT	The existence of raw material mines in the province and ease of geographical access The existence of raw material mines in the province and ease of geographical access	Lack of outlook and strategic planning in the field of market and export
	Access to new technologies in the field of machinery	Weakness in packaging for export
	Abundant and skillful workforce	Weakness in human resources management
	Acceptable quality products at the standard level	Lack of educational, research and applied laboratory services
	Centralized plant growth regarding the energy access and low cost of natural gas (dependency of the ownership and management), access to funds	Convenient transportation with a low compared to an average per capita supply chain practices
		Weakness in the design for export
		The dependency between the ownership and management in terms of control
Opportunities	SO target strategies of the optimal and fast use of the opportunities	WO strengthen strategies to maintain opportunities
Neighbour countries that passed the reconstruction era		
The existence of wealthy countries in the region (the Persian Gulf littoral states)		Gaining technical knowledge and designing and manufacturing of enamels
Interest in the direct investment in producing enamels		Localization (joint venture)
Suitable domestic construction development market in the Fifth Development Plan of the country		Confidence building
The developing condition of the interior factories of paints and enamels	Export development	Efficient use of BDS in line with the industry-related research
The development of the country's transportation system, non-membership in the WTO (due to the poor quality of goods in some units)	Achieve the maximum nominal production capacity	
	Focus more on the domestic consumption market	
Threats	ST sustainability strategies of opportunity creation	WT avoiding strategies of opportunity searching
The entry of new competitors with high production capacities		
The possibility of changing the government's macro strategy		
The absence of an internal centralized market for export		
The possibility of changing the consumption pattern towards substitute goods		
The development of substitute goods in the market		
Growth of tendency towards environment	Wide inside and outside advertisement	
Political sanctions on the restriction of access to technology and spare parts imports	Evaluating the performance of the inside and outside competitors	Sales of managers and experts' services in other markets
The laws of labour, social security and tax	Producing various products with excellent quality	General strengthening of factory for taking advantage of the possible opportunities
Lack of attention to customers' needs and considering customers' feedbacks in the product	Producing various sets of commodities (Portfolio)	
Lack of a comprehensive documentation system in the R&D section		

• Step 4: The grey evaluation weight matrix of every first-class index X_{ij} can be obtained:

$$R_i = \begin{bmatrix} r_{i1} \\ r_{i2} \\ \cdots \\ r_{in_i} \end{bmatrix} = \begin{bmatrix} r_{i11} & r_{i12} & \cdots & r_{i1g} \\ r_{i21} & r_{i22} & \cdots & r_{i2g} \\ \cdots & \cdots & \cdots & \cdots \\ r_{in_i1} & r_{in_i2} & \cdots & r_{in_ig} \end{bmatrix}$$

$$i = 1, 2, \ldots, m \tag{25}$$

With that, the grey overall evaluation weight vector $B_i = (b_{i1}, b_{i2}, \ldots, b_{ig})$ can be obtained:

$$B_i = W_i \cdot R_i = (\omega_{ij}, \omega_{i2}, \ldots, \omega_{ig}) \tag{26}$$

