Iranian Journal of Management Studies (IJMS) *http://ijms.ut.ac.ir/*
Vol. 9, No. 2, Spring 2016 *Print ISSN: 2008-7055*
pp. 359-382 *Online ISSN: 2345-3745*

Two comparative MCDM approaches for evaluating the financial performance of Iranian basic metals companies

Mojtaba Farrokh[1*], Hossein Heydari[2], Hamid Janani[3]

1. Farabi Campus, University of Tehran, Qom, *Iran*
2. Faculty of Management, University of Tehran, Tehran, Iran
3. Faculty of Management & Economy, University of Qom, Qom, Iran

(Received: 23 March, 2015; Revised: 27 July, 2015; Accepted: 2 August, 2015)

Abstract

Due to the increasing competition and the continuous changes in current business environments, appropriate evaluation of the companies' performance is a useful tool not only for themselves but also for their own investors and creditors. In this paper, a model is presented for evaluating the basic metals producing companies. The proposed model based on analyzing the financial ratios is a combination of the FAHP (fuzzy analytical hierarchy process) and the VIKOR. The FAHP is used for determining the weights of the financial ratios and the VIKOR is applied for ranking the companies. To clarify the effectiveness and the accuracy of the developed method, the obtained result from the VIKOR is compared with the results of the TOPSIS technique. It can be seen from the results that the VIKOR based ranking is relatively similar to the result by the TOPSIS. In this research, the proposed method is utilized for evaluation of the performance of eight Iranian basic metals companies exist in Tehran stock exchange list.

Keywords

Basic metals companies, Financial ratios, Fuzzy AHP, TOPSIS, VIKOR.

∗ **Corresponding Author, Email:** m.farrokh@ut.ac.ir

Introduction

In today's competitive environment, a suitable evaluation of the companies' performance is critical not only for themselves but also for their own creditors and investors. The evaluation is one of the most important tools for identifying the internal strengths and weaknesses and determining the external opportunities and threats, and also can clarify the companies' position than other ones. Moreover, the evaluation based information can be used by future investors and creditors for selecting companies for the investment and lending to them, respectively. Despite the high importance of performance evaluation, a few numbers of the methods have been developed in this context, including some conventional and simple methods. Here, the important issue in the evaluation is the development of mathematical approaches for ranking and the proposition of criteria.

In the current study, the performance of Iranian basic metals companies has been evaluated by using financial ratios. In Iran, basic metals industry is the most important industry after the petrochemical one; Iran, the 10th mine producer country, annually extracts from five thousand and six hundred active mines with about 400 million tons of minerals. In 2014, Iran's aluminum and copper production ranked 19th and 20th in the world, respectively. Recently, with improvement in the construction and manufacturing sector, the demand for basic metals has been increased. The improvement is relied on the economic stability, the population increase, reduction in the interest, and exchange rates. Despite the increasing importance of the evaluation of the companies for the investors and creditors, there is no capital enterpriser in Iran to rank the companies, only annually is published by Industrial Management Organization. The ranking of Iranian companies is done as evaluations based on one variable or harmonic mean. Due to lack of a comprehensive ranking methodology for the users, development of an efficient approach (that uses various indicators) is important. In this study, the evaluation of Iranian basic metals firms is implemented by multi-criteria decision-making (MCDM) methods. Because of the importance of the financial indicators for the investors and creditors, measurement of the companies' performance can be done by using financial ratios as the criteria are acquired from the balance sheet, income statement, and cash flow. The financial ratios provide applicable information by analyzing the basic and relevant data for making decisions by the applicant (Singh & Schmidgall, 2002).

In this paper, to consider the performance of Iranian basic metals companies, a Fuzzy AHP and VIKOR based approach was applied. The fuzzy AHP is used to determine weights of financial ratios and the VIKOR is applied to rank the companies. In the multi criteria decision-making problem, the decision-makers usually feel more ambiguity giving linguistic variables rather than present their judgments as crisp values. Hence, fuzzy set theory is an applicable means to deal with imprecise and vagueness data (Zadeh, 1965). The AHP, proposed by Saaty (1980), is a practical decision-making method. The fuzzy AHP is an extension of the AHP to solve the hierarchical decision-making problems in uncertain environments. The fuzzy AHP method has been widely used by various researchers to solve different decision-making problems. The VIKOR method (Vlse Kriterijumska Optimizacija I Kompromisno Resenje in Serbian, meaning multi-criteria optimization and compromise solution) has been developed for multi-criteria optimization of complex systems, similar to some other MCDM methods like the TOPSIS. This method relies on an aggregating function that represents closeness to the ideal (Opricovic & Tzeng, 2004). Main characteristic of the VIKOR method matched with class of our problem is to provide compromise solutions for a problem with conflicting criteria, which can help the decision makers to reach a decision with high quality. With the proposed method, the evaluation problem of financial performance can be easily solved. The result obtained from the VIKOR has been compared with the TOPSIS (technique for order preference by similarity to an ideal solution) technique.

This study is first work implemented on Iranian basic metals companies based on an integrated fuzzy AHP and VIKOR approach and differentiated from previous studies in the literature due to comparing the obtained results of the VIKOR with the ranking derived from the TOPSIS method.

Literature review

In recent years, many researchers have concentrated on evaluation of performance in different areas by different approaches. In the studies, the evaluations have had different aims such as provision of guides for investors and purchasers. Among methods developed for multi criteria decision making problem, the fuzzy AHP method has been widely applied in recent research to solve different problems. Kahraman *et al.* (2004) to compare the performance of Turkey's grocer companies used the fuzzy AHP. Al-Ahmari (2008) applied the AHP to rank technologies in Saudi industries. Akbari *et al.* (2008) also incorporated the geographic information system (GIS) and the fuzzy AHP to solve the landfill site selection problem and to develop the assessment of the potential landfill.

