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AN INTEGRATED MODEL FOR PRIORITIZING STRATEGIES OF THE IRANIAN MINING SECTOR

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Abstract. Mining is one of the most important sectors in most countries. It produces raw material for other sectors such as industry, agriculture, etc. So, determining and prioritizing the mining strategies are critical to development plans in countries. Miscellaneous types of tools are presented 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. On the other hand, Balanced Scorecard (BSC) is a management system that helps organizations at dealing with today's pace of business and enables business managers to make better decisions. Fuzzy multi criteria decision making (FMCDM) techniques are appropriate tools to prioritize under sophisticated environmental. Fuzzy analytical hierarchy process (FAHP) and Fuzzy Technique for Order Preference by Similarity to Ideal Solution (FTOPSIS) are two hands of FMCDM methods that are used in different researches. In this paper, an integrated model for prioritizing the strategies of Iranian mining sector is proposed. The SWOT analysis employed to assign enforceable strategies; then, the BSC parameters were used as criteria in order to rank the strategies. The weight of criteria (the BSC parameters) and the priority of alternatives (generated strategies by SWOT) were earned by FAHP and FTOPSIS respectively. The results show that improving the ability of exploitation and production outperforms other strategies.

Keywords: SWOT, Balanced Scorecard, Fuzzy AHP, Fuzzy TOPSIS, Mining Strategies.

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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. For this reason, they need background information of SWOT situation in order to investigate the challenges and prospects of adopting their organization. SWOT analysis is an effective framework 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). It is used in different sectors such as transportation industry (Kandakoglu *et al.* 2009; Kheirkhah *et al.* 2009, Ghazinoory, Kheirkhah 2008; 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). This paper employed the SWOT analysis to identify the feasible strategies.

The evaluation of strategies performance has a critical importance to managers and decision makers. Many methods and techniques can be employed in order to evaluate the strategies. Balanced Scorecard (BSC) can be a good solution because it is a performance measurement framework that provides an integrated look at the business performance of a company by a set of both financial and non-financial measures (Lee *et al.* 2008). This technique has attracted considerable interest in recent years that it is due to its unique merits. Success stories of companies that have implemented BSC seem to confirm its high benefits (Speckbacher *et al.* 2003). It is a proper tool for evaluating of operational strategies in mining sector. This paper employed this technique to determine the evaluation criteria.

However, conventional BSC does not consolidate theses evaluations, and an incorporation of BSC and multi criteria decision making methods, such as analytical hierarchy process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), is an improvement.

In constructing a model, the main aim maximizes its usefulness that closely connected with the relationship among three key characteristics of every systems model: *complexity, credibility,* and *uncertainly* (Klir, Yuan 1995). Modeling the uncertainty is very valuable so that it cause to reduce complexity and increase credibility of the resulting model. Fuzzy logic is able to model the uncertainty. Fuzzy multi criteria decision making approach such as Fuzzy Technique for Order Preference by Similarity to Ideal Solution (FTOPSIS) is a useful tool because of different advantages, including logical concepts, simple and fast computations, and tolerating the uncertainty.

According to, Iran is one of the most important mineral producers in the world, ranked among 15 major mineral rich countries, holding some 68 types of minerals, 37 billion tons of proven reserves and more than 57 billion tons of potential reservoirs. These include coal, iron ore, copper, lead, zinc, chromium, barite, salt, gypsum, molybdenum, strontium, silica, uranium, and gold. The mines at Sar Cheshmeh in Kerman Province contain the world's second largest reserve of copper ore (5% of the world's total). According to Iran's fifth development plan, Iranian mining strategies should be determined and prioritized in order to generate value-added in the mining sector, adding the target will be achieved by preventing imports and modernizing technologies. We used an organized methodology for ranking the strategies of Iranian mining sector because of more precise, accurate, and sure results.

For achieving the aim, the SWOT analysis determines the feasible strategies. Then, the BSC technique defines main and sub-criteria. Finally, FTOPSIS is used to prioritize the strategies of Iranian mining sector to obtain the final ranking order. The importance weights of BSC evaluation indicators are calculated via FAHP.

The remainder of this paper is organized as follows. Fuzzy set theory is explained in the next section. Then in section 3, fuzzy AHP method is introduced. In section 4, fuzzy TOPSIS method is explained and the steps of the method are summarized. SWOT analysis and its application for strategies development is presented in section 5. In section 6, Balanced Scorecard is discussed. Case study is explained in section 7. In section 8, a numerical example is given to illustrate the proposed method and the results that are gained with these methods are presented. And finally section concludes the paper.

2. Fuzzy set theory

Fuzzy set theory was introduced by Zadeh (1965) in order to deal with vagueness of human thought. A fuzzy set is a category of objects with a continuum of grades of membership. The latter is recognized by a membership function. Membership function is a grade of membership ranging between zero and one. A fuzzy set is a generalization of a crisp set. Crisp sets only take full membership (number 1) or non-membership (number 0) at all, whereas fuzzy sets take partial membership (Ertuğrul, Karakaşoğlu 2008). Fuzzy sets and fuzzy logic are powerful mathematical tools in order to model uncertain in decision-making.

Uncertainty is resulted from two areas: (1) uncertainty in subjective judgments (2) uncertainty due to lack of data or incomplete information. The former is due to experts may not be 100% sure when making subjective judgments. The later is caused by sometimes information of some attributes may not be fully available or even not available at all.

Fuzzy sets are appropriate in the absence of vague and imprecise information. These sets are able to describe complex phenomena when traditional mathematical methods cannot analyze them. As well as, these sets can find a good approximate solution (Bojadziev, Bojadziev 1998).

There are miscellaneous types of fuzzy membership functions that triangular fuzzy number (TFN) is one of them (see Fig. 1).

A TFN is shown as $\tilde{A} = (a_1, a_2, a_3)$, where $a_1 < a_2 < a_3$ and a_1, a_2, a_3 are crisp numbers. The membership function of a number such as $\tilde{A}$ is:

$$f_{\tilde{A}}(x) = \begin{cases} 0, & x < \text{a}, \\ (x - a_1)/(a_2 - a_1), & a_1 < x < a_2, \\ (a_3 - x)/(a_3 - a_2), & a_2 < x < a_3, \\ 0, & x > a_3. \end{cases} \quad (1)$$

Let $\tilde{A} = (a_1, a_2, a_3)$, $\tilde{B} = (b_1, b_2, b_3)$ be two fuzzy numbers, so their mathematical relations expressed as:

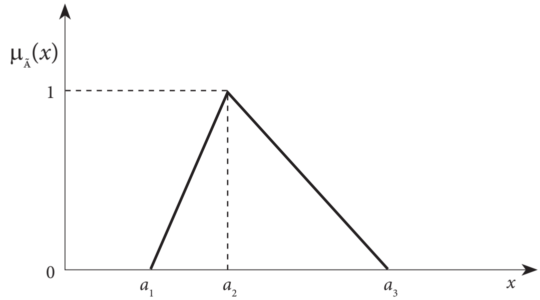

Fig. 1. Membership function of a triangular fuzzy number $\tilde{A} = (a_1, a_2, a_3)$

$$\tilde{A}\ (+)\ \tilde{B} = (a_1, a_2, a_3)\ (+)\ (b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3); \quad (2)$$

$$\tilde{A}\ (-)\ \tilde{B} = (a_1, a_2, a_3)\ (-)\ (b_1, b_2, b_3) = (a_1 - b_3, a_2 - b_2, a_3 - b_1); \quad (3)$$

$$\tilde{A}\ (\times)\ \tilde{B} = (a_1, a_2, a_3)\ (\times)\ (b_1, b_2, b_3) = (a_1 b_1, a_2 b_2, a_3 b); \quad (4)$$

$$\tilde{A}\ (\div)\ \tilde{B} = (a_1, a_2, a_3)\ (\div)\ (b_1, b_2, b_3) = (a_1/b_3, a_2/b_2, a_3/b_1). \quad (5)$$

The distance between two TFNs $\tilde{A} = (a_1, a_2, a_3)$, $\tilde{B} = (b_1, b_2, b_3)$ can be defined by the Euclidean distance (Chen 2000):

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3}\left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2\right]}. \quad (6)$$

3. Fuzzy analytical hierarchy process (FAHP)

Analytical hierarchy process (AHP) was introduced by Saaty (1980) that is a mathematical technique for multi-criteria decision making. This technique is based on pair-wise comparison matrix. The AHP method is based on three principles (Dağdeviren *et al.* 2009): first, structure of the model; second, comparative judgment of the alternatives and the criteria; third, synthesis of the priorities.

AHP method is combined with fuzzy methodology by miscellaneous methodologies (Buckley 1985; Cheng 1997; Chang 1996).

In this study the extent FAHP is utilized, which was originally introduced by Chang (1996). Let $X = \{x_1, x_2, \ldots, x_n\}$ be an object set and $U = \{u_1, u_2, \ldots, u_m\}$ be a goal set. According to the method of Chang's extent analysis, each object is taken and extent analysis for each goal, gi, is performed, respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs: $M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^m$, $i = 1, 2, \ldots, n$. Where all the M_{gi}^j $(j = 1, 2, \ldots, m)$ are TFNs.

The steps of Chang's extent analysis can be given as in the following:

Step 1: The value of fuzzy synthetic extent with respect to *i*th object is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}. \tag{7}$$

To obtain $\sum_{j=i}^{m} M_{gi}^{j}$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_i, \sum_{j=1}^{m} m_i, \sum_{j=1}^{m} u_i \right). \tag{8}$$

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

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right). \tag{9}$$

And then compute the inverse of the vector in Eq. (10) such that

$$\left[\sum_{n=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right). \tag{10}$$

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

$$V(M_2 \geq M_1) = \sup_{y \geq x} \left[\min(\mu_{M1}(x), \mu_{M2}(y)) \right]. \tag{11}$$

And can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M2}(d) = \begin{cases} 1, \text{ if } m_2 \geq m_1, \\ 0, \text{ if } l_1 \geq u_2. \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, \text{ otherwise.} \end{cases} \tag{12}$$

Where d is the ordinate of highest intersection point D between μ_{M1} and μ_{M2} (see Fig. 2).

To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

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

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \ldots \text{ and } (M \geq M_k)] = \min V(M \geq M_i), \quad \text{i=1, 2, … , k} \tag{13}$$

Assume that

$$d'(A_i) = \min V(S_i \geq S_k). \tag{14}$$

For k = 1, 2, … , n; $k \neq i$. Then the weight vector is given by

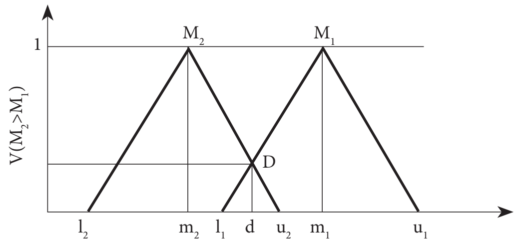

Fig. 2. The intersection between M_1 and M_2 (Chang 1996)

$$W' = (d'(A_1), d'(A_2),..., d'(A_n))^T, \tag{15}$$

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

Step 4: Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2),..., d(A_n))^T, \tag{16}$$

where W is a non-fuzzy number.

4. Fuzzy TOPSIS (FTOPSIS)

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). Fuzzy TOPSIS technique was developed as FTOPSIS to solve ranking and evaluating problems, because fuzzy allows the decision-makers to handle the incomplete information, non-obtainable information into decision model (Kulak *et al.* 2005). FTOPSIS and its extensions are applied to various applications (see Table 1).

Table 1. The various applications of FTOPSIS

Proposed by	Year	Used tools	Application
Chen	2000	FTOPSIS	Fuzzy environment
Antucheviciene	2005	FTOPSIS	Evaluations of alternatives
Wang, Elhag	2006	FTOPSIS	Risk assessment, selecting a system analysis engineer
Zavadskas, Antucheviciene	2006	FTOPSIS	Sustainable revitalization
Kuo *et al.*	2007	FTOPSIS, Fuzzy SAW	Location selection
Dağdeviren *et al.*	2009	FTOPSIS, AHP	Weapon selection

Continued Table 1

Proposed by	Year	Used tools	Application
Ebrahimnejad *et al.*	2009	FTOPSIS, Fuzzy LINMAP	Risk ranking
Sreeda, Sattanathan	2009	FTOPSIS, FAHP	To buy an apartment
Wang, Lee	2009	FTOPSIS, Shannon's Entropy	Software selection
Ebrahimnejad *et al.*	2010	FTOPSIS, fuzzy LINMAP	Risk assessment
Perçin, Kahraman	2010	FTOPSIS, AHP	Six Sigma project selection
Torfi *et al.*	2010	AHP, FAHP, TOPSIS, FTOPSIS, DEA	Various areas
Kelemenis *et al.*	2011	FTOPSIS	Personnel selection
Rostamzadeh, Sofian	2011	FTOPSIS, FAHP, DSS	Production systems performance
Singh, Benyoucef	2011	FTOPSIS, entropy	E-sourcing

The Fuzzy MCDM can be concisely expressed in matrix format as Eqs. (17) and (18).

$$\begin{matrix} & C_1\ C_2 \dots C_n & \\ & \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & & \tilde{x}_{mn} \end{bmatrix} & \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \end{matrix} \tag{17}$$

$$W = [\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n], \tag{18}$$

where $\tilde{x}_{ij}$, $i = 1, 2, \dots, m$; $j = 1, 2, \dots, n$ and $\tilde{w}_j$, $j = 1, 2, \dots, n$ are linguistic triangular Fuzzy numbers, $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ and $\tilde{w}_j = (a_{j1}, b_{j2}, c_{j3})$. Note that $\tilde{x}_{ij}$ is the performance rating of the *i*th alternative, Ai, with respect to the jth criterion, Cj and $\tilde{w}_j$ represents the weight of the *j*th criterion, Cj. The normalized Fuzzy decision matrix denoted by $\tilde{R}$ is shown as Eq. (19):

