RANKING THE STRATEGIES OF MINING SECTOR THROUGH ANP AND TOPSIS IN A SWOT FRAMEWORK

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Abstract. Mining plays one significant role in most countries and it acts as a foundation for growth and development. It produces raw material for other sectors such as industry, agriculture, etc. So, determining and prioritizing the strategies of mining are so important. Miscellaneous types of tools are offered for determining and evaluating of operational strategies. Analyzing the internal and external environments using strengths, weaknesses, opportunities, and threats (SWOT) helps to determine the current situation and to identify major prospects and challenges that could significantly impact strategy implementation in mining sector. Multi criteria decision making (MCDM) methods are appropriate tools to prioritize under sophisticated environment. Analytical network process (ANP) and TOPSIS are two hands of MCDM methods that are used in different researches. In this paper, we proposed an integrated model for prioritizing the strategies of Iranian mining sector. We employed the SWOT analysis to assign feasible strategies; then, ANP was applied in order to obtain the weight of SWOT factors, finally the strategies were ranked through TOPSIS technique. The results show that improving the ability of exploitation and production outperforms other strategies.

Keywords: SWOT, MCDM, ANP, TOPSIS, mining strategies, ranking.

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1. Introduction

Organizations today deal with unprecedented challenges and opportunities in carrying out their vital mission. Managers always look for comprehensive picture of present situation of the organization and a clear understanding of its future organization. For this reason, they need background information of strengths, weaknesses, opportunities,

and threats (SWOT) situation of the organization in order to invest the challenges and prospects of adopting organization. SWOT analysis is an effective framework for an organization (or a company) that helps to address the effectiveness of a project planning and implementation (Taleai *et al.* 2009; Podvezko 2009; Podvezko *et al.* 2010; Diskiene *et al.* 2008). SWOT analysis is used in different sectors such as maritime transportation industry (Kandakoglu *et al.* 2009; Ghazinoory, Kheirkhah 2008; Kheirkhah *et al.* 2009; Maskeliunaite *et al.* 2009), technology development (Ghazinoory *et al.* 2009, 2011), device design (Wu *et al.* 2009), food microbiology (Ferrer *et al.* 2009), Hazard Analysis Critical Control Point (Sarter *et al.* 2010), Environmental Impact Assessment (Paliwal 2006; Medineckiene *et al.* 2010), tourism management (Kajanus *et al.* 2004).

However, the factors that can affect the SWOT are complex and often conflicting. One way to overcome the problem of evaluation performance with regard to various factors is the use of multiple criteria decision making (MCDM). The assumption of independence of criteria is not always correct because in real world the criteria are often dependent with each other. Analytical network process (ANP) is an appropriate tool in order to model complex problems with all kinds of relationship, dependency and feedback in the model and draws a systematical figure of the decision making problem. Likewise, TOPSIS technique is a suitable tool to evaluate alternatives.

In this paper, we applied the SWOT analysis and two multi-attribute evaluation methods that are called the analytic network process (ANP) and TOPSIS techniques to rank the strategies of Iranian mining sector. Iranian mining sector has a critical role in Iran's economy. This sector had exports reaching $8.13 billion in 2009–2010, accounting for about 32 percent of the country's non-oil exports[1]. This level of export of minerals marked 45 percent of total exports in the industrial and mine sector. Based on the fifth development plan, this sector should represent about 1.6% of GDP (Gross Domestic Product). For achieving the aim, it is necessary to suitable strategies be determined and their priorities in order implement should be evaluated.

The remainder of this paper is organized as follows. The SWOT analysis is explained in section 2. Then in Section 3, ANP method is introduced. TOPSIS technique is defined in section 4. In section 5, we define probable mining strategies in Iran. The evaluation of mining strategies and the steps of proposed method are summarized in section 6. And finally section 7 concludes the paper.

2. The SWOT analysis

The SWOT analysis has its origins in the 1960s (Kandakoglu *et al.* 2009). It is an environmental analysis tool that integrates the internal strengths/weaknesses and external opportunities/threats.

This method is implemented in order to identify the key internal and external factors that are important to the objectives that the organization wishes to achieve (Houben

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et al. 1999). The internal and external factors are known as strategic factors and are categorized via the SWOT analysis. Based on the SWOT analysis, strategies are developed which may build on the strengths, eliminate the weaknesses, exploit the opportunities, or counter the threats (Kandakoglu *et al.* 2009).

SWOT maximizes strengths and opportunities, and minimizes threats and weaknesses (Amin *et al.* 2011), and transforms the identified weaknesses into strengths in order to take advantage of opportunities along with minimizing both internal weaknesses and external threats. SWOT can provide a good basis for successful strategy formulation (Chang, Huang 2006).

According to the capability and efficiency of the SWOT analysis, this technique is applied to different aspects of strategic management. Nikolaou and Evangelinos (2010) employed SWOT analysis for environmental management practices in Greek Mining and Mineral Industry, their stated policy recommendations both for the government and industry which, if adopted, could facilitate improved environmental performance. Chang and Huang (2006) used SWOT analysis to assess the competing strength of each port in East Asia and then suggest an adoptable competing strategy for each. Stewart *et al.* (2002) employed SWOT analysis in order to present a strategic implementation framework for IT/IS projects in construction. Terrados *et al.* (2007) developed regional energy planning through SWOT analysis and strategic planning tools, they proved that SWOT analysis is an effective tool and has constituted a suitable baseline to diagnose current problems and to sketch future action lines.