However, the integrating AHP with other methods such as the TOPSIS and the VIKOR is conventional, as the integration help effective solving of many real-life decision making problems due to the strengths of the complement methods. The TOPSIS is widely applied as a tool for solving the problems based on the concept that the optimal alternative should have the shortest distance from the positive idea solution and the farthest distance from the negative idea solution (Hwang & Yoon, 1981). Wang (2008) applied the TOPSIS method to evaluate the financial performance of domestic airlines in Taiwan. Ertugrul and Karakasoglu (2009) used the fuzzy AHP and the TOPSIS methods for performance evaluation of Turkish cement companies. Wu *et al.* (2009) applied the fuzzy AHP and the TOPSIS based on Balanced Score Card (BSC) to evaluate the banking performance in Taiwan. Rezaei *et al.* (2014) considered supplier selection problem in the airline retail industry by using a funnel methodology and conjunctive screening method and also applied the fuzzy AHP to rank and select the best suppliers. Lee *et al.* (2015) incorporated the AHP and the TOPSIS to obtain the weights of multiple criteria and select the effective suppliers in a fuzziness framework. Due to characteristics and capabilities of the VIKOR method, it has been widely used in group decision making problems in recent years (Liu *et al.*, 2013; Vahdani *et al.*, 2013; Kassaee *et al.*, 2013; Hosseini-Nia & Farrokh, 2014; Liu *et al.*, 2014). Compared with the TOPSIS, the VIKOR not only consider group utility maximization and individual regret minimization, but also can fully reflect the decision makers subjective preferences (Opricovic & Tzeng, 2004; Wan *et al.*, 2013; Alam-Tabriz, 2014). In the present study, VIKOR has been selected as the method for firms' assessment. Sanayei *et al.* (2010) proposed a hierarchy MCDM model based on fuzzy sets theory and the VIKOR method to deal with the supplier selection problems in the supply chain. Fu *et al.* (2011) also applied a VIKOR methodology to perform a benchmarking analysis in the hotel industry. Ardekani *et al.* (2013) comprehensively evaluated the performance of Ceramic and Tile industry using a FAHP and fuzzy VIKOR approach based on balanced scorecard. Alvandi *et al.* (2013) ranked the companies' financial performance of auto and spare parts industry accepted in Tehran Stock Exchange using the FAHP and the VIKOR. Shaverdia *et al.* (2014) applied the FAHP approach for financial performance evaluation of Iranian petrochemical sector.

Financial ratios

Financial ratios are appropriate indicators to assess the economic status and performance of a company. It is considered that they can be listed based on meaningful information provided for their decision-making (Tehrani, 2005). The following ratios, some of the common financial ones, will be used in this research:

i. **Liquidity ratios (C_1):** the ratio is calculated by dividing cash, cash equivalents and securities, readily convertible to cash, to the current liabilities. Liquidity ratios can be used to assess whether a company can respond to short-term financial obligations or not. The ratios include current ratio and quick ratio.

- **Current ratio (C_{11}):** future creditors utilize current ratio in determining whether or not to make short-term loans. The current ratio can also provide for investors information about a company's ability to turn its product into cash.

- **Quick ratio (C_{12}):** this ratio as an indicator of a company's financial strength or weakness provides information about a company’s short term liquidity. The ratio tells creditors how much of the company's short term debt can be met by selling all the company's liquid assets at very short time.

ii. **Financial leverage ratios (C_2):** This ratio can be described as the sign of a company's capacity to meet short-term and long-term debt obligations.

- **Debt ratio (C_{21}):** This ratio is an indicator that shows the proportion of a company's total liabilities to its total assets. The debt ratio provides for creditors and investors a quick measure of the amount of company's debt on its balance sheets compared to its assets.
- **The shareholder's equity to total assets ratio (C_{22}):** The ratio indicates the percentage of assets financed through shareholder's equity obtained by dividing shareholder's equity by total assets.
- **The fixed assets to shareholder's equity ratio (C_{23}):** It is the percentage of the total assets ratio thorough shareholder's equity calculated by dividing fixed assets by shareholder's equity.
- **Fixed assets to long-term debt ratio (C_{24}):** this ratio is an index indicates the company's long term solvency. It is calculated by dividing fixed assets by long term debt.

iii. **Profitability ratios (C_3):** this ratio indicates the ability of a firm to receive revenues in excess of expenses.

- **Net profit margin ratio (C_{31}):** This ratio deliberates how profitable a firm's sales are after entire expenses. The ratio is obtained by dividing earnings after taxes by sales.
- **Return on equity ratio (C_{32}).** This ratio is measured by dividing net profit before taxes by net worth.

iv. **Growth Ratios (C_4):** These ratios indicate if the position of the firm in the industry is good or not.

- **The Sales Growth (C_{41}):** this ratio shows the percentage increase in sales within specific period than its last period's sales.

- **The operating profit growth (C_{42}):** the ratio measures the percentage of the increase in current period's operating profit for a firm between the two time periods.
- **The Shareholders' Equity Growth (C_{43}):** this ratio measures the percentage of the increase in current period's shareholders' equity than last periods.
- **The Asset Growth (C_{44}):** it shows the percentage of the increase in the current period's assets for a company than last period's asset.

The Proposed Methodology

In the current study, an integrated approach is developed including the FAHP and the VIKOR techniques. This approach is used to evaluate the performance of the basic metals firms in Iran. Steps of the developed methodology are illustrated in Fig. 1.

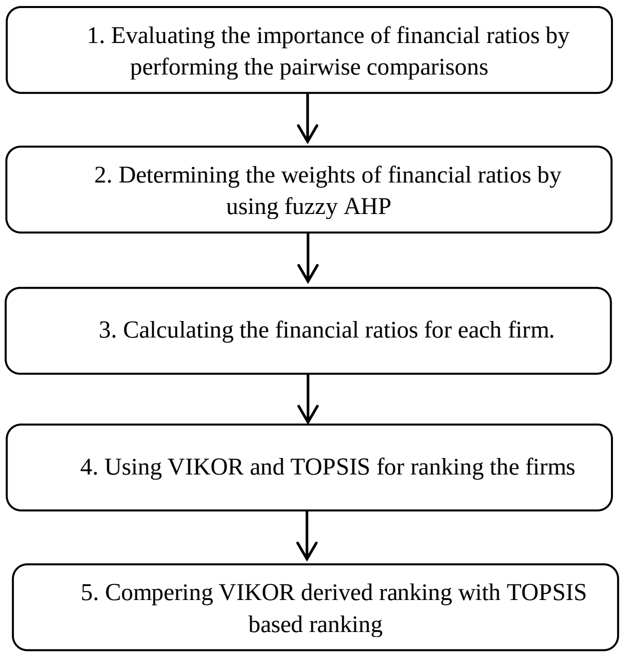

Fig. 1. The developed methodology

Fuzzy sets and fuzzy numbers

Fuzzy set theory, firstly proposed by Zadeh in 1965, provided a framework for solving problems in a fuzzy environment. The Fuzzy set is useful when situation of evaluation is full of uncertainty and imprecision due to the human judgments that make the decision making very complex and unstructured. Fuzzy set theory is a suitable tool for modeling imprecision arising from mental system which is not random or stochastic. Given that data on the phenomenon stated by different experts is ambiguous and vague, utilization of linguistic variable is essential to cope with the situations. A linguistic variable is one whose values are as linguistic terms (Zadeh, 1975). Each linguistic variable can be represented by a fuzzy number which can be assigned to a membership function.