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{m \times n}. \tag{19}$$

The weighted Fuzzy normalized decision matrix is shown in Eq. (20):

$$\tilde{V} = \begin{bmatrix} \tilde{v}_{11} & \tilde{v}_{12} & \cdots & \tilde{v}_{1n} \\ \tilde{v}_{21} & \tilde{v}_{22} & \cdots & \tilde{v}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{v}_{m1} & \tilde{v}_{m2} & & \tilde{v}_{mn} \end{bmatrix} = \begin{bmatrix} w_1\tilde{r}_{11} & w_2\tilde{r}_{12} & \cdots & w_n\tilde{r}_{1n} \\ w_1\tilde{r}_{21} & w_2\tilde{r}_{22} & \cdots & w_n\tilde{r}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_1\tilde{r}_{m1} & w_2\tilde{r}_{m2} & & w_n\tilde{r}_{mn} \end{bmatrix}. \tag{20}$$

The advantage of using a Fuzzy approach is to allocate the relative importance of the criteria using Fuzzy numbers instead of crisp numbers. FTOPSIS is particularly suitable for solving the group decision maker problem under Fuzzy environment. FTOPSIS procedure is defined as follows (Hwang,Yoon 1992; Yang, Hung 2007):

Step 1: Choose the linguistic ratings $(\tilde{x}_{ij}, i = 1,2,...,m, j = 1,2,...,n)$ for alternatives with respect to criteria and the appropriate linguistic variables $(\tilde{w}_{ij}, j = 1,2,...,n)$ for the weight of the criteria. The fuzzy linguistic rating $(\tilde{x}_{ij})$ preserves the property that the ranges of normalized triangular fuzzy numbers belong to [0, 1].

Step 2: Construct the weighted normalized fuzzy decision matrix. The weighted normalized value is calculated by Eq. (20).

Step 3: Identify positive ideal (A^*) and negative ideal (A^-) solutions. The fuzzy positive –ideal solution and the fuzzy negative-ideal solution are shown in Eqs. (21), (22).

$$A^* = (\tilde{v}_1^+, \tilde{v}_2^+, \tilde{v}_3^+, ..., \tilde{v}_n^+) = \left\{ \max_i \ v_{ij} \mid (i = 1,2,...,n) \right\}, \tag{21}$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \tilde{v}_3^-, ..., \tilde{v}_n^-) = \left\{ \min_i \ v_{ij} \mid (i = 1,2,...,n) \right\}. \tag{22}$$

Step 4: Calculate separation measures. The distance of each alternative from A^* and A^- can be currently calculated using Eqs. (23), (24).

$$d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^+) \ , i = 1,2,...,m, \tag{23}$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \ , i = 1,2,...,m. \tag{24}$$

Step 5: Calculate the similarities to ideal solution. This step solves the similarities to an ideal solution by Eq. (25).

$$CC_i^* = \frac{d_i^-}{d_i^- + d_i^*}. \tag{25}$$

Step 6: Rank preference order. Choose an alternative with maximum CC_i^* or rank alternatives according to CC_i^* in descending order.

5. SWOT analysis and its application for strategies development

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 *et al.* 1999). The internal and external factors are known as strategic factors and are categorized via the SWOT analysis. Based on this 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.* 2010), and transform the identified weaknesses into strengths, and to take advantage of opportunities along with minimizing both internal weaknesses and external threats. It can provide a good basis for successful strategy formulation (Chang, Huang 2006).

According to the high ability of the SWOT analysis, miscellaneous researches applied this method to strategies development.

Nikolaou, 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. Arslan, Er (2008) developed strategic plans of action for safer tanker operation. Chang, 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, 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. They made SWOT analysis through an integrated professional team using the Delphi method.

Wang, Hong (2011) proposed a novel approach to strategy formulation, which utilizes 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) utilized 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 using the case of Dar es Salaam City in Tanzania. Dyson (2004) applied SWOT analysis and strategic development at the University of Warwick. Taleai *et al.* (2009) proposed a combined method based on the SWOT and analytic hierarchy process (AHP) to investigate the challenges and prospects of adopting geographic information systems (GIS) in developing countries. Lu (2010) provides an augmented SWOT analysis approach for strategists to conduct strategic planning in the construction industry.

6. Balanced Scorecard

Balanced Scorecard (BSC) is created by Kaplan and Norton (1992). It is looking for the different goals in its implementation. It tries to build a framework for strategic planning through four different areas; the four areas are Customer Perspective (CP), Learning and Growth Perspective (LGP), Financial Perspective (FP) and Internal Business Process Perspective (IBPP) (Kaplan and Norton 1992). It creates an insight for both managers and employers to better understanding the company's objectives. Figure 3 shows the relationship among various factors of BSC.

The BSC is a systemic approach, which helps integrating physical and intangible assets into a comprehensive model and builds a meaningful relationship among different criteria.

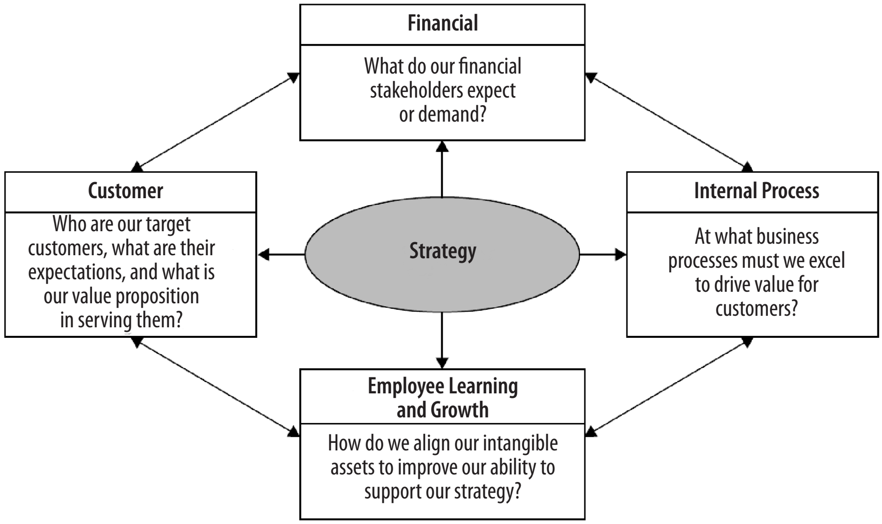

Fig. 3. A simple framework of BSC elements (Niven 2008)

Whereas ordinary accounting techniques can measure the physical assets of the companies and it means less than one – fourth of the value of the corporate sector are accountable (Niven 2008).