Quezada *et al.* (2009) used a modified SWOT analysis in order to identify strategic objectives in strategy maps. Zaerpour *et al.* (2008) proposed a novel hybrid approach consisting of SWOT analysis and analytic hierarchy process. Misra and Murthy (2011) developed a SWOT analysis of Jatropa with specific reference to Indian conditions and found that Jatropa indeed is a plant which can make the Indian dream of self-sufficiency in energy-a reality. Chang *et al.* (2002) applied SWOT analysis in order to forecast the development trends in Taiwan's machinery industry. Wang and Hong (2011) proposed a novel approach to strategy formulation, which employs the theory of competitive advantage of nations (a revised diamond model), SWOT analysis and strategy matching using the TOWS matrix and competitive benchmarking. Leskinen *et al.* (2006) used SWOT analyses to form the basis for further operations that were applied in the strategy process of the forest research station. Halla (2007) employed SWOT analysis for planning strategic urban development. Taleai *et al.* (2009) proposed a combined method based on the SWOT and analytic hierarchy process (AHP) in order to investigate the challenges and prospects of adopting geographic information systems (GIS) in developing countries. Leung *et al.* (2011) developed a SWOT dimensional analysis technique which is able to integrate the strengths and weaknesses of overseas real estate developers and also the opportunities and threats found in the market for formulating their strategic plans and market positions.

3. Analytical network process (ANP)

Analytical hierarchy process (AHP) was introduced by Saaty (1980) that is a mathematical technique for multi-criteria decision making. This technique is based on pairwise comparison matrix.

ANP is the general form of the analytic hierarchy process (AHP), which is introduced by Saaty (1996) in order to solve problems involving interaction and feedback among criteria or alternative solutions. This method is able to consider network structures because many real world problems cannot be structured hierarchically. ANP is a general tool that is helpful in assisting the mind to organize its thoughts and experiences and to elicit judgments recorded in memory and quantify them in the form of priorities (Saaty, Vargas 2006). This method is applied to multi-criteria decision making (MCDM) in order to release the restriction of hierarchical structure.

Fig. 1 illustrates the difference between hierarchy and network structures. As shown in Fig. 1, a hierarchy is a linear top down structure and network is a non-linear structure that spreads out in all directions.

ANP can be described in the following steps (Chung *et al.* 2005):

Step 1: Model construction and problem structuring: The derivation of the weights for all n components C_n regarding the dependencies in relevance to an overall criterion, which can be elicited based on expert knowledge.

Step 2: Pair-wise comparison matrices and priority vectors: decision elements at each component are compared Pair-wise with respect to their importance towards their control criterion, and the components themselves are also compared pair-wise with respect to their contribution to the goal. The relative importance values are determined by using the Saaty's (Saaty 1980) 1–9 scale (Table 1).

Step 3: Supermatrix formation: the concept of supermatrix is similar to the Markov chain process that Saaty has developed it to synthesize ratio scales (Saaty 1996). Let the components (clusters) of a decision system be C_h, $h = 1, \ldots n$, and let each component h have m_h elements, denoted by $e_{h1}, e_{h2}, \ldots, e_{hmn}$. The influence of a set of elements belonging to a component, on any element from another component, can be represented as a priority vector by applying pair-wise comparisons in the same way as the AHP.
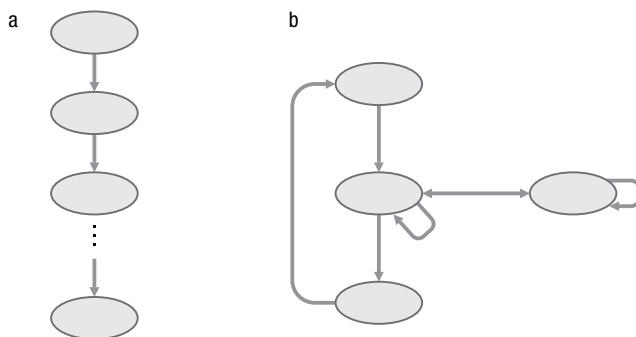

Fig. 1. The difference between a hierarchy (a) and a network (b)

Table 1. Pair-wise comparison scale (Saaty 1980)

Option	Numerical value(s)
Equal	1
Marginally strong	3
Strong	5
Very strong	7
Extremely strong	9
Intermediate values to reflect fuzzy inputs	2, 4, 6, 8
Reflecting dominance of second alternative compared with the first	reciprocals

These priority vectors are grouped and located in appropriate positions in a supermatrix based on the flow of influence from a component to another component, or from a component to itself as in the loop. A standard form of a supermatrix is as follows (Liou *et al.* 2007).