Generally, in practice, triangular and trapezoidal fuzzy numbers are used (Kabak *et al.*, 2012). It is often convenient to work with triangular fuzzy numbers (TFNs) because the numbers have been identified as useful means of quantifying the uncertainty in decision making because of their intuitive appeal and efficiency in computation. In this study, TFNs in the FAHP are applied.

The TFN can be shown as $\tilde{A} = (l, m, u)$. The membership function of a TFN is shown as bellow.

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x-l}{m-l} & l \le x \le m \\ \dfrac{u-x}{u-m} & m \le x \le u \\ 0 & x \prec l \quad or \quad x \succ u \end{cases} \tag{1}$$

where $-\infty < x > \infty$; $\mu_{\tilde{A}}(x)$ is the membership function which assigns to each x a degree of membership between 0 to 1. A triangular fuzzy number is shown in Figure 2. The parameters l, m, and u indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy number, respectively.

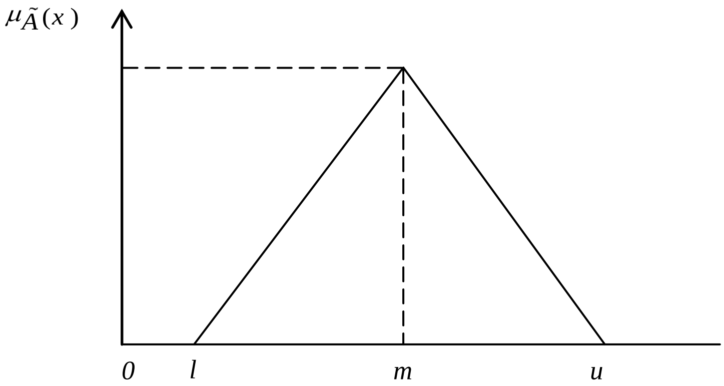

Fig. 2. A triangular fuzzy number

For two TFNs $\tilde{A} = (l_1, m_1, u_1)$ and $\tilde{B} = (l_2, m_2, u_2)$, some of the main mathematical operational laws are as bellow:

$$\begin{aligned}
&\tilde{A} + \tilde{B} = (l_1 + l_2, m_1 + m_2, u_2 + u_2)\\
&\tilde{A} - \tilde{B} = (l_1 - u_2, m_1 - m_2, u_2 - l_2)\\
&\tilde{A} * \tilde{B} = (l_1 l_2, m_1 m_2, u_2 u_2) \quad for\ l_i > 0, m_i > 0, u_i > 0,\ i = 1,2 \qquad (2)\\
&\tilde{A} / \tilde{B} = (l_1 / u_2, m_1 / m_2, u_2 / l_2)\ for\ l_i > 0, m_i > 0, u_i > 0,\ i = 1,2\\
&\tilde{A}^{-1} = (1/u_1, 1/m_1, 1/l_1), \quad for\ l_1 > 0, m_1 > 0, u_1 > 0
\end{aligned}$$

In this approach (similar to the importance scale defined in Saaty's classical AHP; Saaty, 1980), we have used five main linguistic terms to compare the criteria as shown in Table 1.

Table 1. Linguistic scale for importance

Linguistic scale	Triangular fuzzy number
Equally important	(1, 1, 1)
Weak importance	(2, 3, 4)
Strong importance	(4, 5, 6)
dominant importance	(6, 7, 8)
Absolute importance	(8, 9, 10)

Fuzzy AHP method

According to Saaty (1980), the AHP is a decision making method used to solve a complex multi-criteria decision making problem.

There are different AHP methods in the literature. Among several methods, Chang method (1996) has been developed as a fuzzy extent analysis for the AHP, which has similar steps as that of Saaty's crisp AHP. In this paper, we make use of Chang's fuzzy extent analysis.

Let O= $\{o_1,o_2,...,o_n\}$ be an object set, and U= $\{g_1,g_2,...,g_m\}$ be a goal set. According to the Chang's extent analysis, each object is considered one by one, and for each object, the analysis is carried out for each of the possible goals, g_i. Therefore, m extent analysis values for each object are obtained and shown as follows:

$$\widetilde{M}_{g_i}^1, \widetilde{M}_{g_i}^2, \dots, \widetilde{M}_{g_i}^m, \text{ i=1, 2,…,n}$$

Let $\tilde{A}_k = (a_{ijk})n \times m$ be a fuzzy pairwise comparison matrix as assessed by the *k* decision maker, where $\tilde{a}_{ijk} = (l_{ijk}, m_{ijk}, u_{ijk})$ is the relative importance of element *i* to *j* represented by triangular fuzzy numbers. Each individual judgment matrix represents the opinion of one decision-maker. Aggregation is necessary to achieve a group agreement of decision-makers. Aggregation of the triangular fuzzy numbers in the group judgment matrix can be obtained by using the following equation:

$$l_{ij} = \min_k\{l_{ijk}\} \quad u_{ij} = \max_k\{l_{ijk}\} \quad m_{ij} = \left(\prod_{k-1}^{k} m_{ijk}\right)^{\frac{1}{k}} \qquad (3)$$

In order to perform a pairwise comparison among the parameters, a linguistic scale has been provided as Table 1. The steps of the Chang's extent analysis can be summarized as follows:

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

$$S_i = \sum_{j=1}^{m} \widetilde{M}_{g_i}^j \times \left[\sum_{i=1}^{n}\sum_{j=1}^{m} \widetilde{M}_{g_i}^j\right]^{-1} \qquad (4)$$

To obtain $\sum_{j=1}^{m} \widetilde{M}_{g_i}^j$, the addition operation of m extent analysis values for a particular matrix is performed such as:

$$\sum_{j=1}^{m} \widetilde{M}_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \qquad (5)$$

And to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} \widetilde{M}_{g_i}^j\right]^{-1}$, fuzzy addition operation of $\widetilde{M}_{g_i}^j$ (j=1,2,…,m) values is performed such as:

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\widetilde{M}_{g_i}^{j} = (\sum_{i=1}^{n} l_i\ , \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i) \qquad (6)$$

Then, the inverse of the vector is computed such as:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}\widetilde{M}_{g_i}^{j}\right]^{-1} = (\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}) \qquad (7)$$

Step 2. The degree of possibility of $\widetilde{M}_2$= (l_2,m2,u_2)≥ $\widetilde{M}_1$= (l_1,m_1,u_1) is defined as:

$$V(\widetilde{M}_2 \geq \widetilde{M}_1) = sup[\min(\widetilde{M}_1(x), \widetilde{M}_2(y))] \qquad (8)$$

This can be equivalently expressed as,

$$V(\widetilde{M}_2 \geq \widetilde{M}_1) = hgt(\widetilde{M}_1 \cap \widetilde{M}_2) = \mu_{M_2}(d) = \begin{cases} 1 & if\ m_2 \geq m_1 \\ 0 & if\ l_1 \geq u_2 \\ \frac{l_1-u_2}{(m_2-u_2)-(m_1-l_1)}, & otherwise \end{cases} \qquad (9)$$

Figure 3 illustrates V ($\widetilde{M}_2$≥ $\widetilde{M}_1$) for the case d for the case m_1<l_1<u_2<m_1, where d is the abscissa value corresponding to the highest crossover point between $\widetilde{M}_1$ and $\widetilde{M}_2$. To compare $\widetilde{M}_1$ and $\widetilde{M}_2$, we need both of the values V($\widetilde{M}_1 \geq \widetilde{M}_2$) and V($\widetilde{M}_2 \geq \widetilde{M}_1$).

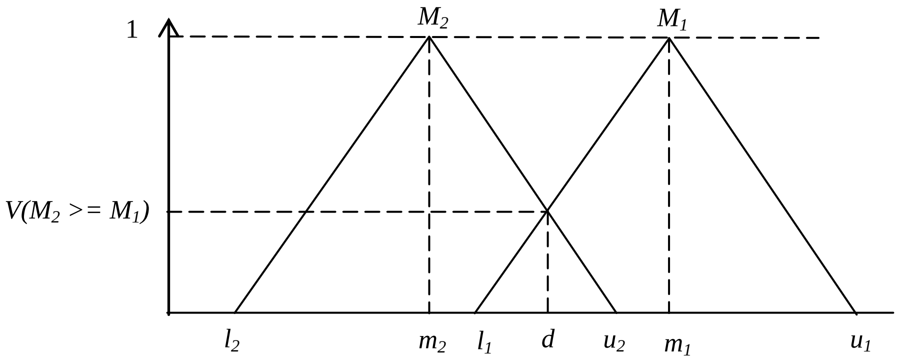

Fig. 3. The degree of possibility of $\widetilde{M}_1 \geq \widetilde{M}_2$

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) is defined as:

$$V(\widetilde{M} \geq \widetilde{M}_1, \widetilde{M}_2, \ldots, \widetilde{M}_k) = \min V(\widetilde{M} \geq \widetilde{M}_i), i = 1, 2, \ldots, k$$

Step 4. Finally the weight vector is calculated. Assume that $d(A_i) = \min(S_i \geq S_k)$ for $k = 1, 2, \dots, n \; and \; k \neq i$, then the weight vector is calculated by:

$$W' = [d'(A_1); d'(A_2); \dots; d'(A_n)]^T \quad (10)$$

Step 5. Via normalization, the normalized weight vectors are:

$$W = [d(A_1); d(A_2); \dots; d(A_n)]^T \quad (11)$$

VIKOR method

In the study, the VIKOR method is applied to determine the ranking of alternatives known as one applicable method for multi-criteria optimization of complex systems and can be implemented within the MADM (Opricovic & Tzeng, 2004). In contrast, the basic principle of the TOPSIS method is that the chosen alternative should have the "shortest distance" from the ideal solution and the "farthest distance" from the "negative-ideal" solution (Ertugrul & Karakasoglu, 2009). Here in the VIKOR method, the compromise solution is a feasible one which is the closest to the ideal, and a compromise means an agreement established by mutual concessions (Opricovic & Tzeng, 2007). The calculation processes for this method are as follows:

Step 1. Decision matrix is normalized via as fellow:

$$N_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}} \; ; i = 1, 2, \dots, m \; and \; j = 1, 2, \dots, n \quad (12)$$

Step 2. Identify the best rating f_j^* and the worst rating f_j^- values of all criterions.

$$f_j^* = \max_i x_{ij} \quad (13)$$

$$f_j^- = \max_i x_{ij} \quad (14)$$

where, candidates with a score $(f_1^*, f_2^*, \dots, f_n^*)$ and $(f_1^-, f_2^-, \dots, f_n^*)$ would be ideal and anti-ideal candidate, respectively.

Step 3. Calculate the values S_i and R_i for $(i = 1,2, \dots, m)$, which represent the average and the worst group scores for the alternative A_j respectively, by the following:

$$S_i = \sum_{j-1}^{n} \frac{w_j\left(f_i^* - f_{ij}\right)}{\left(f_i^* - f_i^-\right)} \tag{15}$$

$$R_i = \max_j \frac{w_j\left(f_i^* - f_{ij}\right)}{\left(f_i^* - f_i^-\right)} \tag{16}$$

Here, w_j are the relative importance weights of the criteria group attained by the FAHP method. The smaller values of S_i and R_i express the better average and the worse group scores for the alternative A_j, respectively.

Step 4. Compute the index value Q_i $(i = 1,2,\dots,m)$ by:

$$Q_i = \frac{v(S_i - S^*)}{(S^- - S^*)} + (1 - v)\frac{(R_i - R^*)}{(R^- - R^*)} \tag{17}$$

where

$$S^* = \min_i S_i, \quad S^* = \max_i S_i$$
$$R^* = \min_i R_i, \quad R^* = \max_i R_i$$

v is expressed as a weight for the strategy of maximum group utility, whereas $1-v$ is the weight of the individual regret. The compromise can be selected with voting by majority $(v > 0.5)$, with consensus $(v = 0.5)$, or with veto $(v < 0.5)$.