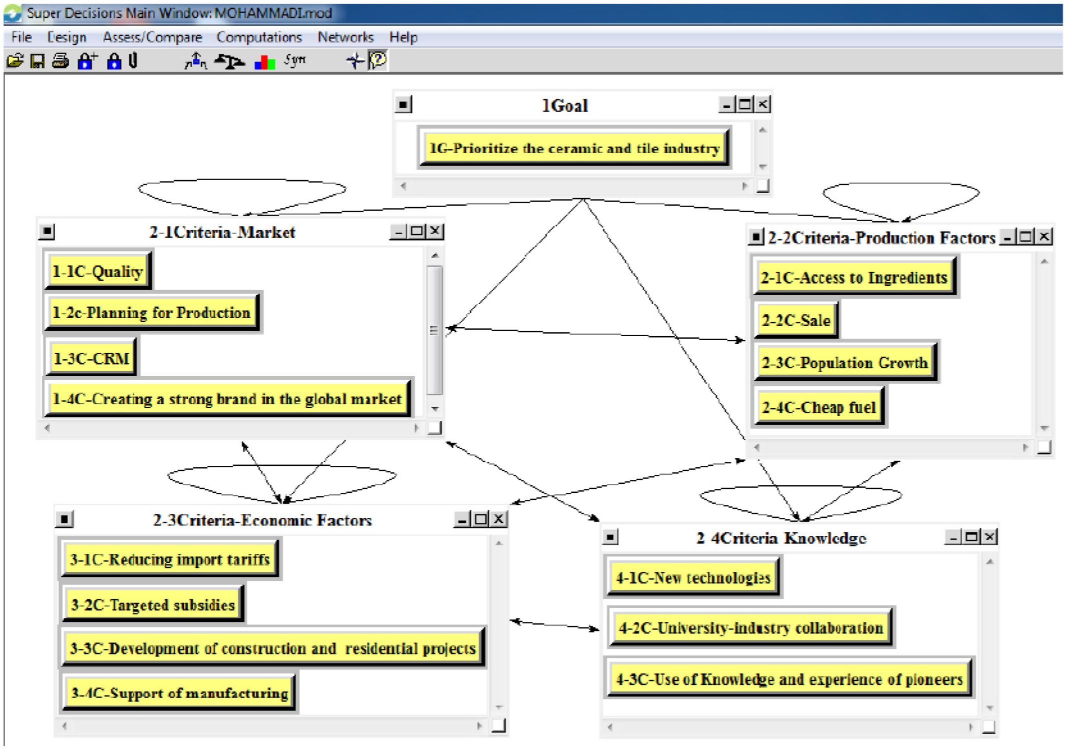


Fig. 4. ANP diagram.

• Step 5: The grey overall evaluation weight vector B of U can be calculated as the following:

$$B = W \cdot R = \begin{bmatrix} B_1 \\ B_2 \\ \dots \\ B_m \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1g} \\ b_{21} & b_{22} & \dots & b_{2g} \\ \dots & \dots & \dots & \dots \\ b_{m1} & b_{m2} & \dots & b_{mg} \end{bmatrix} \quad (27)$$

$$U = B \cdot \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \dots \\ \lambda_g \end{bmatrix} = b_1\lambda_1 + b_1\lambda_1 + \cdots \quad (28)$$

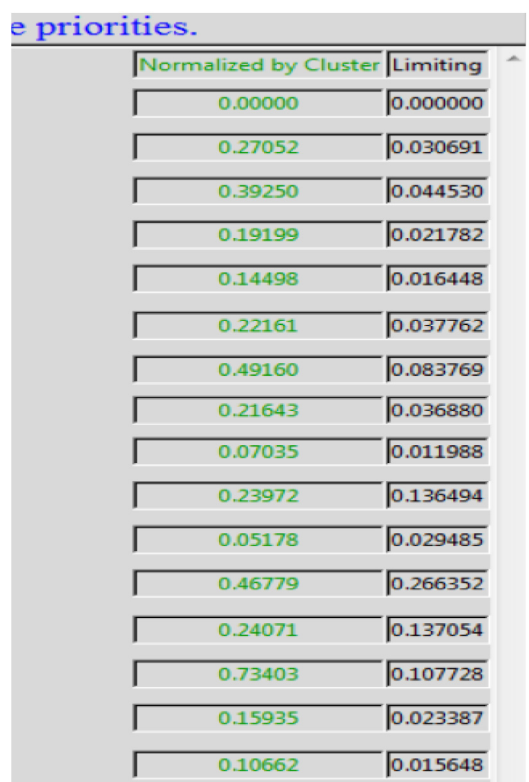
In the above, the value of U is just a grey number, and it needs to calculate each whitenization weight function $f_g(U)$ of evaluation grey type, and according to max $f_g(U)$, the maturity grade of U can be finally estimated.

4.3. Using fuzzy logic

The steps involved in employing the proposed approach are as follows.

Step 1: As the problem is converted into a hierarchical structure in order to transform the sub-factors and alternative strategies, they can be measured by the ANP technique. The established schematic structure is illustrated in Fig. 4. The aim of "choosing the best strategy" is found in the first level of the ANP model. Afterward, the SWOT factors (Strengths, Weaknesses, Opportunities, and Threats) are described in the second level. The SWOT sub-factors are shown in Fig. 5 using the Super Decision Matrix. The SWOT sub-factors in the third level include five sub-factors for each of the strengths, weaknesses, opportunities, and threats factor. Furthermore, the aforementioned seven alternative strategies in the SWOT matrix denoted by SO1, SO2, WO1, WO2, ST1, ST2, and WT1 are placed in the last levels.

Step 2: Assuming that there are no dependencies among the SWOT factors, the pair-wise comparisons of the SWOT factors are made by the expert team via triangular fuzzy numbers (TFN) regarding the goal, i.e. $\tilde{1} - \tilde{9}$. The pair-wise comparison matrix, presented in Table 4, is analysed using the Microsoft Excel software, based on which the following fuzzy eigenvector is achieved. On the other


e priorities.

Normalized by Cluster	Limiting
0.00000	0.000000
0.27052	0.030691
0.39250	0.044530
0.19199	0.021782
0.14498	0.016448
0.22161	0.037762
0.49160	0.083769
0.21643	0.036880
0.07035	0.011988
0.23972	0.136494
0.05178	0.029485
0.46779	0.266352
0.24071	0.137054
0.73403	0.107728
0.15935	0.023387
0.10662	0.015648

Fig. 5. The priorities of the sub-criteria.