$$
W = \begin{array}{c} \\ c_1 \\ \\ \\ c_2 \\ \\ \\ \\ c_N \\ \\ \end{array}
\begin{array}{c}
e_{11} \\ e_{12} \\ \vdots \\ e_{1n_1} \\ e_{21} \\ e_{22} \\ \vdots \\ e_{2n_2} \\ e_{N1} \\ e_{N2} \\ \vdots \\ e_{Nn_N}
\end{array}
\left[
\begin{array}{ccc}
W_{11} & W_{12} & W_{1N} \\
\vdots & \vdots & \vdots \\
W_{21} & W_{22} & W_{2N} \\
\vdots & \vdots & \vdots \\
W_{N1} & W_{N2} & W_{NN}
\end{array}
\right] .
$$

Where W_{ij} is the principal eigenvector of the influence of the elements compared in the *j*th component to the *i*th component. In addition, if the *j*th component has no influence to the *j*th component, then $W_{ij} = 0$. The form of the supermatrix relies on the variety of its structure. For instance, if assume there are two cases involve four components with different structures as shown in Fig. 2. Based on Fig. 2, the supermatrix can be formed as:

$$
w_a = \begin{array}{c} C_1 \\ C_2 \\ C_3 \\ C_4 \end{array}
\begin{pmatrix}
0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 \\
1 & 0 & 1 & 1 \\
1 & 1 & 0 & 0
\end{pmatrix}
, \quad
w_b = \begin{array}{c} C_1 \\ C_2 \\ C_3 \\ C_4 \end{array}
\begin{pmatrix}
0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 \\
1 & 0 & 0 & 0
\end{pmatrix}
$$

The eigenvector for each column component, is multiplied by all the elements from the first component to the last component of that column. In this way, the component in each column of the supermatrix is weighted. The weighted supermatrix should be raised to the power of 2k + 1 (k is an arbitrarily large number) in order to converge the importance weights (Saaty 1996), because raising a matrix to exponential powers gives the long-term relative influences of the elements on each other.
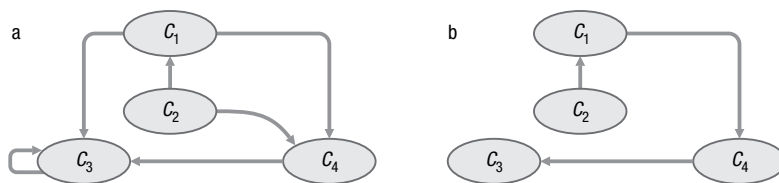
Fig. 2. Structures of two cases

Step 4. Selection of the best alternatives: If supermatrix only includes components that are interrelated, additional calculations must be made to obtain the overall priorities of the alternatives. The alternative with the largest weight should be selected, as it is the best alternative as determined by the calculations made using matrix operations.

4. TOPSIS approach

TOPSIS approach was developed by Hwang and Yoon (1981). This approach is used when the user prefers a simpler weighting approach. TOPSIS technique is based on the concepts that the chosen alternative should have the shortest distance from the ideal solution, and the farthest from the negative ideal solution. The usual TOPSIS approach has been applied for ranking construction and development alternative solutions since 1986 (Zavadskas 1986; Kalibatas *et al.* 2011; Tupenaite *et al.* 2010; Zavadskas *et al.* 1994, 2010; Jakimavicius, Burinskiene 2009; Liaudanskiene *et al.* 2009; Kucas 2010). Evaluation of ranking accuracy of TOPSIS was performed by Zavadskas *et al.* (2006). Modified method applying Mahalanobis distance was proposed by Antucheviciene *et al.* (2010). TOPSIS is defined as follows (Opricovic, Tzeng 2004):

Step 1: Normalize the decision matrix. The normalized value (r_{ij}) is calculated as:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{J} f_{ij}^2}}, \quad j = 1, 2, ..., J; \quad i = 1, 2, ..., n. \tag{1}$$

Step 2: Multiply the columns of the normalized decision matrix by the associated weights to generate the weighted normalized decision matrix. The weighted normalized value (v_{ij}) is calculated as:

$$v_{ij} = w_i r_{ij}, \quad j = 1, 2, ..., J; \quad i = 1, 2, ..., n, \tag{2}$$

where w_i is the weight of the *i*th criterion, and

$$\sum_{i=1}^{n} w_i = 1. \tag{3}$$

Step 3: Determine the ideal and negative-ideal solutions through Eqs. (4) and (5).

$$A^* = \{v_1^*, ..., v_n^*\} = \{(\max_j v_{ij} \mid i \in I'), (\min_j v_{ij} \mid i \in I'')\}, \tag{4}$$

$$A^- = \{v_1^-, ..., v_n^-\} = \{(\min_j v_{ij} \mid i \in I'), (\max_j v_{ij} \mid i \in I'')\}. \tag{5}$$

Where I' is associated with benefit criteria, and I'' is associated with cost criteria.

Step 4: Measure distances from positive and negative ideal solutions using the n-dimensional Euclidean distance. The distance from positive ideal solution is:

$$D_j^* = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^-)^2}, \ j = 1, 2, ..., J.$$ (6)

Similarly, the distance from negative ideal solution is:

$$D_j^- = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^-)^2}, \ j = 1, 2, ..., J.$$ (7)

Step 5: Calculate the relative closeness to the ideal solution. The relative closeness of alternative A_j with respect to A^* is defined as:

$$C_j^* = \frac{D_j^-}{(D_j^- + D_j^*)}, j = 1, 2, ..., J.$$ (8)

Step 6: Rank the preference order.