Step 5. Rank the alternatives, sorting by the values S, R and Q in increasing order

Step 6. Propose as a compromise solution the alternative ($A^{(1)}$) which is the best ranked by the measure Q (minimum) if the following two conditions are satisfied:

C1. Acceptable advantage:

$$Q\left(A^{(2)}\right) - Q\left(A^{(1)}\right) \geq \frac{1}{m-1}, \tag{18}$$

where $A^{(2)}$ is the alternative with second position in the ranking list by Q; m is the number of alternatives.

C2. Acceptable stability in decision making:

The alternative $A^{(1)}$ must also be the best ranked by S or/and R. This compromise solution is stable within a decision making process, which could be the strategy of maximum group utility (when $v > 0.5$ is needed), or ‘‘by consensus”$v \approx 0.5$, or ‘‘with veto” ($v < 0.5$). Here, v is the weight of decision making strategy of maximum group utility.

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

Alternatives $A^{(1)}$ and $A^{(2)}$ if only the condition C2 is not satisfied, or

Alternatives $A^{(1)}$; $A^{(2)}$; ... ; $A^{(M)}$ if the condition C1 is not satisfied; $A^{(M)}$ is determined by the relation $Q(A^{(M)}) - Q(A^{(1)}) \geq \frac{1}{m-1}$, for maximum M (the positions of these alternatives are ‘‘in closeness”).

TOPSIS method

To confirm the effectiveness of the developed FAHP-VIKOR method, the obtained result from the VIKOR has been compared with the FAHP-TOPSIS technique. In this section, the TOPSIS method is presented to solve linguistic performance evaluation problems. The method can be described as the follows:

Step 1. The decision-making matrix (D) by $N_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}}$ is converted to normalized decision-making matrix (ND) matrix.

Step 2. Calculate the weighted normalized decision matrix as follows:

$$V_{ij} = w_j \times N_{ij} \tag{19}$$

Step 3. Determine the positive and negative ideal solutions as follows:

$$A^* = \{v_1^*, v_2^*, \ldots, v_n^*\}, where\ v_j = \{\max_i v_{ij}\} \tag{20}$$

$$A^- = \{v_1^-, v_2^-, \ldots, v_n^-\}, where\ v_j = \{\min_i v_{ij}\} \tag{21}$$

Step 4. Calculate the distance of each alternative from A^* and A^- calculated as:

$$D_i^* = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^*)^2}, i = 1,2,...,m \tag{22}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}, i = 1,2,...,m \tag{23}$$

Step 5. Calculate the relative closeness to the ideal solution as follow:

$$CC_i = \frac{D_i^-}{D_i^- + D_i^*}, \{i = 1,2,3,...,m\} \tag{24}$$

Thus, the best alternative can be selected with CC_i closest to 1.

Experiments and Results

The proposed methodology for the ranking problem combined of the fuzzy AHP and the VIKOR methods consists of three basic phase: (1) identifying the criteria (financial ratios) and alternatives (basic metals companies) and also depict the (performance evaluation) problem as hierarchical structure (2) using the fuzzy AHP for computing criteria weight and (3) evaluating the performance of basic metals companies with the VIKOR and also the TOPSIS. Comparing the ranking of the both methods can help users achieve a safe solution.

The purpose of the empirical application is to illustrate the use of the proposed model. For the aim, in this section, a basic metals company's selection project derived from Iranian stock exchange list is described to illustrate the details of the proposed approach and show how it can be employed in practice. These companies include ones that are not included in the list of investment companies and have the transparency of information. They also are the most important mineral producers in Iran and attractive in terms of investment. This decision making problem has eight alternatives and 12 sub-criteria. The criteria and sub-criteria involved in ranking of the companies have been chosen according to the financial ratios list. The hierarchical structure for evaluating the basic metals companies is depicted in Figure 4.