The concepts of BSC are widely applied to performance measurement. Lee *et al.* (2008) used the BSC approach for evaluating performance of IT department in the manufacturing industry, they define the hierarchy with four major perspectives of the BSC and then the FAHP approach was proposed in order to tolerate vagueness and ambiguity of information. Bremser, Chung (2005) proposed framework based on balanced scorecard methodology and existing taxonomies of e-business models. Chytas *et al.* (2011) developed a methodology based on fuzzy cognitive maps in order to generate a dynamic network of interconnected key performance indicators.

Wu *et al.* (2009) proposed a Fuzzy Multiple Criteria Decision Making approach based on BSC for banking performance evaluation, they the three MCDM analytical tools of SAW, TOPSIS, and VIKOR were adopted to rank the banking performance. Yuan, Chiu (2009) developed a three-level feature weights design to enhance inference performance of case-based reasoning. Bobillo *et al.* (2009) proposed a semantic fuzzy expert system which implements a generic framework for the BSC. Wachtel *et al.* (1999) applied the burn center to test whether the BSC methodology was appropriate for the core business plan of a healthcare strategic business unit.

7. Case study

Mining is one of the central activities so that other activities such as manufacturing, construction, and transportation, are directly and/or indirectly related to 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 has one of the world's largest zinc reserves and second-largest reserves of copper. It also has significant reserves of iron, uranium, lead, chromate, manganese, coal and gold.

8. The implementation of proposed model

The proposed model of this paper uses an integrated model that provides a framework for ranking the mining strategies of Iran. In order to implement the model, we first discuss the SWOT, then the BSC is analyzed; finally the strategies are prioritized the FTOPSIS method. In this framework, the weights of evaluation criteria are calculated via FAHP. Schematic diagram of the proposed model for ranking the strategies is provided in Fig. 4.

The data for 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 explore the strengths,

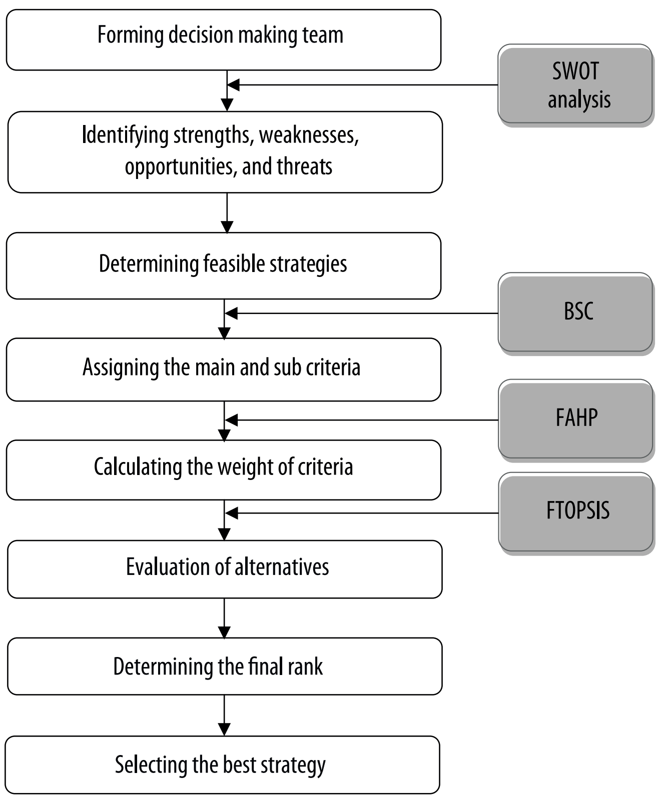

Fig. 4. Schematic diagram of the proposed model

some typical questions were designed such as what are the benefits of such practices, 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 are not done appropriately, what should be better or be avoided. Moreover, opportunities may include external benefits for companies from the acceptance of strategic management practices. Some relevant questions are; what benefits may take place for companies future, what competitive advantages will companies 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 analysis are fall into two categories: external and internal. The external category contains strengths and opportunities and the 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.

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. 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. 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. A6. Revising the mining law and cadastral system: this strategy is extracted by T1, T2, T3, S2.
	Weakness: W1. The lack of a completed mining database, W2. Long period from exploration to manufacturing, W3. Low efficiency in mining activities.	
External	Opportunities: O1. Cheap Labor force, O2. Access to energy resource, O3. The geopolitical situation of Iran, O4. Increasing demand for raw materials.	
	Threats: T1. Exporting raw material, T2. Non-membership of Iran in WTO, T3. High risk involved, T4. The fluctuations of raw mineral prices.	

As shown in Table 2, six strategies are concluded from the SWOT analysis. These strategies should be ranked due to financial and time constrains. We applied BSC criteria in order to prioritize the strategies. Consequently, the weight of criteria, the BSC criteria, is gained by FAHP and also, the alternatives, strategies obtained from SWOT, are carried out by FTOPSIS.

Achieving the aim, we first prepared a list of evaluation indicators base on the four perspectives of the BSC, and then with having an interview with the mining experts, the list were modified. Two questionnaires were designed in order to obtain the weights of criteria and alternatives. One of them is based on the four perspectives of the BSC and the selected performance indicators using the AHP questionnaire format, to obtain the relative importance of the four perspectives and the relative importance of the key performance indicators under each perspective. The other is provided by using the FTOPSIS questionnaire in order to gain the appropriate weights for the alternatives with respect to criteria. The questionnaires were distributed to senior managers from mining sector.

The Proposed model is continued as follows:

Step 1: Create the hierarchical model for the BSC

The first step changes the complex and multi criteria problems into a hierarchical structure. According to the case study, the first level comprises the goal from the different criteria, the second level includes the main criteria, the third level involves the sub-criteria, and finally the forth level contains the alternatives. In the Table 3 the hierarchical structure is represented.

Table 3. The hierarchical structure

Goal	Perspectives	Evaluation indicators	Alternatives extracted from the SWOT analysis
Selection of the best strategy for mining sector of Iran	Financial (F)	F1. Enhancing the added value. F2. Increasing the investments. F3. Decreasing the costs. F4. Risks reduction.	A1 A2 A3 A4 A5 A6
	Customer (C)	C1. Improvement of the level of services. C2. Customer satisfaction. C3. Management of supply chain.	
	Internal business (I)	I1. Increasing the level of production. I2. The efficiency improvement. I3. Raising the gross domestic production (GDP). I4. Marketing.	
	Learning and growth (L)	L1. Innovation and creativeness. L2. Employing the high technology. L3. Improving the labor force efficiency.	