Table 4
Pair-wise comparisons of SWOT factors without dependencies among them.

SWOT factors	S	W	O	T	Importance degrees of SWOT factors		
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

hand, the priorities between sub-criteria are illustrated in Fig. 5. As a result, we have

$$\tilde{w}_1 = \begin{bmatrix} S \\ W \\ O \\ T \end{bmatrix} = \begin{bmatrix} 0.250 & 0.370 & 0.370 \\ 0.250 & 0.280 & 0.370 \\ 0.250 & 0.198 & 0.370 \\ 0.250 & 0.152 & 0.370 \end{bmatrix} \tag{29}$$

Step 3: Inner dependencies among the SWOT factors is calculated by investigating the effect of each factor on every other factor through fuzzy pair-wise comparisons. In the introduction section, it is 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 utilizing both SWOT analysis and the ANP technique together. The dependencies among the SWOT factors are achieved through utilizing the analysis of both the internal and external environments of the organization. Pair-wise comparison matrices are established for the proposed factors according to the inner dependencies, presented further in Tables 5–8.

Based on the case study at hand, the following question: "what is the relative importance of strengths when compared with threats on controlling weaknesses?" arises in the pair-wise comparisons and leads to a value of $\tilde{9}$ (absolute importance) as listed in Table 2. The resulting fuzzy eigenvectors are shown in the last column of Tables 5–8. Note that the inner dependency matrix of the SWOT factors $\left(\tilde{W}_2\right)$ is formed after the relative fuzzy importance weights are computed as Eq. (30) shown in Box I.

Step 4: The interdependent fuzzy priorities of the SWOT factors are obtained in this step as:

$$\tilde{w}_{factors} = \tilde{W}_2 \times \tilde{w}_1 = \begin{bmatrix} 0.374 & 0.427 & 0.433 \\ 0.159 & 0.165 & 0.162 \\ 0.208 & 0.225 & 0.227 \\ 0.259 & 0.183 & 0.179 \end{bmatrix} \tag{31}$$

Step 5: Using the pair-wise comparison matrix, the local fuzzy priorities of the SWOT sub-factors are determined as:

$$\tilde{w}_{sub\text{-}factors(\text{strengths})} = \begin{bmatrix} 0.364 & 0.426 & 0.446 \\ 0.192 & 0.227 & 0.222 \\ 0.148 & 0.124 & 0.118 \\ 0.148 & 0.113 & 0.108 \\ 0.148 & 0.111 & 1.106 \end{bmatrix} \tag{32}$$

$$\tilde{w}_{sub\text{-}factors(\text{weakness})} = \begin{bmatrix} 0.113 & 0.075 & 0.071 \\ 0.319 & 0.392 & 0.401 \\ 0.152 & 0.112 & 0.108 \\ 0.190 & 0.170 & 0.167 \\ 0.226 & 0.250 & 0.253 \end{bmatrix} \tag{33}$$

$$\tilde{w}_{sub\text{-}factors(\text{opportunities})} = \begin{bmatrix} 0.306 & 0.358 & 0.373 \\ 0.155 & 0.122 & 0.117 \\ 0.155 & 0.122 & 0.117 \\ 0.192 & 0.199 & 0.196 \\ 0.192 & 0.199 & 0.196 \end{bmatrix} \tag{34}$$

Step 6: In this important step, the overall fuzzy priorities of the SWOT sub-factors are computed by multiplying the interdependent fuzzy priorities of the SWOT factors obtained in **Step 4**, by the fuzzy local priorities of the SWOT sub-factors achieved in **Step 5**. The computations are provided in Table 9, where the $\tilde{w}_{sub\text{-}factors(global)}$ vector, achieved by the overall priority values of the sub-factors, is found in the last column.

Step 7: After completing the prior steps, the critical degrees of the alternative strategies considering each fuzzy SWOT sub-factors should be obtained. The fuzzy eigenvectors are calculated by investigating these matrices and the $\tilde{W}_4 = (W_4^{Bottom}, W_4^{Medium}, W_4^{Top})$ matrix presented in Table A.1 of the Appendix.