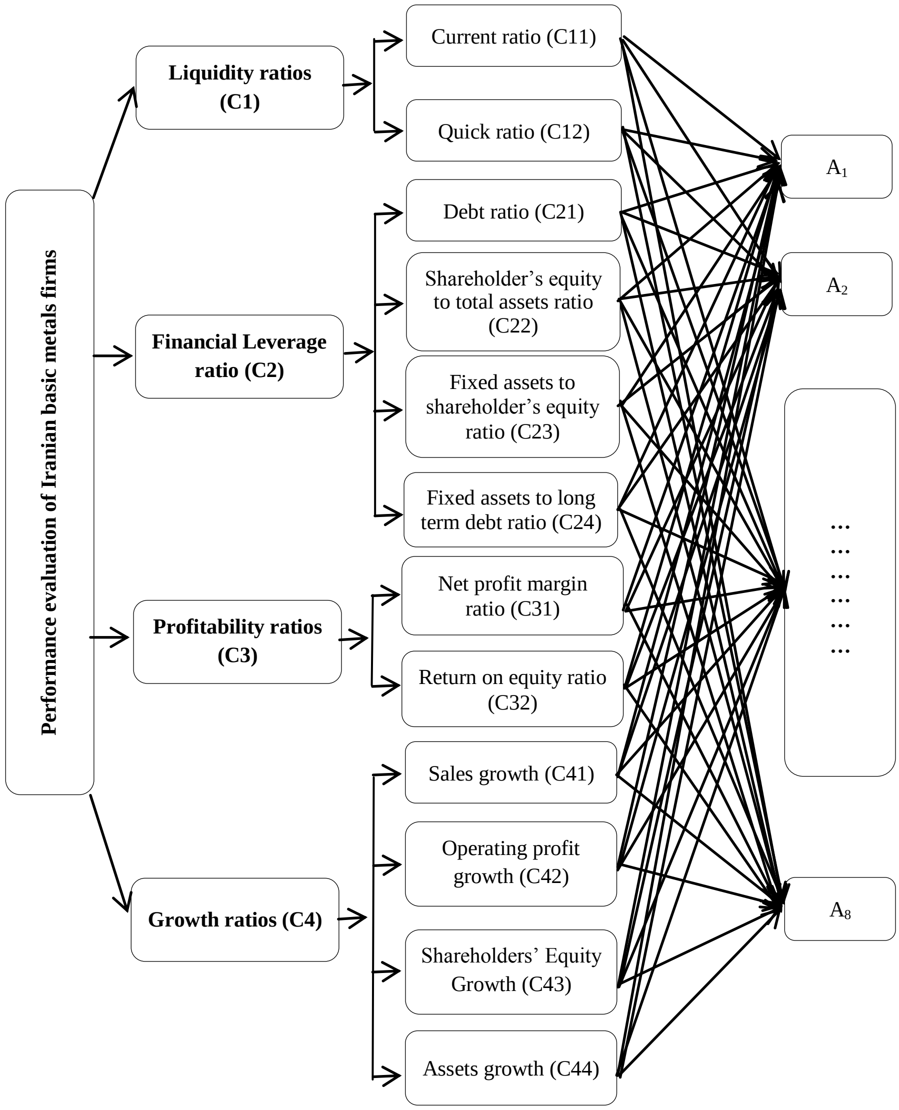

Fig. 4. Hierarchical structure for the performance evaluation

In the second phase, the fuzzy importance degrees of the four ratios by using fuzzy numbers are determined in respect to the decision makers' preferences. The team members are with the different financial viewpoint bringing particular concerns and interesting into the evaluation. Therefore, preference degree alters from one decision maker to another and the ratios were modified according to the decision maker's preference. In other word, the financial ratios have different significance for multi-area decision makers. For the purpose, a committee of three decision makers (D_1, D_2, D_3) is established including managers of the companies, investors and creditors.

Applying fuzzy AHP

After determining the criteria for evaluating the performance of Iranian basic metals firms and depicting the problem as hierarchical structure, now the FAHP method is applied to calculate the weight of the criteria applied in the VIKOR and the TOPSIS. In the fuzzy AHP method, each decision maker would separately perform pairwise comparison using Table 1. An aggregated pairwise comparison matrix was set by integrating the three decision makers' preferences through Eq. 3 as following:

Table 2. Aggregated fuzzy pairwise comparison matrix of criteria

Criteria	C1	C2	C3	C4
C1	(1, 1, 1)	(1, 1.67, 4)	(2, 3, 4)	(4, 5.67, 8)
C2	(0.25, 0.78, 1)	(1, 1, 1)	(0.25, 0.56, 1)	(0.13, 1.76, 6)
C3	(0.25, 0.33, 0.5)	(1, 2.33, 4)	(1, 1 , 1)	(0.17, 1.18, 4)
C4	(0.13, 0.18, 0.25)	(0.17, 4.73, 8)	(0.25, 2.78, 6)	(1, 1 , 1)

Then, the synthesis values were calculated in accordance with the FAHP method as following:

$S_1 = (8, 11.33, 17) \times (0.02, 0.035, 0.074) = (0.158, 0.391, 1.252)$
$S_2 = (1.63, 4.1, 9) \times (0.02, 0.035, 0.074) = (0.032, 0.141, 0.663)$
$S_3 = (2.42, 4.84, 9.5) \times (0.02, 0.035, 0.074) = (0.048, 0.167, 0.699)$
$S_4 = (1.54, 8.69, 15.25) \times (0.02, 0.035, 0.074) = (0.03, 0.3, 1.123)$

After calculating the values, big values of triangle numbers were calculated as fellow:

$V(S_1>S_2) = 1$ $V(S_1>S_3) = 1$
$V(S_1>S_4) = 1$ $V(S_2>S_1) = 0.67$
$V(S_2>S_3) = 0.96$ $V(S_2>S_4) = 0.8$
$V(S_3>S_1) = 0.71$ $V(S_3>S_2) = 1$
$V(S_3>S_4) = 0.83$ $V(S_4>S_1) = 0.91$
$V(S_4>S_2) = 1$ $V(S_4>S_3) = 1$

Then, priority weights, d(I), were calculated using:

$d^{/}$ (C_1) = Min ($S_1 \geq S_2$,S_3 , S_4) = Min (1, 1, 1) = 1
$d^{/}$ (C_2) = Min ($S_2 \geq S_1$,S_3 , S_4) = Min (0.67, 0.96, 0.8) = 0.67
$d^{/}$ (C_3) = Min ($S_3 \geq S_1$,S_2 , S_4) = Min (0.71, 1, 0.83) = 0.71
$d^{/}$ (C_4) = Min ($S_4 \geq S_1$,S_2 , S_3) = Min (0.91, 1, 1) = 0.91

Amounts of d(I) were used to create the final matrix:

$W^{/}$ = $(1, 0.67, 0.71, 0.91)^T$
$W^{/}$ = (0.3, 0.2, 0.22, 0.28)

According to the FAHP method, the most important financial ratios are liquidity ratio, and growth ratio, profitability ratio and financial leverage ratio, respectively.

Implementation of VIKOR and TOPSIS

After determining the individual criteria's weights, the VIKOR method is used for prioritizing performance of the basic metals companies. The data were extracted from the financial statements of companies. The financial data were extracted from the financial statements of companies exist in www.tsetmc.com. The normalized data for ranking the eight companies based on the 12 sub-criteria are listed in Table 3.

Table 3. Normalized data for the companies and weight of the criteria

Sub-Criteria	**C_{11}**	**C_{12}**	**C_{21}**	**C_{22}**	**C_{23}**	**C_{24}**	**C_{31}**	**C_{32}**	**C_{41}**	**C_{42}**	**C_{43}**	**C_{44}**
Zanjan Industry	0.41	0.21	0.39	0.31	0.39	0.22	0.19	0.50	0.35	0.45	0.40	0.43
Khouzestan Steel	0.20	0.48	0.26	0.38	0.34	0.09	0.45	0.31	0.24	0.05	0.42	0.15
Calcimine	0.27	0.34	0.16	0.48	0.34	0.09	0.17	0.37	0.20	0.38	0.20	0.07
Navard Aluminium	0.20	0.27	0.18	0.20	0.42	0.03	0.54	0.49	0.13	0.68	0.52	0.25
National Iranian Lead and Zinc	0.39	0.41	0.41	0.32	0.28	0.32	0.19	0.14	0.42	0.36	0.14	0.27
Yazd Fold	0.55	0.47	0.43	0.06	0.19	0.86	0.53	0.33	0.14	0.21	0.22	0.22
Mobarakeh Steel	0.29	0.10	0.46	0.54	0.45	0.20	0.36	0.32	0.21	0.12	0.35	0.76
Bahonar Copper	0.38	0.38	0.39	0.30	0.36	0.24	0.09	0.20	0.73	0.03	0.41	0.14

The best f_j^* and the worst f_j^-values of all sub-criterions are shown in Table 4. Then, the values of S, R and Q are calculated for all companies and are shown in Table 5. The weight for the strategy of maximum group utility (v) has been selected as 0.2, 0.5 and 0.8.