5. Case study

Mining is one of the most activities so that other activities such as manufacturing, construction, and agriculture, could not exist without raw mineral production. Mining plays a leading social-economic role in Iran. At its various stages – from exploration to production and selling – it generates a significant number of jobs and income for the country. Due to the rising demand for raw minerals by the industrial countries and most rapidly growing economies, mining is becoming increasingly important.

Iran is a country located in the Middle East with a non-federated governmental system. Iran is divided into thirty provinces.

Iran is one of the most important mineral producers in the world, ranked among 15 major mineral rich countries, 37 billion tons of proven reserves and more than 57 billion tons of potential reservoirs. Iran has one of the world's largest zinc reserves and second-largest reserves of copper. It also has significant reserves of iron, uranium, lead, chromium, manganese, coal and gold.

According to the importance of mining sector, at the end of Iran's fifth development plan, Iran should produce 31492.5, 480813.4, 3420, 110, 155, 360, 361, and 771 tons of crude steel, iron concentration, coal concentration, cement, building stone, zinc, copper (Cathode), and aluminum, respectively. For this reason, Iran's ministry of industries and mines should assign the feasible strategies and ranks the extracted strategies.

6. The implementation of proposed model

The proposed model of this paper uses an integrated method of the SWOT analysis, ANP, and TOPSIS to provide a framework for ranking the Iranian mining strategies. In order to implement the model, three stages are proposed: (1) the SWOT analysis of the Iranian mining sector is discussed and feasible strategies are determined, (2) then the

ANP approach is applied to obtain the weight of the SWOT factors, and (3) finally, the TOPSIS technique ranks the Iranian mining strategies.

In the first stage, the possible strategies are determined by decision-making team in a framework of the SWOT analysis. In the second stage, the importance weights of main and sub-criteria are determined by decision-making team from high level managers in the template of the AHP questionnaire. The decision making team contains of twelve experts with high degree of knowledge in the field of management and mining. In this phase, the weights of criteria are obtained by pairwise comparison matrixes constructed by decision-making team through asking which is more important based on the scale provided in Table 1. The values obtained from individual evaluations are converted into final pairwise comparison matrix in order to find a consensus on weight of main and sub-criteria. In the last stage, strategies are ranked in descending order by TOPSIS method. In the first step of this phase, experts were asked to provide a set of crisp values within a range from 1 to 10 that represents the performance of each mining strategy with respect to each evaluation criteria. After forming decision making matrix, the computations of TOPSIS method is accomplished. In the last step of this stage, ranking of alternatives is carried out in descending order and the optimal strategy is selected. Schematic diagram of the proposed model for ranking the strategies is provided in Fig. 3.

The data of the SWOT analysis are based on the aggregate mining strategy reports of the ministry of industries and mines. The term 'strengths' contains advantages and benefits from the adoption of strategic management practices. In order to help the explorations of strengths, some typical questions should be answered such as what the benefits of such practices are, what strategic management practices can do well. Similarly, weaknesses would encompass agents and parameters that are difficulties in the efforts of companies to accept any strategic management practices. Some important questions could be what is not done appropriately, what should be better and what should be avoided.
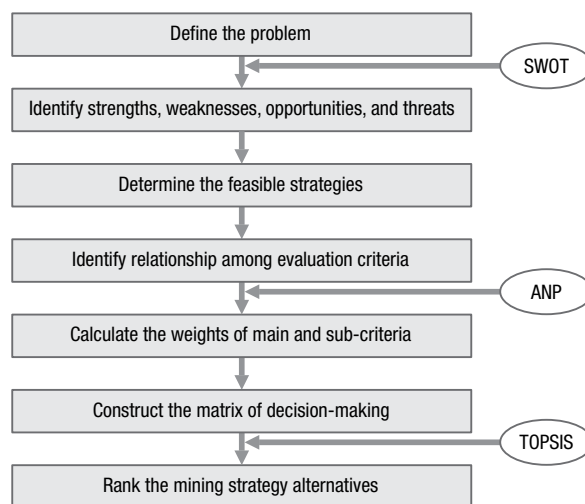

Fig. 3. Schematic diagram of the proposed model

Moreover, opportunities may include external benefits for companies from the acceptance of strategic management practices. Some relevant questions are what future benefits may take place for companies, what competitive advantages companies will gain and what changes may occur in consumer demands. Finally, threats may encompass future problems and difficulties from the prevention of implementing any strategic management practices. The basic parameters of the SWOT analyses are fall into two categories: external and internal. External category contains strengths and opportunities and internal category encompasses weaknesses and threats.

We prepared a list of strengths, weaknesses, opportunities, and threats, and then had an interview with the experts in mining strategies of Iran to modify the list. The results of the SWOT analysis based on expert knowledge are presented in Table 2.