Step 2: Accomplish the pair-wise comparison of criteria

After building the hierarchical structure, we designed an AHP questionnaire format and arrange the pair-wise comparisons matrix. Firstly each decision maker individually carry out pair-wise comparison by using Saaty's 1–9 scale (Saaty 1980) as shown in Table 4. The consistency of the decision maker's judgments during the evaluation phase is calculated by consistency ratio (CR) that cloud be defined as follows (Aguaron *et al.* 2003):

$$CR = \frac{\lambda_{\max} - n}{n-1}, \tag{26}$$

where λ_{max} is the principal eigenvalue and n is the rank of judgment matrix. The closer the inconsistency ratio to zero, the greater the consistency (Torfi *et al.* 2010). The resulting CR values for our case study are smaller than the critical value of 0.1, this show that there is no evidence of inconsistency.

The importance weights of the criteria determined by twelve decision-makers that are obtained through Eq. (27) are shown in Table 5.

$$\tilde{x}_{ij} = (l_{ij}, m_{ij}, u_{ij}),$$
$$l_{ij} = \min\{x_{ij}^{k}\},\ m_{ij} = \frac{1}{k}\sum_{k=1}^{k} x_{ij}^{k},\ u_{ij} = \max\{x_{ij}^{k}\}, \quad (27)$$

where $\tilde{x}_{ij}$ is the fuzzy importance weights of each criterion that are determined by all experts, x_{ij} is the crisp weight of each criterion, k is the number of expert (here, k is equal to 12).

The responses collected from questionnaires are input to the FAHP system, and the results are analyzed by the FAHP.

Table 4. 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

According to the FAHP method, firstly synthesis values must be calculated. From (Table 5), synthesis values respect to main goal are calculated like in Eq. (8):

$S_F = (1/36.5, 1/18.57, 1/10.52) \otimes (2.16, 5.06, 10) = (0.059, 0.272, 0.95);$

$S_I = (1/36.5, 1/18.57, 1/10.52) \otimes (2.08, 3.82, 7) = (0.057, 0.206, 0.665);$

$S_{F1} = (1/35.5, 1/20.32, 1/10.6) \otimes (4.5, 7.85, 11) = (0.127, 0.386, 1.037);$

$S_{F2} = (1/35.5, 1/20.32, 1/10.6) \otimes (2.16, 6.56, 11) = (0.061, 0.323, 1.037);$

$S_{F4} = (1/35.5, 1/20.32, 1/10.6) \otimes (1.91, 2.51, 6) = (0.054, 0.124, 0.565);$

$S_{C1} = (1/18.5, 1/10.97, 1/7.7) \otimes (4, 6.09, 10) = (0.216, 0.555, 1.29);$

$S_{C2} = (1/18.5, 1/10.97, 1/7.7) \otimes (1.45, 2.1, 2.5) = (0.078, 0.191, 0.324);$

$S_{C3} = (1/18.5, 1/10.97, 1/7.7) \otimes (2.25, 2.78, 6) = (0.122, 0.253, 0.779);$

$S_{I1} = (1/40, 1/18.87, 1/9.22) \otimes (2.16, 5.21, 11) = (0.054, 0.276, 1.193);$

$S_{I2} = (1/40, 1/18.87, 1/9.22) \otimes (2.75, 6.34, 14) = (0.069, 0.336, 1.518);$

$S_{I3} = (1/40, 1/18.87, 1/9.22) \otimes (1.78, 2.43, 5) = (0.045, 0.129, 0.54);$

Table 5. Importance weight of criteria and sub-criteria

	BSC criteria	**F**				**C**			**I**				**L**		
	F	(1,1,1)				(0.33,0.96,2)			(0.5,1.34,3)				(0.33,1.76,4)		
	C	(0.5, 1.04,3)				(1,1,1)			(1,2.33,4)				(2,2.76,5)		
	I	(0.33,0.75,2)				(0.25,0.43,1)			(1,1,1)				(0.5,1.64,3)		
	L	(0.25,0.59,3)				(0.2,0.36,0.5)			(0.33,0.61,2)				(1,1,1)		
	Sub-criteria	**F1**	**F2**	**F3**	**F4**	**C1**	**C2**	**C3**	**I1**	**I2**	**I3**	**I4**	**L1**	**L2**	**L3**
F	**F1**	(1,1,1)	(0.5,1.86,3)	(2,2.77,3)	(1,2.22,4)										
	F2	(0.33,0.54,2)	(1,1,1)	(0.33,2.89,5)	(0.5,2.13,3)										
	F3	(0.33,0.36,0.5)	(0.2,0.35,3)	(1,1,1)	(0.5,1.69,3)										
	F4	(0.25,0.45,1)	(0.33,0.47,2)	(0.33,0.59,2)	(1,1,1)										
C	**C1**					(1,1,1)	(2,2.77,5)	(1,2.32,4)							
	C2					(0.2,0.36,0.5)	(1,1,1)	(0.25,0.74,1)							
	C3					(0.25,0.43,1)	(1,1.35,4)	(1,1,1)							
I	**I1**								(1,1,1)	(0.33,1.26,4)	(0.5,1.64,3)	(0.33,1.31,3)			
	I2								(0.25,0.79,3)	(1,1,1)	(1,2.21,4)	(0.5,2.34,5)			
	I3								(0.33,0.61,2)	(0.25,0.45,1)	(1,1,1)	(0.2,0.37,1)			
	I4								(0.33,0.76,3)	(0.2,0.43,1)	(1,2.7,5)	(1,1,1)			
L	**L1**												(1,1,1)	(0.14,0.21,0.5)	(0.5,1.17.3)
	L2												(2,4.76,7)	(1,1,1)	(2,3.32,5)
	L3												(0.33,0.85,2)	(0.2,0.3,0.5)	(1,1,1)

$S_{I4} = (1/40, 1/18.87, 1/9.22) \otimes (2.53, 4.89, 10) = (0.063, 0.259, 1.08);$

$S_{L1} = (1/21, 1/13.61, 1/8.17) \otimes (1.64, 2.38, 4.5) = (0.078, 0.175, 0.55);$

$S_{L2} = (1/21, 1/13.61, 1/8.17) \otimes (5, 9.08, 13) = (0.238, 0.667, 1.59);$

$S_{L3} = (1/21, 1/13.61, 1/8.17) \otimes (1.53, 2.15, 3.5) = (0.073, 0.158, 0.428).$

These fuzzy values are compared by using Eq. (12) and these values are obtained:

$V(S_F > S_C) = 0.881,\ \ V(S_F > S_I) = 1,\ \ V(S_F > S_L) = 1,$
$V(S_C > S_F) = 1,\ \ V(S_C > S_I) = 1,\ \ V(S_C > S_L) = 1,$
$V(S_I > S_F) = 0.901,\ \ V(S_I > S_C) = 0.752,\ \ V(S_I > S_L) = 1,$
$V(S_L > S_F) = 0.806,\ \ V(S_L > S_C) = 0.668,\ \ V(S_L > S_I) = 0.892,$
$V(S_{F1} > S_{F2}) = 1,\ \ V(S_{F1} > S_{F3}) = 1,\ \ V(S_{F1} > S_{F4}) = 1,$
$V(S_{F2} > S_{F1}) = 0.934,\ \ V(S_{F2} > S_{F3}) = 1,\ \ V(S_{F2} > S_{F4}) = 1,$
$V(S_{F3} > S_{F1}) = 0.726,\ \ V(S_{F3} > S_{F2}) = 0.806,\ \ V(S_{F3} > S_{F4}) = 1,$
$V(S_{F4} > S_{F1}) = 0.625,\ \ V(S_{F4} > S_{F2}) = 0.717,\ \ V(S_{F4} > S_{F3}) = 0.921,$
$V(S_{C1} > S_{C2}) = 1,\ \ V(S_{C1} > S_{C3}) = 1,$
$V(S_{C2} > S_{C1}) = 0.229,\ \ V(S_{C2} > S_{C3}) = 0.766,$
$V(S_{C3} > S_{C1}) = 0.65,\ \ V(S_{C3} > S_{C1}) = 1,$
$V(S_{I1} > S_{I2}) = 0.949,\ \ V(S_{I1} > S_{I3}) = 1,\ \ V(S_{I1} > S_{I4}) = 1,$
$V(S_{I2} > S_{I1}) = 1,\ \ V(S_{I2} > S_{I3}) = 1,\ \ V(S_{I2} > S_{I4}) = 1,$
$V(S_{I3} > S_{I1}) = 0.768,\ \ V(S_{I3} > S_{I2}) = 0.695,\ \ V(S_{I3} > S_{I4}) = 1,$
$V(S_{I4} > S_{I1}) = 0.984,\ \ V(S_{I4} > S_{I2}) = 0.93,\ \ V(S_{I4} > S_{I3}) = 1,$
$V(S_{L1} > S_{L2}) = 0.388,\ \ V(S_{L1} > S_{L3}) = 1,$
$V(S_{L2} > S_{L1}) = 1,\ \ V(S_{L2} > S_{L3}) = 1,$
$V(S_{L3} > S_{L1}) = 0.95,\ \ V(S_{L3} > S_{L2}) = 0.27.$

Then priority weights are calculated by using Eq. (13):

$d'(F) = \min(0.881, 1, 1) = 0.881.$
$d'(C) = \min(1, 1, 1) = 1.$
$d'(I) = \min(0.901, 0.752, 1) = 0.752.$
$d'(L) = \min(0.806, 0.668, 0.892) = 0.668.$
$d'(F1) = \min(1, 1, 1) = 1.$
$d'(F2) = \min(0.934, 1, 1) = 0.934.$
$d'(F3) = \min(0.726, 0.806, 1) = 0.726.$
$d'(F4) = \min(0.625, 0.717, 0.921) = 0.625.$
$d'(C1) = \min(1, 1) = 1.$
$d'(C2) = \min(0.229, 0.766) = 0.229.$
$d'(C3) = \min(0.65, 1) = 0.65.$
$d'(I1) = \min(0.949, 1, 1) = 0.949.$
$d'(I2) = \min(1, 1, 1) = 1.$
$d'(I3) = \min(0.768, 0.695, 1) = 0.695.$
$d'(I4) = \min(0.984, 0.93, 1) = 0.93.$
$d'(L1) = \min(0.388, 1) = 0.388.$
$d'(L2) = \min(1, 1) = 1.$
$d'(L3) = \min(0.95, 0.27) = 0.27.$

Priority weights for each criterion are presented in Table 6. The FAHP analysis of the criteria is summarized in Fig. 5.

Table 6. Priority weights for each criterion

Criteria	Weights under the same perspective	Normalized weights under the same perspective	Normalized weights among all indicators
F	0.881	0.267	–
C	1	0.303	–
I	0.752	0.228	–
L	0.668	0.202	–
F1	1	0.304	0.081
F2	0.934	0.284	0.076
F3	0.726	0.221	0.059
F4	0.625	0.190	0.051
C1	1	0.532	0.161
C2	0.229	0.122	0.037
C3	0.65	0.346	0.105
I1	0.949	0.266	0.060
I2	1	0.280	0.064
I3	0.695	0.194	0.044
I4	0.93	0.260	0.059
L1	0.388	0.234	0.047
L2	1	0.603	0.122
L3	0.27	0.163	0.033

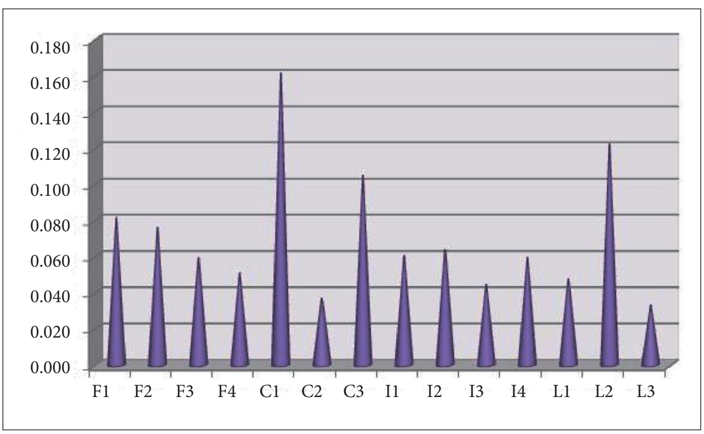

Fig. 5. Ranking of criteria

Step 3: Determining the final priority

At this step of the proposed model, the team members were asked to establish the decision matrix by comparing alternatives under each of the criteria separately. Linguistic values were used for evaluation of strategies in this step. The membership functions of these linguistic values, and the triangular fuzzy numbers related with these variables are shown in Fig. 6 and Table 7 respectively. The fuzzy performance ratings of the alternatives with regard to each criterion were determined by twelve decision makers that are obtained by Eq. (28).

$$\tilde{x}_{ij} = (\tilde{x}_{ij}^{\ 1} \otimes \tilde{x}_{ij}^{\ 2} \otimes ... \otimes \tilde{x}_{ij}^{\ k}) \text{ (Here, k = 12).} \tag{28}$$

Fuzzy evaluation matrix for the alternatives with regard to each criterion is determined. After the fuzzy evaluation matrix was determined, the next stage is to obtain a fuzzy normalized decision matrix as presented in Table 8. The fuzzy performance ratings are normalized into the range of [0,1] through Eqs. (29) and (30) (Yang, Hung 2007):

$$r_{ij} = \frac{x_{ij} - \min\{x_{ij}\}}{\left[\max\{x_{ij}\} - \min\{x_{ij}\}\right]} \text{ The larger, the better type,} \tag{29}$$

$$r_{ij} = \frac{\min\{x_{ij}\} - x_{ij}}{\left[\max\{x_{ij}\} - \min\{x_{ij}\}\right]} \text{ The smaller, the better type} \tag{30}$$