Table 4. Best and worst values of all criteria

	C_{11}	C_{12}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{41}	C_{42}	C_{43}	C_{44}
f_j^*	0.55	0.48	0.46	0.54	0.45	0.86	0.54	0.50	0.73	0.68	0.52	0.76
f_j^-	0.20	0.10	0.16	0.06	0.19	0.03	0.09	0.14	0.13	0.03	0.14	0.07

Table 5. Values of S, R and Q for all companies

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
Si	1.36	1.76	1.99	1.53	1.72	1.44	1.49	1.60
Ri	0.22	0.30	0.28	0.30	0.28	0.27	0.30	0.28
Qi(v=0.2)	0.00	0.33	0.34	0.25	0.25	0.16	0.24	0.21
Qi(v=0.5)	0.00	0.81	0.85	0.64	0.63	0.39	0.61	0.54
Qi(v=0.8)	0.00	1.30	1.35	1.02	1.01	0.63	0.97	0.86

For the TOPSIS method, we find the weighted normalized fuzzy decision matrix and presented in table 6.

Table 6. Weighted data of the 8 basic metals companies

	C_{11}	C_{12}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{41}	C_{42}	C_{43}	C_{44}
Zanjan Industry	0.12	0.06	0.08	0.06	0.08	0.04	0.04	0.11	0.10	0.13	0.11	0.12
Khouzestan Steel	0.06	0.14	0.05	0.08	0.07	0.02	0.10	0.07	0.07	0.01	0.12	0.04
Calcimine	0.08	0.10	0.03	0.10	0.07	0.02	0.04	0.08	0.06	0.10	0.06	0.02
Navard Aluminium	0.06	0.08	0.04	0.04	0.08	0.01	0.12	0.11	0.04	0.19	0.14	0.07
National Iranian Lead and Zinc	0.12	0.12	0.08	0.07	0.06	0.07	0.04	0.03	0.12	0.10	0.04	0.08
Yazd Fold	0.17	0.14	0.09	0.01	0.04	0.17	0.11	0.07	0.04	0.06	0.06	0.06
Mobarakeh Steel	0.09	0.03	0.09	0.11	0.09	0.04	0.08	0.07	0.06	0.03	0.10	0.21
Bahonar Copper	0.12	0.12	0.08	0.06	0.07	0.05	0.02	0.04	0.20	0.01	0.11	0.04

The positive ideal solution (A^*) and negative ideal solution (A^-) for each criteria determined by using the ranking values of the weighted normalized decision matrix is shown in Table 7.

Table 7. Ideal values (A^+) and anti-ideal values (A^-)

	C_{11}	C_{12}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{41}	C_{42}	C_{43}	C_{44}
A^*	0.17	0.14	0.09	0.11	0.09	0.17	0.12	0.11	0.20	0.19	0.14	0.21
A^-	0.06	0.03	0.03	0.01	0.04	0.01	0.02	0.03	0.04	0.01	0.04	0.02

Then, the distance of each alternative (D_i^* and D_i^-) from A^* and A^- are determined. Closeness index (CC_i) of each company to the ideal solution is calculated. Table 8 presents the distances and closeness coefficient.

Table 8. Closeness index and rank of the companies

	d^+	d^-	CC
Zanjan Industry	0.24	0.23	0.486
Khouzestan Steel	0.34	0.18	0.346
Calcimine	0.34	0.16	0.323
Navard Aluminium	0.31	0.26	0.450
National Iranian Lead and Zinc	0.27	0.20	0.422
Yazd Fold	0.29	0.26	0.474
Mobarakeh Steel	0.29	0.25	0.461
Bahonar Copper	0.31	0.23	0.420

An alternative with maximum CC_i is chosen or alternatives according to CC_i are ranked in descending order.

According to the verification rules of the VIKOR, if the two conditions (acceptable advantage and acceptable stability) were satisfied, the best rank can be assigned as a compromise solution. According to Table 8, Zanjan Industry over the second-best firm, in here Yazd Fold, was greater than the average distance $(Q(A^{(2)}) - Q(A^{(1)}) \geq \frac{1}{m-1})$. And also Zanjan Industry was ranked first in terms of *Si* and *Ri*. Thus, in our case this alternative satisfies both condition and chosen as the best company.

For the TOPSIS method, the ranking order of all alternatives can be determined and the optimum choice can be selected according to the closeness coefficient. The best alternative for the companies' selection problem is determined as Zanjan Industry. The alternatives are ranked as shown in Table 9.

Table 9. Ranking of the all companies

Rank	VIKOR					TOPSIS
	S	R	Q(v=0.2)	Q(v=0.5)	Q(v=0.8)	CC
Zanjan Industry	1	1	1	1	1	1
Khouzestan Steel	7	8	8	7	8	7
Calcimine	8	5	5	8	5	8
Navard Aluminium	4	6	4	6	4	4
National Iranian Lead and Zinc	6	4	3	5	3	5
Yazd Fold	2	2	2	2	2	2
Mobarakeh Steel	3	7	6	4	6	3
Bahonar Copper	5	3	7	3	7	6

According to Table 9, Zanjan Industry is chosen as the best company according to both the TOPSIS and the VIKOR. In the VIKOR method, Zanjan Industry also is best alternative in term of different values of v .

Conclusion

Today the increasing demand in construction and production segment is raising importance of the basic metals segment's performance not only for firms but also for investors and creditors. Performance of the firms can usually be summarized in form of financial ratios provided useful quantitative financial information. Thus, in this multipart market, they can evaluate the actions of the firms and recognize their competitive strength and weakness. The main objective of this study was to use financial criteria to evaluate performance of Iranian basic metals firms using an effective decision making method. In this paper, the firms in Iran's basic metals industry have been ranked using the hybrid FAHP-VIKOR method and also verified by the TOPSIS method. Thus, this is a work afforded to apply the methods to evaluate the firms in a growing industry in a comparative framework. With the help of the analysis framework, proposed in the paper, Zanjan Industry has been identified as the highest ranked among the eight basic metals firms in Iran. In future studies, other methods can also be used for evaluating the performance of the basic metals companies such as ELECTRE, PROMETHEE and ORESTE comparatively. Moreover, the BSC perspectives can be also integrated comprehensively instead of only using the financial perspective. It would also be applicable to consider the application of the method presented in this study to deal with evaluation of other segments.