As shown in Table 2, six strategies are earned from the SWOT analysis. These strategies in order to implement should be ranked because of the lack of finance and time as two limitations. For this reason, we applied the ANP technique and the TOPSIS approach in order to obtain the weight of SWOT factors and prioritize strategies respectively.

The proposed model is defined as follows:

Step1: The hierarchy and network model proposed in this study for SWOT analysis is composed of four levels, as shown in Fig. 4. The goal (best strategy) is indicated in the first level, the criteria (SWOT factors) and subcriteria (SWOT sub-factors) are found in the second and third levels respectively, and the last level is composed of the alternatives (alternative strategies).

Table 2. SWOT analysis and strategic recommendations

|	SWOT analysis		Mining strategies
Internal	Strengths: S1. High potential of ore deposits, S2. Large mining resources, S3. Miscellaneous minerals		A1. Improving the ability of exploitation and production: this strategy is obtained according to S1, S2, O1, O2, O3.
	Weakness: W1. The lack of a completed mining database W2. Long period from exploration to manufacturing, W3. Low efficiency in mining activities		A2. Investment in exploration sector: this strategy is resulted by O3, O4, W1, W2. A3. Investing in the earth sciences (information, technology, and labor force): this strategy is extracted from W1, W3, T1, T3.
External	Opportunities: O1. Cheap Labor force, O2. Access to energy resource, O3. The geopolitical situation of Iran, O4. Increasing demand for raw materials		A4. Making persuasive policies to attract mining investors and promotion of R&D: this strategy is obtained through S1, S2, S3, T1, T2, T4. A5. The privatization of mines and mineral industries: this strategy is resulted by O4, O3, W2, W3.
	Threats: T1. Exporting raw material, T2. Non-membership of Iran in WTO, T3. High risk involved, T4. The fluctuations of raw mineral prices		A6. Revising the mining law and cadastral system: this strategy is extracted by T1, T2, T3, S2.
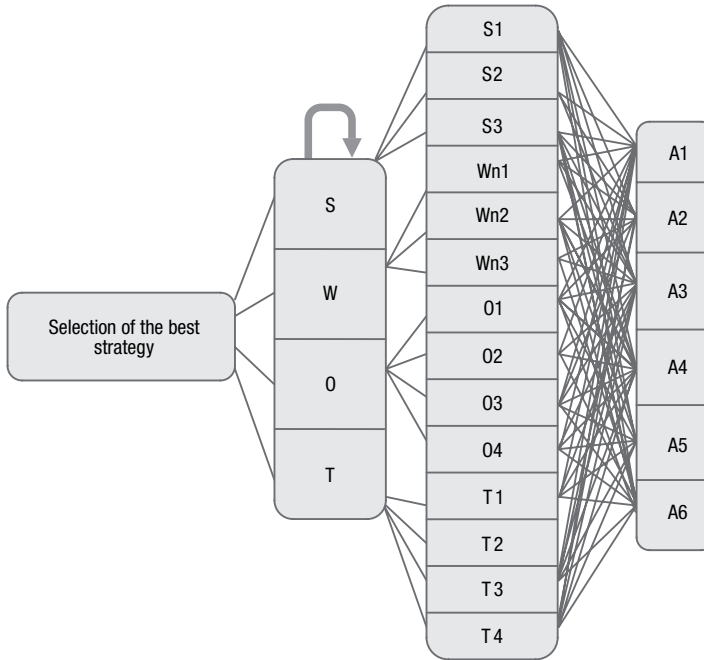
Fig. 4. The hierarchy and network structure

The supermatrix of a SWOT hierarchy with four levels is as follows:

$$w = \begin{matrix} \text{Goal} \\ \text{SWOT factors} \\ \text{SWOT sub-factors} \\ \text{Alternatives} \end{matrix} \begin{pmatrix} 0 & 0 & 0 & 0 \\ w_1 & W_2 & 0 & 0 \\ 0 & W_3 & 0 & 0 \\ 0 & 0 & W_4 & I \end{pmatrix}.$$

Step 2: Assuming that there is no dependence among the SWOT factors, pairwise comparison of the SWOT factors using a 1–9 scale is made with respect to the goal. The importance weights of the criteria determined by twelve decision-makers that are obtained through Eq. (9) are shown in Table 3. The group consistency ratio (GCR) (Escobar *et al.* 2004) is available in the last row of the matrix.

$$x_{ij} = (\prod_{k=1}^{k} x_{ij}^k)^{1/k}, \tag{9}$$

where x_{ij} is the crisp weight of each criterion that are determined by all experts, k is the number of experts (here, k is equal to 12).

Step 3: Inner dependence among the SWOT factors is extracted by analyzing the impact of each factor on every other factor using pairwise comparisons. As mentioned, existence of dependence among factors can be modeled through the ANP approach. Based on the SWOT analysis, the dependences among the SWOT factors are determined that are shown schematically in Fig. 5.