Step 8: In this step, the overall fuzzy priorities of the proposed alternative strategies, representing the interrelationships within the SWOT factors, are obtained as follows:

$$\tilde{w}_{alternatives} = \begin{bmatrix} SO1 \\ SO2 \\ WO1 \\ WO2 \\ ST1 \\ ST2 \\ WT1 \end{bmatrix} = \tilde{W}_4 \times \tilde{w}_{sub\text{-}factors(global)}$$
$$= \begin{bmatrix} 0.257 & 0.312 & 0.123 \\ 0.380 & 0.206 & 0.211 \\ 0.085 & 0.061 & 0.057 \\ 0.272 & 0.264 & 0.286 \\ 0.110 & 0.305 & 0.335 \\ 0.110 & 0.254 & 0.057 \\ 0.256 & 0.346 & 0.111 \end{bmatrix} \tag{35}$$

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

$$\tilde{w}_{alternatives} = \begin{bmatrix} SO1 \\ SO2 \\ WO1 \\ WO2 \\ ST1 \\ ST2 \\ WT1 \end{bmatrix} = \tilde{W}_4 \times \tilde{w}_{sub\text{-}factors(global)} = \begin{bmatrix} 0.191 \\ 0.198 \\ 0.052 \\ 0.122 \\ 0.111 \\ 0.110 \\ 0.137 \end{bmatrix} \tag{36}$$

The results suggest that SO2 is the best strategy with an overall priority value of 0.198. After that, SO1 is the second important strategy. Moreover, WO1 is the least important strategy calculated for the decision maker. The results confirm the applicability of the proposed model and the solving methodologies.

4.4. Utilizing the grey relational approach

The steps involved to employ the grey rational approach to the case at hand are:

Step 1: Assuming that there are no dependencies among the SWOT factors, the pair-wise comparison of the SWOT factors is made using a Grey number (TFN) scale regarding the goal. All pair-wise comparisons in this application are performed by the expert team as prior mentioned. The pair-wise comparison matrix, presented in Table 10, is analysed using the Microsoft Excel software to obtain the following grey eigenvector. Note that the priorities between sub-criteria are illustrated in Fig. 5.

$$w_1 = \begin{bmatrix} S \\ W \\ O \\ T \end{bmatrix} = \begin{bmatrix} 0.250 & 0.370 & 0.370 \\ 0.250 & 0.280 & 0.370 \\ 0.250 & 0.198 & 0.370 \\ 0.250 & 0.152 & 0.370 \end{bmatrix}. \tag{37}$$

Step 2: Inner dependencies among the SWOT factors is calculated by investigating the effect of each factor on every other factor through grey. As mentioned previously, it is not always possible to assume the SWOT factors to be independent. As such more

$$\tilde{W}_2 = \begin{bmatrix} \overset{B}{1.000} & \overset{M}{1.000} & \overset{T}{1.000} & \overset{B}{0.833} & \overset{M}{0.875} & \overset{T}{0.900} & \overset{B}{0.500} & \overset{M}{0.667} & \overset{T}{0.667} & \overset{B}{0.655} & \overset{M}{0.706} & \overset{T}{0.733} \\ 0.115 & 0.087 & 0.072 & 1.000 & 1.000 & 1.000 & 0.000 & 0.000 & 0.000 & 0.158 & 0.118 & 0.106 \\ 0.480 & 0.609 & 0.626 & 0.000 & 0.000 & 0.000 & 1.000 & 1.000 & 1.000 & 0.187 & 0.176 & 0.161 \\ 0.405 & 0.304 & 0.301 & 0.167 & 0.125 & 0.100 & 0.500 & 0.333 & 1.000 & 1.000 & 1.000 & \end{bmatrix} \quad (30)$$

Box I.

Table 5
The inner dependency 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 6
The inner dependency matrix of the SWOT factors with respect to "weaknesses".

Weaknesses (W)	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 7
The inner dependency matrix of the SWOT factors with respect to "opportunities".

Threats (T)	S	W	Relative importance weights		
			Bottom	Medium	Top
Strengths (S)	$\tilde{1}$	$\tilde{3}$	0.500	0.665	0.665
Threats (T)		$\tilde{1}$	0.500	0.335	0.335

Table 8
The inner dependency matrix of the SWOT factors with respect to "threats".

Threats (T)	S	W	O	Relative importance weights		
				Bottom	Medium	Top
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

appropriate and realistic results can likely be obtained by utilizing both SWOT analysis and the ANP technique together. The dependencies among the SWOT factors are achieved through utilizing the analysis of both the internal and external environments of the organization. The pair-wise comparison matrices established for the proposed factors according to their inner dependencies are presented in Tables 11–14.

For the case study at hand, the answer "absolute importance", i.e. a value of 9 in Table 2, is obtained based on the pair-wise comparisons for the question "what is the relative importance of strengths when compared with threats on controlling weaknesses?" The results of the grey approach are shown in the last column of Tables 11–14. Note that the inner dependency matrix of the SWOT factors (W_2) is formed after the relative grey importance weights are computed as Eq. (38) shown in Box II.

Table 9
The fuzzy 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 10
Pair-wise comparisons of SWOT factors without dependencies.