References

Ardekani, S.S., Sharifabadi, A. M., Jalaly, M. & Zarch, M. E., (2013). “Comprehensive Performance Evaluation Using FAHP-FVIKOR Approach Based on Balanced Scorecard (BSC): A Case of Yazd's Ceramic and Tile Industry”. *Iranian Journal of Management Studies*, 6(2), 81-104.

Alvandi, M., Fazli, S., Gholamreza Kordestani, G. & Rezaei, R., (2013). “Evaluation and ranking the companies of auto and spare parts industry accepted in Tehran Stock Exchange using FAHP and VIKOR”. *International Research Journal of Applied and Basic Sciences*, 5(7), 883-890.

Al-Ahmari, A.M.A. (2008). “Evaluation of CIM technologies in Saudi industries using AHP”. *International Journal of Advanced Manufacturing Technology*, 34(7-8), 736–747.

Akbari, V., Rajabi, M., Chavoshi, S. & Shams, R. (2008). “Landfill site selection by combining GIS and fuzzy multi-criteria decision analysis, case study: Bandar Abbas, Iran”. *World Applied Sciences*, 3(1), 39-47.

Ertugrul, I., Karakasoglu, N. (2009). “Performance evaluation of Turkish cement companies with fuzzy analytic hierarchy process and TOPSIS methods”. *Expert* Systems *with Applications*, 36(1), 702–715

Fu, H. P., Chu, K. K., Chao, P., Lee, H. H. & Liao, Y. C. (2011). “Using fuzzy AHP and VIKOR for benchmarking analysis in the hotel industry”. *The Service Industries Journal*, 31(14), 2373–2389.

Hosseini-Nia, H. & Farrokh, M. (2014). “A Vendor Selection Model Based on ANP and VIKOR under Fuzzy Environment”. *Global Journal of Management Studies and Researches*, 1(2), 62-72.

Hwang, C. L. & Yoon, K. (1981). *Multiple attribute decision making-methods and applications: A state of the art survey*. Springer-Verlag.

Kahraman, C., Cebeci, U. & Ruan, D. (2004). “Multi-attribute comparison of catering service companies using fuzzy AHP: The case of turkey”. *International Journal of production Economics*, 87(2),171-184.

Kabak, M., Serhat, B. & Yigit, K. (2012). “A fuzzy hybrid MCDM approach for professional selection”. *Expert Systems with Applications*, 39(3), 3516–3525.

Kassaee, M., Farrokh, M. & Nia, H.H. (2013). “Integrated hybrid MCDM approach for vendor selection problem (Case Study: Iran Khodro)”. *Business and Management Horizons*, 1(1), 153–170.

Liu, H. C., Mao, L. X., Zhang, Z. Y. & Li, P. (2013). “Induced aggregation operators in the VIKOR method and its application in material selection”. *Applied Mathematical Modelling,* 37(9), 6325-6338.

Liu, H. C., You, J. X., Fan, X. J. & Chen, Y. Z. (2014). “Site selection in waste management by the VIKOR method using linguistic assessment”. *Applied Soft Computing*, 21, August, 453-461.

Lee, J., Cho, H. & Kim, Y. S. (2015). “Assessing business impacts of agility criterion and order allocation strategy in multi-criteria supplier selection”. *Expert Systems with Applications*, 42(3), 1136–1148.

Opricovic, S. & Tzeng, G.H. (2007). “Extended VIKOR method in comparison with outranking methods”. *European Journal of Operational Research*, 178(2), 514–529. doi:10.1016/j.ejor.2006.01. 020.

Opricovic, S. & Tzeng, G.H. (2004). “Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS”. *European Journal of Operational Research*, 156(2), 445–455. doi:10.1016/S0377-2217(03)00020-1.

Rezaei, J., Fahim, P. B. M. & Tavasszy, L. (2014). “Supplier selection in the airline retail industry using a funnel methodology: Conjunctive screening method and fuzzy AHP”. *Expert Systems with Applications*, 41(18), 8165-8179.

Shaverdia, M., Heshmatib, M. R., Ramezanic, I. (2014). Application of Fuzzy AHP Approach for Financial Performance Evaluation of Iranian Petrochemical Sector, *Procedia Computer Science*, 31, 995-1004.

Singh, A.J. & Schmidgall, R. S. (2002). “Analysis of financial ratios commonly used by US lodging financial executives”. *Journal of Retail and Leisure Property*, 2(3), 201–213.

Sanayei, A., Mousavi, S.F. & Yazdankhah, A. (2010). “Group decision making process for supplier selection with VIKOR under fuzzy environment”. *Expert Systems with Applications*, 37(1), 24–30.

Saaty, T.L. (1980). *The analytic hierarchy process*. McGraw-Hill, New York.

Seçme, N. Y., B .A. & C. Kahraman, (2009). “Fuzzy Performance Evaluation in Turkish Banking Sector Using Analytic Hierarchy Process and TOPSIS”. *Expert Systems with Applications*, 36(9), 11699–11709.

Tehrani, R. (2005). *Financial management*. Negahe Denesh Publishers, Tehran. ISBN: 964-7119-49-6.

Vahdani, B., Mousavi, S. M., Hashemi, H., Mousakhani, M. & Tavakkoli-Moghaddam, R. (2013). “A new compromise solution method for fuzzy group decision-making problems with an application to the contractor selection". *Engineering Applications of Artificial Intelligence*, 26(2), 779-788.

Wang, Y.J. (2008). "Applying FMCDM to evaluate financial performance of domestic airlines in Taiwan". *Expert Systems with Applications*, 34(3), 1837–1845.

Wu, H., Tzeng, G. & Chen, Y. H. (2009). "A Fuzzy MCDM Approach for Evaluating Banking Performance Based on Balanced Scorecard". *Expert Systems with Applications*, 36(6), 10135–10147.

Zouggari, A. & Benuoucef, L. (2011). *Multi-criteria group decision supplier selection problem using fuzzy TOPSIS based approach*. EUSFLATLFA, Aix-les-Bains, pp 628–635.

Alam-Tabriz, A., Rajabani, N. & Farrokh, M. (2014). "An Integrated Fuzzy DEMATEL-ANP-TOPSIS Methodology for Supplier Selection Problem". *Global Journal of Management Studies and Researches*, 1(2), 85- 99.

Zadeh, L.A. (1975). "The concept of a linguistic variable and its application to approximate reasoning–IN". *Information Sciences*, 8(3), 199–249.

Zadeh, L.A. (1965). "Fuzzy sets". *Information and Control*, 8(3), 338–353.