Table 3. Pairwise comparison of SWOT factors with assumption of independence

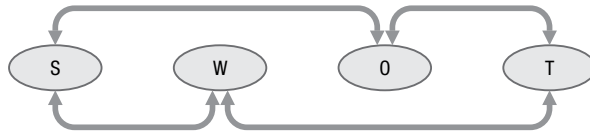| SWOT factors	S	W	O	T	Relative importance of SWOT factors
S	1	2.37	3.76	3.22	0.49
W	0.42	1	1.25	1.87	0.21
O	0.26	0.8	1	0.69	0.13
T	0.31	0.53	1.45	1	0.15
GCR = 0.014					

Fig. 5. Inner dependence among SWOT factors

With respect to the inner dependencies shown in Fig. 5, pairwise comparison matrices are formed for the SWOT factors as presented in Tables 4, 5, 6 and 7 using Eq. (9). Based on the computed relative importance weights, the inner dependence matrix of the SWOT factors (W_2) is generated. As each factor of the SWOT is affected by two other factors, so that; S factor is affected by W and O factors, W factor is affected by S and T factors, O factor is affected by T and S factors, T factor is affected by W and O factors.

Table 4. The inner dependence matrix with respect to "S"

S	W	O	Relative importance weights
W	1	1.63	0.62
O	0.61	1	0.38
GCR = 0.0			

Table 5. The inner dependence matrix with respect to "W"

W	S	T	Relative importance weights
S	1	2.59	0.72
T	0.38	1	0.28
GCR = 0			

Table 6. The inner dependence matrix with respect to "O"

O	T	S	Relative importance weights
T	1	0.29	0.77
S	3.36	1	0.23
GCR = 0			

Table 7. The inner dependence matrix with respect to "T"

T	W	O	Relative importance weights
W	1	1.27	0.56
O	0.61	1	0.44
GCR = 0			

$$
W_2 = \begin{pmatrix} 1 & 0.72 & 0.77 & 0 \\ 0.62 & 1 & 0 & 0.56 \\ 0.38 & 0 & 1 & 0.44 \\ 0 & 0.28 & 0.23 & 1 \end{pmatrix}.
$$

Step 4: The interdependent weights of the SWOT factors are calculated by Eq. (10) (Yüksel, Dağdeviren 2007) as follows:

$$
w_{factors} = W_2 \times w_1,
$$

$$
w_{factors} = W_2 \times w_1 = \begin{pmatrix} 1 & 0.72 & 0.77 & 0 \\ 0.62 & 1 & 0 & 0.56 \\ 0.38 & 0 & 1 & 0.44 \\ 0 & 0.28 & 0.23 & 1 \end{pmatrix} \times \begin{bmatrix} 0.49 \\ 0.21 \\ 0.13 \\ 0.15 \end{bmatrix} = \begin{bmatrix} 0.38 \\ 0.30 \\ 0.19 \\ 0.13 \end{bmatrix}. \tag{10}
$$

The results change from 0.49 to 0.38, 0.21 to 0.3, 0.13 to 0.19, and 0.15 to 0.13 for the priority values of factors S, W, O and T, respectively. As observed in the results obtained for the factor weights are different significantly.

Step 5: The local weights of the SWOT sub-factors are calculated using the pairwise comparison matrix. The pairwise comparison matrices, which are weighted by twelve experts and then are calculated by Eq. (9), are presented in Table 8.

Table 8. Pairwise comparison matrices for SWOT sub-factors local weights

S	S1	S2	S3		Local weights
S1	1.00	0.56	3.21		0.331309
S2	1.79	1.00	4.86		0.55957
S3	0.31	0.21	1.00		0.109121
GCR = 0.0017					
W	Wn1	Wn2	Wn3		
Wn1	1.00	0.43	0.34		0.158972
Wn2	2.33	1.00	0.71		0.356581
Wn3	2.94	1.41	1.00		0.484446
GCR = 0.0007					
O	O1	O2	O3	O4	
O1	1.00	1.12	0.39	0.58	0.176427
O2	0.89	1.00	0.91	2.23	0.289132
O3	2.56	1.10	1.00	0.97	0.304467
O4	1.72	0.45	1.03	1.00	0.229975
GCR = 0.073					
T	T1	T2	T3	T4	
T1	1.00	0.66	0.35	1.17	0.179075
T2	1.52	1.00	0.47	0.87	0.204373
T3	2.86	2.13	1.00	0.54	0.32839
T4	0.85	1.15	1.85	1.00	0.288162
GCR = 0.097					

Step 6: The overall weights of the SWOT sub-factors are calculated by multiplying the interdependent weights of SWOT factors obtained in Step 4 with the local weights of SWOT sub-factors found in Step 5. The computations of $w_{\text{sub-factors (global)}}$ vector are provided below. The rank of global sub-factors is shown in Fig. 6.