SWOT factors	S	W	O	T	Importance degrees of SWOT factors		
Strengths (S)	[1, 2]	[2, 3]	[3, 4]	[4, 5]	0.250	0.370	0.370
Weaknesses (W)		[2, 3]	[3, 4]	[4, 5]	0.250	0.280	0.280
Opportunities (O)			[3, 4]	[4, 5]	0.250	0.198	0.198
Threats (T)				[4, 5]	0.250	0.152	0.152

$$W_2 = \begin{bmatrix} \overset{B}{1.000} & \overset{M}{1.000} & \overset{T}{1.000} & \overset{B}{0.833} & \overset{M}{0.875} & \overset{T}{0.900} & \overset{B}{0.500} & \overset{M}{0.667} & \overset{T}{0.667} & \overset{B}{0.655} & \overset{M}{0.706} & \overset{T}{0.733} \\ 0.115 & 0.087 & 0.072 & 1.000 & 1.000 & 1.000 & 0.000 & 0.000 & 0.000 & 0.158 & 0.118 & 0.106 \\ 0.480 & 0.609 & 0.626 & 0.000 & 0.000 & 0.000 & 1.000 & 1.000 & 1.000 & 0.187 & 0.176 & 0.161 \\ 0.405 & 0.304 & 0.301 & 0.167 & 0.125 & 0.100 & 0.500 & 0.333 & 1.000 & 1.000 & 1.000 & 1000 \end{bmatrix} \quad (38)$$

Box II.

Table 11
The inner dependency matrix of the SWOT factors with respect to "strengths".

Strengths	W	O	T	Relative importance weights		
				Bottom	Medium	Top
Weaknesses (W)	[1, 3/5]	[1/9, 4]	[1/4, 2]	0.115	0.087	0.072
Opportunities (O)		[1/9, 4]	[1/4, 2]	0.480	0.609	0.626
Threats (T)			[1/4, 2]	0.405	0.304	0.301

Table 12
The inner dependency matrix of the SWOT factors with respect to "weaknesses".

Weaknesses (W)	S	T	Relative importance weights		
			Bottom	Medium	Top
Strengths (S)	[1, 5]	[4, 9]	0.833	0.875	0.900
Threats (T)		[4, 9]	0.167	0.125	0.100

Table 13
The inner dependency matrix of the SWOT factors with respect to "opportunities".

Threats (T)	S	W	Relative importance weights		
			Bottom	Medium	Top
Strengths (S)	[1, 5]	[2, 4]	0.500	0.665	0.665
Threats (T)		[2, 4]	0.500	0.335	0.335

Table 14
The inner dependency matrix of the SWOT factors with respect to "threats" under certainty.

Threats (T)	S	W	O	Relative importance weights		
				Bottom	Medium	Top
Strengths (S)	1	8	5	0.655	0.706	0.733
Weaknesses (W)		1	1/2	0.158	0.118	0.106
Opportunities (O)			1	0.187	0.176	0.161

Step 3: The interdependent grey priorities of the SWOT factors are determined in this step as:

$$w_{factors} = W_2 \times w_1 = \begin{bmatrix} 0.548 & 0.527 & 0.703 \\ 0.951 & 0.500 & 0.322 \\ 0.008 & 0.200 & 0.657 \\ 0.311 & 0.201 & 0.542 \end{bmatrix} \quad (39)$$

Step 4: Using the pair-wise comparison matrix, the local grey priorities of the SWOT sub-factors are calculated as:

$$w_{sub\text{-}factors(\text{strengths})} = \begin{bmatrix} 0.364 & 0.426 & 0.446 \\ 0.192 & 0.227 & 0.222 \\ 0.148 & 0.124 & 0.118 \\ 0.148 & 0.113 & 0.108 \\ 0.148 & 0.111 & 1.106 \end{bmatrix} \quad (40)$$

$$w_{sub\text{-}factors(\text{weakness})} = \begin{bmatrix} 0.113 & 0.075 & 0.071 \\ 0.319 & 0.392 & 0.401 \\ 0.152 & 0.112 & 0.108 \\ 0.190 & 0.170 & 0.167 \\ 0.226 & 0.250 & 0.253 \end{bmatrix} \lim_{x\to\infty} \quad (41)$$

$$w_{sub\text{-}factors(\text{opportunities})} = \begin{bmatrix} 0.306 & 0.358 & 0.373 \\ 0.155 & 0.122 & 0.117 \\ 0.155 & 0.122 & 0.117 \\ 0.192 & 0.199 & 0.196 \\ 0.192 & 0.199 & 0.196 \end{bmatrix} \quad (42)$$

Step 5: In this important step, the overall grey priorities of the SWOT sub-factors are computed by multiplying the interdependent grey priorities of the SWOT factors obtained in **Step 3**, by the grey local priorities of the SWOT sub-factors achieved in **Step 4**. The computations are provided in Table 15, where the $w_{sub\text{-}factors(global)}$ vector, obtained by the overall priority values of the sub-factors, is found in the last column.