Table 7. Linguistic values and fuzzy numbers

Linguistic values	Fuzzy numbers
Very low (VL)	(0, 0, 0.2)
Low (L)	(0, 0.2, 0.4)
Medium (M)	(0.2, 0.4, 0.6)
High (H)	(0.4, 0.6, 0.8)
Very high (VH)	(0.6, 0.8, 1)
Excellent (E)	(0.8, 1, 1)

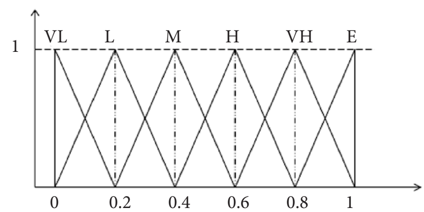

Fig. 6. Membership functions of linguistic values

Table 8. Fuzzy normalized decision matrix

	A1	A2	A3	A4	A5	A6	Weight
F1	(0.45,0.73,1)	(0.0,0.27,0.55)	(0.0,0.27,0.55)	(0.09,0.36,0.64)	(0.18,0.45,0.73)	(0.0,0.27,0.55)	0.081
F2	(0.22,0.56,0.89)	(0.22,0.56,0.89)	(0.11,0.44,0.78)	(0.0,0.33,0.67)	(0.33,0.67,1)	(0.22,0.56,0.89)	0.076
F3	(0.4,0.7,1)	(0.3,0.6,0.8)	(0.2,0.5,0.8)	(0.0,0.3,0.6)	(0.1,0.4,0.7)	(0.2,0.5,0.8)	0.059
F4	(0.42,0.67,1)	(0.0,0.25,0.5)	(0.08,0.33,0.58)	(0.08,0.25,0.5)	(0.33,0.58,0.83)	(0.08,0.33,0.58)	0.051
C1	(0.42,0.67,0.92)	(0.0,0.25,0.5)	(0.25,0.5,0.75)	(0.08,0.25,0.5)	(0.17,0.42,0.67)	(0.5,0.75,1)	0.161
C2	(0.45,0.73,1)	(0.0,0.18,0.45)	(0.18,0.36,0.64)	(0.09,0.27,0.55)	(0.45,0.73,1)	(0.27,0.55,0.82)	0.037
C3	(0.3,0.5,0.8)	(0.0,0.3,0.6)	(0.0,0.2,0.5)	(0.2,0.5,0.8)	(0.4,0.7,1)	(0,0.3,0.6)	0.105
I1	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.08,0.25,0.5)	(0.33,0.58,0.83)	(0.08,0.33,0.58)	(0,0.25,0.5)	0.060
I2	(0.42,0.67,0.92)	(0.0,0.17,0.42)	(0.08,0.25,0.5)	(0.08,0.33,0.58)	(0.5,0.75,1)	(0.17,0.42,0.67)	0.064
I3	(0.5,0.75,1)	(0.0,0.08,0.25)	(0.08,0.33,0.58)	(0.17,0.42,0.67)	(0.08,0.42,0.67)	(0.17,0.42,0.67)	0.044
I4	(0.33,0.67,1)	(0.0,0.11,0.33)	(0.0,0.22,0.56)	(0.0,0.22,0.56)	(0.11,0.44,0.78)	(0.11,0.44,0.78)	0.059

Continued Table 8

	A1	A2	A3	A4	A5	A6	Weight
L1	(0.5,0.7,1)	(0.0,0.1,0.3)	(0.0,0.2,0.5)	(0.2,0.4,0.7)	(0.3,0.6,0.9)	(0.1,0.4,0.7)	0.047
L2	(0.36,0.64,0.91)	(0.0,0.18,0.45)	(0.09,0.27,0.55)	(0.18,0.45,0.73)	(0.45,0.73,1)	(0.0,0.36,0.64)	0.122
L3	(0.5,0.75,1)	(0.0,0.08,0.25)	(0.0,0.25,0.5)	(0.08,0.25,0.5)	(0.33,0.58,0.83)	(0.08,0.42,0.67)	0.033

Using the criteria weights calculated by FAHP in the former step, the fuzzy weighted decision matrix is established with Eq. (20). The resulting fuzzy weighted decision matrix is presented in Table 9.

Since the all criteria are benefit type, we can define the fuzzy positive-ideal solution and the fuzzy negative-ideal as $\tilde{v}_j^* = (1,\ 1,\ 1)$ and $\tilde{v}_j^- = (0,\ 0,\ 0)$ respectively. So, the distance of each alternative from D^* and D^- can be currently calculated using Eq. (23) and Eq. (24). Finally, FTOPSIS solves the similarities to an ideal solution by Eq. (25). In order to distinguish the matter, an example is presented as follows:

$$D_1^* = \sqrt{\frac{1}{3}\left[(1-0.04)^2 + (1-0.06)^2 + (1-0.08)^2\right]} + \sqrt{\frac{1}{3}\left[(1-0.02)^2 + (1-0.04)^2 + (1-0.07)^2\right]} + \ldots + \sqrt{\frac{1}{3}\left[(1-0.04)^2 + (1-0.08)^2 + (1-0.11)^2\right]} + \sqrt{\frac{1}{3}\left[(1-0.02)^2 + (1-0.02)^2 + (1-0.03)^2\right]} = 13.33.$$

$$D_1^- = \sqrt{\frac{1}{3}\left[(0-0.04)^2 + (0-0.06)^2 + (0-0.08)^2\right]} + \sqrt{\frac{1}{3}\left[(0-0.02)^2 + (0-0.04)^2 + (0-0.07)^2\right]} + \ldots + \sqrt{\frac{1}{3}\left[(0-0.04)^2 + (0-0.08)^2 + (0-0.11)^2\right]} + \sqrt{\frac{1}{3}\left[(0-0.02)^2 + (0-0.02)^2 + (0-0.03)^2\right]} = 0.701.$$