$$w_{sub-factors(global)} = \begin{bmatrix} 0.126 \\ 0.212 \\ 0.041 \\ 0.047 \\ 0.107 \\ 0.145 \\ 0.033 \\ 0.055 \\ 0.057 \\ 0.043 \\ 0.023 \\ 0.026 \\ 0.042 \\ 0.037 \end{bmatrix}.$$
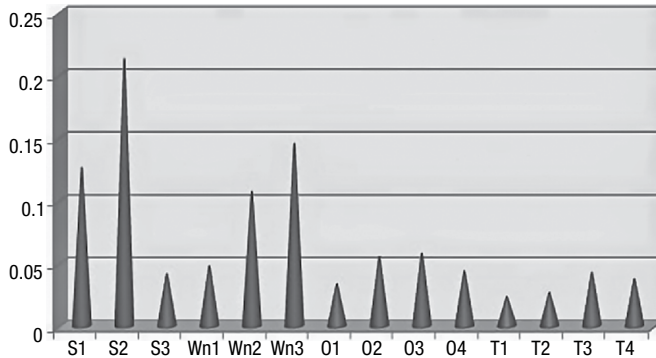
Fig. 6. Ranking of sub-factors

Step 7: At this step of the proposed model, the team members were asked to establish the decision matrix by comparing alternatives under each of the SWOT sub-factors, a sample of decision matrix is presented in Table 9. Based on the responses of twelve experts, and using Eq. (9) the obtained results are as shown in Table 10.

Step 8: After forming the decision matrix, the normalized decision matrix is established with Eq. (1) as depicted in Table 11. Then, by multiplying the result of normalized decision matrix and obtained weighted for sub-factors in step 6, the weighted decision matrix is calculated as shown in Table 12. According to S1, S2, S3, O1, O2, O3, and O4

criteria are benefit criteria, and Wn1, Wn2, Wn3, T1, T2, T3, and T4 are cost criteria, the positive ideal and negative ideal solutions are defined by Eqs. (4), (5) as presented in two last rows of Table 12.

Table 9. A sample of decision matrix

	S1	S2	S3	Wn1	Wn2	Wn3	O1	O2	O3	O4	T1	T2	T3	T4
A1	4	8	3	2	3	2	6	7	4	6	6	6	4	3
A2	5	4	2	8	4	3	3	4	5	5	5	7	9	2
A3	4	4	5	8	3	4	5	5	5	5	5	5	6	4
A4	5	3	4	6	4	5	6	4	6	6	6	4	5	3
A5	5	5	5	4	3	1	7	5	5	8	5	5	7	2
A6	6	5	4	5	2	2	5	5	3	5	7	1	6	5

Table 10. Important rating of each alternative

	S1	S2	S3	Wn1	Wn2	Wn3	O1	O2	O3	O4	T1	T2	T3	T4
A1	5.21	7.56	3.43	2.21	3.37	1.67	6.13	7.79	5.24	6.56	6.46	4.93	4.21	3.19
A2	6.11	5.23	2.18	8.14	4.56	3.32	2.27	4.15	5.76	6.33	4.09	6.78	8.47	1.83
A3	5.73	3.67	5.26	7.43	4.12	4.21	4.16	4.77	4.33	5.89	6.24	4.43	6.31	4.15
A4	5.09	3.16	3.78	6.57	5.23	6.42	6.68	3.24	5.67	5.12	6.92	3.25	3.56	3.26
A5	4.13	6.2	4.97	4.31	2.69	1.62	8.06	5.86	5.23	8.47	5.13	5.14	7.49	2.16
A6	5.89	5.14	4.29	4.74	2.34	2.31	4.19	4.89	3.41	5.11	7.65	1.87	6.23	5.57

Table 11. the normalized decision matrix

	S1	S2	S3	Wn1	Wn2	Wn3	O1	O2	O3	O4	T1	T2	T3	T4
A1	0.394	0.575	0.340	0.152	0.357	0.186	0.448	0.599	0.427	0.422	0.426	0.432	0.274	0.363
A2	0.462	0.398	0.216	0.561	0.483	0.370	0.166	0.319	0.469	0.407	0.270	0.594	0.550	0.208
A3	0.433	0.279	0.522	0.512	0.436	0.469	0.304	0.366	0.353	0.379	0.411	0.388	0.410	0.473
A4	0.385	0.240	0.375	0.453	0.554	0.715	0.488	0.249	0.462	0.329	0.456	0.285	0.231	0.371
A5	0.312	0.472	0.493	0.297	0.285	0.180	0.589	0.450	0.426	0.545	0.338	0.450	0.487	0.246
A6	0.445	0.391	0.426	0.327	0.248	0.257	0.306	0.376	0.278	0.329	0.504	0.164	0.405	0.634

Table 12. The weighted decision matrix

	S1	S2	S3	Wn1	Wn2	Wn3	O1	O2	O3	O4	T1	T2	T3	T4
A1	0.05	0.12	0.01	0.01	0.04	0.03	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.01
A2	0.06	0.08	0.01	0.03	0.05	0.05	0.01	0.02	0.03	0.02	0.01	0.02	0.02	0.01
A3	0.05	0.06	0.02	0.02	0.05	0.07	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.02
A4	0.05	0.05	0.02	0.02	0.06	0.10	0.02	0.01	0.03	0.01	0.01	0.01	0.01	0.01
A5	0.04	0.10	0.02	0.01	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.01
A6	0.06	0.08	0.02	0.02	0.03	0.04	0.01	0.02	0.02	0.01	0.01	0.00	0.02	0.02
A⁻	0.04	0.05	0.01	0.05	0.11	0.15	0.01	0.01	0.02	0.01	0.02	0.03	0.04	0.04
A*	0.06	0.12	0.02	0.01	0.03	0.03	0.02	0.03	0.03	0.02	0.01	0.00	0.01	0.01