Step 6: After completing the prior steps, the critical degrees of the alternative strategies considering each grey SWOT sub-factors should be obtained. The Grey eigenvectors are calculated by investigating these matrices and the $W_4 = [W_a, W_b]$ presented in Table A.2 of the Appendix.

Step 7: In this step, the overall grey priorities of the proposed alternative strategies, representing the interrelationships within the SWOT factors, are obtained as follows:

$$\tilde{w}_{alternatives} = \begin{bmatrix} SO1 \\ SO2 \\ WO1 \\ WO2 \\ ST1 \\ ST2 \\ WT1 \end{bmatrix} = \tilde{W}_4 \times \tilde{w}_{sub\text{-}factors(global)}$$

$$= \begin{bmatrix} 0.257 & 0.312 & 0.123 \\ 0.380 & 0.206 & 0.211 \\ 0.085 & 0.061 & 0.057 \\ 0.272 & 0.264 & 0.286 \\ 0.110 & 0.305 & 0.335 \\ 0.110 & 0.254 & 0.057 \\ 0.256 & 0.346 & 0.111 \end{bmatrix} \quad (43)$$

Step 8: Finally, the overall grey priorities of the proposed alternative strategies are converted to the crisp values as:

$$w_{alternatives} = \begin{bmatrix} \text{SO1} \\ \text{SO2} \\ \text{WO1} \\ \text{WO2} \\ \text{ST1} \\ \text{ST2} \\ \text{WT1} \end{bmatrix} = W_4 \times w_{sub\text{-}factors(global)}$$

$$= \begin{bmatrix} 0.131 \\ 0.132 \\ 0.152 \\ 0.022 \\ 0.101 \\ 0.110 \\ 0.137 \end{bmatrix} \quad (44)$$

Table 15
The grey SWOT sub-factors.

SWOT factors	Priority of the factors	SWOT sub-factors	Priority of the sub-factors	Overall priority of the sub-factors
Strengths	[0.334, 0.473]	(S1)	[0.164, 0.446]	[0.136, 0.193]
		(S2)	[0.192, 0.222]	[0.072, 0.096]
		(S3)	[0.050, 0.118]	[0.050, 0.051]
		(S4)	[0.100, 0.108]	[0.043, 0.047]
		(S5)	[0.102, 0.106]	[0.031, 0.046]
Weakness	[0.149, 0.162]	(W1)	[0.013, 0.071]	[0.008, 0.011]
		(W2)	[0.319, 0.401]	[0.023, 0.065]
		(W3)	[0.102, 0.108]	[0.013, 0.017]
		(W4)	[0.150, 0.167]	[0.010, 0.027]
		(W5)	[0.226, 0.253]	[0.016, 0.041]
Opportunities	[0.208, 0.227]	(O1)	[0.306, 0.373]	[0.064, 0.085]
		(O2)	[0.105, 0.117]	[0.012, 0.027]
		(O3)	[0.102, 0.117]	[0.022, 0.027]
		(O4)	[0.192, 0.196]	[0.040, 0.040]
		(O5)	[0.192, 0.196]	[0.040, 0.045]
Threats	[0.178 , 0.279]	(T1)	[0.306, 0.380]	[0.079, 0.068]
		(T2)	[0.135, 0.224]	[0.040, 0.022]
		(T3)	[0.100, 0.015]	[0.040, 0.026]
		(T4)	[0.192, 0.203]	[0.050, 0.136]
		(T5)	[0.192, 0.203]	[0.050, 0.136]

4.5. Discussion

The grey output is divided into nine membership functions "Lowest", "Lower", "Low", "Low–medium", "Medium", "High Medium", "High", "Higher", and "Highest". After implementing the approaches, it is revealed based on computational results that fuzzy logic is a suitable tool, which is utilized to enhance the decision-making process of the present work. Although there are many approaches to analyse the result obtained by the fuzzy logic approach, a simple and easy approach is used here to improve the performance of the grey relational analysis. It should be mentioned that the MATLAB toolbox is used in this work to obtain the grey-fuzzy output. Besides, the type of the membership function used in this research is triangular, which is generally implemented to solve engineering problems. The results showed that the SO2 strategy with an overall priority of 0.198 was the best. After that, SO1 is the second important strategy. Moreover, WO1 is the least important strategy obtained. In contrast, utilizing the grey relational analysis, WO1 is the second important strategy with an overall priority value of 0.152. After that, WO2 is the second important strategy. This difference is quite rational as the grey approach, based on literature review, is more applicable than the fuzzy logic approach. The comparison of the results between the grey relational grade and the fuzzy logic reasoning for the grey indicate that implementing the grey relational improves the performance slightly as this method is used to reduce the uncertainty involved in the data available to analyse the strategies. In addition, the grey relational coefficient between all comparability sequences and the reference sequence is calculated. If a comparability sequence translated from an alternative has the highest grey relational grade between the reference sequence and itself, then that alternative will be the best. The fuzzy logic is used here to convert linguistic data into the crisp score. At the end, the results confirm the applicability of the proposed models and the solving methodologies.