As a result,

$$CC_1 = \frac{D_1^-}{D_1^* + D_1^-} = \frac{0.701}{13.33 + 0.701} = 0.0499.$$

Table 9. Fuzzy weighted decision matrix

	A1	A2	A3	A4	A5	A6
F1	(0.04,0.06,0.08)	(0.0,0.02,0.04)	(0.0,0.02,0.04)	(0.01,0.03,0.05)	(0.01,0.04,0.06)	(0.0,0.02,0.04)
F2	(0.02,0.04,0.07)	(0.02,0.04,0.07)	(0.01,0.03,0.06)	(0.0,0.03,0.05)	(0.0,0.03,0.05)	(0.02,0.04,0.07)
F3	(0.02,0.04,0.06)	(0.02,0.04,0.05)	(0.01,0.03,0.05)	(0.0,0.02,0.04)	(0.01,0.02,0.04)	(0.01,0.03,0.05)
F4	(0.02,0.03,0.05)	(0.0,0.01,0.03)	(0.0,0.02,0.03)	(0.0,0.01,0.03)	(0.02,0.03,0.04)	(0.0,0.02,0.03)
C1	(0.07,0.11,0.15)	(0.0,0.04,0.08)	(0.04,0.08,0.12)	(0.01,0.04,0.08)	(0.03,0.07,0.11)	(0.08,0.12,0.16)
C2	(0.02,0.03,0.04)	(0.0,0.01,0.02)	(0.01,0.01,0.02)	(0.0,0.01,0.02)	(0.02,0.03,0.04)	(0.01,0.02,0.03)
C3	(0.03,0.05,0.08)	(0.0,0.03,0.06)	(0.0,0.02,0.05)	(0.02,0.05,0.08)	(0.04,0.07,0.11)	(0.0,0.03,0.06)
I1	(0.03,0.05,0.06)	(0.02,0.03,0.05)	(0.01,0.02,0.03)	(0.02,0.04,0.05)	(0.01,0.02,0.04)	(0.0,0.02,0.03)
I2	(0.03,0.04,0.06)	(0.0,0.01,0.03)	(0.01,0.02,0.03)	(0.01,0.02,0.04)	(0.03,0.05,0.06)	(0.01,0.03,0.04)

Continued Table 9

	A1	A2	A3	A4	A5	A6
I3	(0.02,0.03,0.04)	(0.0,0.0,0.01)	(0.0,0.01,0.03)	(0.01,0.02,0.03)	(0.0,0.02,0.03)	(0.01,0.02,0.03)
I4	(0.02,0.04,0.06)	(0.0,0.01,0.02)	(0.0,0.01,0.03)	(0.0,0.01,0.03)	(0.01,0.03,0.05)	(0.01,0.03,0.05)
L1	(0.02,0.03,0.5)	(0.0,0.0,0.01)	(0.0,0.01,0.02)	(0.01,0.02,0.03)	(0.01,0.03,0.04)	(0.0,0.02,0.03)
L2	(0.04,0.08,0.11)	(0.0,0.02,0.06)	(0.01,0.03,0.07)	(0.02,0.06,0.09)	(0.06,0.09,0.12)	(0.0,0.04,0.08)
L3	(0.02,0.02,0.03)	(0.0,0.0,0.01)	(0.0,0.01,0.02)	(0.0,0.01,0.02)	(0.01,0.02,0.03)	(0.0,0.01,0.02)

Table 10. FTOPSIS results

Alternatives	D_j^+	D_j^-	CC_j	Rank
A1	13.33	0.701	0.0499	1
A2	13.71	0.346	0.0246	6
A3	13.65	0.403	0.0286	5
A4	13.63	0.428	0.0305	4
A5	13.44	0.603	0.0429	2
A6	13.56	0.504	0.0358	3

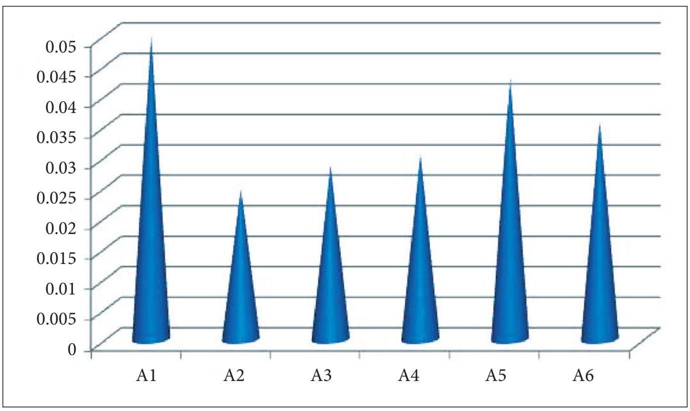

Fig. 7. Ranking of alternatives

Similar calculations were done for the other alternatives and the results of FTOPSIS analyses were summarized in Table 10. According to CCj values, the ranking of the alternatives in descending order are A1, A5, A6, A4, A3 and A2. The rank of alternatives is depicted in Fig. 7. Proposed model results indicate that A1 is the best alternative with CC value of 0.0499.

9. Conclusions

In this study, we developed an integrated model of the SWOT analysis as well as the BSC model to construct a framework, and gained the weights of criteria and alternatives based on FAHP and FTOPSIS respectively. Six strategies were generated by the SWOT analysis of the Iranian mining sector. Then, the BSC criteria were applied to prioritize the strategies. Fuzzy MCDM has recognized wide applications in the solution of real world decision making problems. FAHP and FTOPSIS are the preferred techniques for obtaining the criteria weights and performance ratings when information is vague and inaccurate. The results show that A1 (0.0499) has the highest weighting. As this result, decision makers are advised to improve the ability of exploitation and production. Finally, we recommend that the authorities of mining industries can use this model to evaluate their activities for development or investment purposes.

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IRANO KASYBOS SEKTORIAUS STRATEGIJŲ PRIORITETO NUSTATYMO INTEGRUOTAS MODELIS

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Santrauka. Kasyba yra viena iš svarbiausių ūkio sektorių daugelyje šalių. Ji tiekia žaliavą kitiems sektoriams: pramonei, žemės ūkiui ir t. t. Taigi, gavybos strategijų sudarymas ir prioritetų nustatymas ir yra labai svarbūs šalių plėtros planams. Veiklos strategijoms vertinti siūlomos įvairios metodologijos. Analizuojant vidaus ir išorės aplinką stiprybių, silpnybių, galimybių ir grėsmių (SSGG) metodu, galima nustatyti esamą padėtį, perspektyvas ir iššūkius, kurie galėtų gerokai paveikti strategijos įgyvendinimą kasybos sektoriuje. Balanso rodiklių sistema (BSC) yra valdymo sistema, kuri padeda organizacijoms spręsti nūdienos verslo spartos problemas ir leidžia vadybininkams priimti geresnius sprendimus. Apytiksliai daugiakriteriniai sprendimų priėmimo metodai nustato prioritetus esant sudėtingai aplinkai. Apytikslis analitinės hierarchijos procesas (FAHP) ir apytikslis artumo idealiajam taškui metodas (FTOPSIS) yra du metodai, kurie naudojami įvairiuose tyrimuose. Šiame straipsnyje Irano kasybos sektoriaus prioritetinei strategijai nustatyti, siūlomas integruotas modelis. SSGG analize nustatomos realios strategijos. Balanso rodiklių sistemos (BSC) parametrai naudojami kaip strategijų rikiavimo kriterijai. Kriterijų reikšmingumai nustatyti FAHP metodu, o alternatyvos surikiuotos FTOPSIS metodu. Rezultatai rodo, kad eksploatavimo gerinimo ir produktyvumo didinimo strategija geresnė už kitas.

Reikšminiai žodžiai: SSGG, balanso rodiklių sistema, apytikslis AHP, apytikslis TOPSIS, kasybos strategijos.

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