Step 9: The distance of each alternative from D^* and D^- can be currently calculated using Eq. (6) and (7). Finally, TOPSIS solves the similarities to an ideal solution by Eq. (8). In order to perceive what has been mentioned an example is presented as follows:

$$D_1^* = \sqrt{(0.05-0.06)^2 + (0.12-0.12)^2 + ... + (0.01-0.01)^2 + (0.01-0.01)^2} = 0.0217,$$

$$D_1^- = \sqrt{(0.05-0.04)^2 + (0.12-0.05)^2 + ... + (0.01-0.04)^2 + (0.01-0.04)^2} = 0.1674.$$

As a result,

$$CC_1 = \frac{D_1^-}{D_1^* + D_1^-} = \frac{0.0217}{0.1674 + 0.0217} = 0.0499.$$

Similar calculations are done for the other alternatives and the results of TOPSIS analyses are summarized in Table 13. According to Cj values, the ranking of the alternatives in descending order are A1, A5, A6, A2, A3 and A4. Proposed model results indicate that A1 is the best alternative with CC value of 0.855. The rank of alternatives is presented schematically in Fig. 7.

Table 13. Closeness coefficients and ranking of alternatives

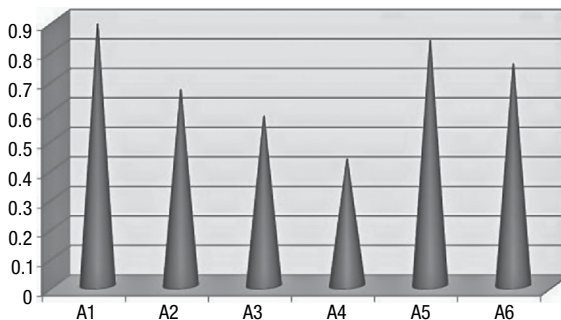| Alternatives	D_j^*	D_j^-	C_j	Rank
A1	0.021737	0.167484	0.885123	1
A2	0.06259	0.123179	0.663078	4
A3	0.082423	0.110303	0.572331	5
A4	0.113525	0.084794	0.427564	6
A5	0.033317	0.161037	0.828573	2
A6	0.0497	0.148577	0.749339	3

Fig. 7. Ranking of alternatives

7. Conclusions

In this study, we applied an integrated model of the SWOT analysis and ANP approach and TOPSIS technique. The SWOT analysis constructs a framework, and the weights of SWOT factors and alternatives are obtained via ANP and TOPSIS respectively. The SWOT analysis was used in order to define strategies for Iranian mining sector. The SWOT analysis determined six strategies in order to implement in Iran. The MCDM methods have recognized wide applications in the solution of real world decision making problems. ANP is the preferred technique for obtaining the criteria weights and performance ratings when there is interdependence of characteristics. TOPSIS is a useful tool for prioritizing alternatives. The results show that A1 (0.885) has the highest weighting. From this result, decision makers or authorities should improve the ability of exploitation and production. Finally, we recommend that decision makers of mining industries can use this model to evaluate their activities for development or investment purposes.

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GAVYBOS SEKTORIAUS STRATEGIJŲ RANGAVIMAS TAIKANT ANP, TOPSIS IR SSGG METODUS

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Santrauka

Gavyba yra vienas svarbiausių veiksnių, turinčių įtaką daugeliui valstybių, jų ekonomikos augimui bei vystymuisi. Todėl labai svarbu tinkamai apibrėžti gavybos strategijas ir nustatyti jų prioritetus. Siūlomi įvairūs būdai siekiant apibrėžti ir parinkti tinkamiausiais strategijas. Autoriai pabrėžia, kad analizuojant vidinius ir išorinius aplinkos veiksnius: stiprumus, silpnybes, galimybes ir grėsmes (SSGG), galima apibrėžti esamą situaciją, identifikuoti bendrą vaizdą, galimus iššūkius ir turėti galimybę aprašyti strategijų svarbą ir įtaką gavybos sektoriui. Daugiakriteriniai sprendimų metodai (MCDM) yra tinkamos priemonės nustatyti prioritetus sudėtingoje aplinkoje. ANP ir TOPSIS – tai du svarbūs MCDM metodai, kurie sėkmingai taikomi skirtingų sričių mokslininkų. Šiame straipsnyje siūlomas integruotas prioritetų nustatymo metodas Irano gavybos sektoriui. Nustatyti galimoms strategijoms taikytas SSGG metodas. ANP metodu nustatyti SSGG faktorių reikšmingumai. Paskutiniame etape taikant TOPSIS metodą nustatyti strategijų prioritetai. Rezultatai parodė, kad siūlomu integruotu metodu galima kompetentingai atlikti gavybos sektoriaus eksploatacijos ir produkcijos perdirbimo strategijų pagrindimą ir rangavimą.

Reikšminiai žodžiai: SSGG, MCDM, ANP, TOPSIS, gavybos strategijos, rangavimas.

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