5. Conclusion

This research has been conducted for the first time in an Iranian ceramic and tile company to investigate the company's export performance based on a grey relational and fuzzy ANP-based SWOT analysis. The benefits of this research include the following:

1. Increasing the level of exports in the tile and ceramic industry
2. Determining the highest amount of investment on valuable, inimitable, and irreplaceable resources of companies.
3. Formulation of a competitive strategy on the basis of the existing potentials in the company and subsequently in the proposed industry.

As SWOT analysis was shown to be an effective approach to investigate and evaluate the strengths, weaknesses, opportunities, and threats involved in various business and industry, it was first weighted by a fuzzy ANP and then a grey relational analysis was utilized to evaluate the strategies. This is due to the inherent uncertainty in the ceramic & tile industries. Note that while some studies utilized the traditional SWOT in a deterministic environment, no

Table A.1
The $\tilde{W}_4$ matrix.

$$W_4^{Bottom} =$$

$$\begin{bmatrix}
0.221 & 0.249 & 0.143 & 0.210 & 0.150 & 0.159 & 0.151 & 0.155 & 0.082 & 0.178 & 0.249 & 0.243 & 0.219 & 0.169 & 0.174 & 0.114 & 0.095 & 0.143 & 0.152 & 0.155 \\
0.202 & 0.249 & 0.186 & 0.176 & 0.093 & 0.111 & 0.151 & 0.155 & 0.082 & 0.134 & 0.249 & 0.135 & 0.219 & 0.229 & 0.262 & 0.114 & 0.095 & 0.143 & 0.219 & 0.249 \\
0.072 & 0.068 & 0.077 & 0.134 & 0.076 & 0.111 & 0.088 & 0.083 & 0.136 & 0.114 & 0.068 & 0.116 & 0.060 & 0.071 & 0.066 & 0.079 & 0.095 & 0.143 & 0.060 & 0.068 \\
0.202 & 0.155 & 0.214 & 0.153 & 0.151 & 0.111 & 0.231 & 0.136 & 0.092 & 0.134 & 0.155 & 0.157 & 0.152 & 0.229 & 0.243 & 0.114 & 0.095 & 0.143 & 0.219 & 0.249 \\
0.102 & 0.093 & 0.053 & 0.102 & 0.081 & 0.090 & 0.151 & 0.117 & 0.236 & 0.093 & 0.093 & 0.116 & 0.152 & 0.136 & 0.092 & 0.270 & 0.095 & 0.143 & 0.098 & 0.093 \\
0.095 & 0.093 & 0.057 & 0.066 & 0.215 & 0.111 & 0.113 & 0.117 & 0.236 & 0.093 & 0.093 & 0.097 & 0.098 & 0.071 & 0.071 & 0.155 & 0.393 & 0.143 & 0.098 & 0.093 \\
0.107 & 0.093 & 0.269 & 0.159 & 0.233 & 0.308 & 0.113 & 0.238 & 0.136 & 0.254 & 0.093 & 0.135 & 0.098 & 0.096 & 0.092 & 0.155 & 0.133 & 0.143 & 0.152 & 0.093
\end{bmatrix}$$

$$W_4^{Medium} =$$

$$\begin{bmatrix}
0.256 & 0.285 & 0.138 & 0.273 & 0.136 & 0.187 & 0.174 & 0.174 & 0.062 & 0.205 & 0.284 & 0.294 & 0.253 & 0.174 & 0.176 & 0.091 & 0.073 & 0.158 & 0.152 & 0.151 \\
0.242 & 0.285 & 0.167 & 0.187 & 0.066 & 0.118 & 0.174 & 0.174 & 0.056 & 0.135 & 0.284 & 0.170 & 0.253 & 0.275 & 0.284 & 0.091 & 0.073 & 0.158 & 0.26 & 0.276 \\
0.047 & 0.046 & 0.062 & 0.102 & 0.069 & 0.085 & 0.060 & 0.052 & 0.147 & 0.093 & 0.044 & 0.084 & 0.044 & 0.048 & 0.052 & 0.053 & 0.073 & 0.158 & 0.043 & 0.050 \\
0.194 & 0.157 & 0.215 & 0.169 & 0.150 & 0.118 & 0.290 & 0.125 & 0.063 & 0.135 & 0.157 & 0.182 & 0.149 & 0.265 & 0.276 & 0.091 & 0.073 & 0.158 & 0.260 & 0.276 \\
0.102 & 0.067 & 0.036 & 0.081 & 0.053 & 0.057 & 0.112 & 0.103 & 0.275 & 0.062 & 0.073 & 0.084 & 0.149 & 0.115 & 0.074 & 0.366 & 0.073 & 0.105 & 0.066 & 0.083 \\
0.083 & 0.093 & 0.059 & 0.049 & 0.258 & 0.085 & 0.083 & 0.078 & 0.275 & 0.062 & 0.079 & 0.061 & 0.068 & 0.054 & 0.057 & 0.154 & 0.474 & 0.105 & 0.066 & 0.083 \\
0.076 & 0.067 & 0.323 & 0.138 & 0.269 & 0.351 & 0.107 & 0.295 & 0.122 & 0.308 & 0.079 & 0.125 & 0.083 & 0.070 & 0.081 & 0.154 & 0.160 & 0.158 & 0.152 & 0.083
\end{bmatrix}$$

$$W_4^{Top} =$$

$$\begin{bmatrix}
0.260 & 0.295 & 0.137 & 0.279 & 0.135 & 0.186 & 0.173 & 0.174 & 0.058 & 0.209 & 0.294 & 0.304 & 0.259 & 0.175 & 0.178 & 0.087 & 0.065 & 0.158 & 0.151 & 0.150 \\
0.247 & 0.295 & 0.169 & 0.189 & 0.062 & 0.113 & 0.173 & 0.174 & 0.052 & 0.133 & 0.294 & 0.168 & 0.259 & 0.285 & 0.292 & 0.087 & 0.065 & 0.158 & 0.266 & 0.287 \\
0.043 & 0.041 & 0.058 & 0.100 & 0.064 & 0.081 & 0.057 & 0.048 & 0.143 & 0.089 & 0.040 & 0.082 & 0.040 & 0.044 & 0.048 & 0.048 & 0.065 & 0.158 & 0.039 & 0.045 \\
0.200 & 0.156 & 0.219 & 0.169 & 0.148 & 0.113 & 0.302 & 0.122 & 0.060 & 0.133 & 0.155 & 0.183 & 0.149 & 0.268 & 0.285 & 0.087 & 0.065 & 0.158 & 0.266 & 0.287 \\
0.099 & 0.063 & 0.032 & 0.078 & 0.049 & 0.053 & 0.113 & 0.099 & 0.283 & 0.059 & 0.068 & 0.082 & 0.149 & 0.112 & 0.069 & 0.385 & 0.065 & 0.105 & 0.063 & 0.077 \\
0.078 & 0.087 & 0.053 & 0.045 & 0.267 & 0.081 & 0.080 & 0.075 & 0.283 & 0.059 & 0.074 & 0.058 & 0.065 & 0.050 & 0.053 & 0.153 & 0.523 & 0.105 & 0.063 & 0.077 \\
0.073 & 0.063 & 0.332 & 0.138 & 0.275 & 0.375 & 0.103 & 0.307 & 0.121 & 0.316 & 0.074 & 0.123 & 0.079 & 0.066 & 0.075 & 0.153 & 0.150 & 0.158 & 0.151 & 0.077
\end{bmatrix}$$

Table A.2
The W_a and W_b represented as $[W_a, W_b]$.

$W_a =$

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	0.060	0.071	0.066	0.079	0.095	0.143	0.060	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
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

$W_b =$

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	0.080	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

discussion took into account the inherent uncertainty of real-world situations.

To address the drawback involved in the application of the classical SWOT analysis, this research attempted to enhance it with fuzzy logic as well as to associate it with a multi-criteria decision-making technique. The aims were to (1) propose an analytical basis to determine the factor ranking in SWOT analysis using ANP that addresses the potential dependencies among the factors using a multi-criteria decision making method, and (2) to consider the inherent uncertainty of the human decision making processes by introducing the fuzzy logic and the Grey relational analysis. The proposed methodology can also be named SWOT fuzzy ANP, which was performed and validated in a demonstrated case study of the ceramic and tile industry of Iran (Ceramara Industrial Co.). The results confirmed the applicability of the proposed model and the solving methodologies taken to solve the problem by showing the most and the least important strategies. The results showed that the SO2 strategy with an overall priority of 0.198 was the best. After that, SO1 is the second important strategy. Moreover, WO1 is the least important strategy obtained.

The industrial application of this study provides additional opportunities in identifying critical factors and strategies in industrial companies. It also offers cost effectiveness for companies that operate in industrial environments under uncertainty.

Acknowledgements

The authors would like to acknowledge the efforts and the consideration of the editor and all reviewers for their valuable comments and suggestions to improve the quality of the paper.

Appendix

See Tables A.1 and A.2.

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