An integrated fuzzy MCDM approach, and analysis, to the evaluation of the financial performance of Iranian cement companies

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Abstract: In today's highly competitive environment, suitable appraisal of a company's performance is of vital importance not only for the company but also for its suppliers and customers. The main objectives of this study were to analyze the financial ratios of Iranian cement-producing companies and to develop a fuzzy model to evaluate financial performance. The proposed fuzzy approach is based on fuzzy analytical hierarchy process (FAHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. In contrast to other studies in the literature, in the present study the FAHP method was used in determining the weightage of criteria by decision makers, and the ranking of the companies was determined by the TOPSIS method. The proposed combined method was used to evaluate the performance of eight Iranian cement companies listed in the Tehran Stock Exchange using data from their financial tables, and subsequent ranking of these companies. The final results of the analysis revealed performance ranking of companies Sabhan, Sarab, Sedasht, Safar, Sekaroun, Sakarma, Sanir and Sahrmoz with priority scores of 0/55, 0/51, 0/50, 0/49, 0/42, 0/37, 0/36 and 0/33, respectively. The results indicate an overall performance ranking because the weights of the criteria were determined by decision makers with different experiences, positions and proficiencies. If it is desired, it is possible to make an evaluation only for creditors, investors or shareholders, however, in such cases the weights of the criteria will vary and the ranking of the companies can change. The proposed method can also be applied tothe evaluation of companies in other sectors.

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1. Introduction

Recently, the demand for cement has increased in parallel with an increase in the construction sector. Interest in the cement sector has increased with the rise in cement demand. This increase is based on the economic stability, decrease in the interest and exchange rates and increase in the popularity of the mortgage system. Iran is the fifth largest manufacturer in the cement market of the Middle East; Iran has 52 cement companies of which29are listed in the Tehran Stock Exchange.

In the present study, performance of Iranian cement companies was evaluated using financial ratios. Wang [1] evaluated financial performance of domestic airlines in Taiwan with the fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. Zouggari and Benuoucef [2] analyzed supplier selection by Multi-criteria Group Decision Fuzzy TOPSIS. Azadeh et al. [3] used a unique version of fuzzy multi-criteria decision making (MCDM) for productive operators' assignment in cellular manufacturing systems.

Al-Ahmari [4] used AHP to evaluate technologies. Tavana and Hatami-Marbini [5] proposed a framework of three different variations of TOPSIS including conventional, adjusted and a modified TOPSIS method. Talluri and Narasimhan [6] have worked on vendor evaluation with performance variability. Ertugrul and Karakasoglu [7] developed a model for evaluating the performance of Turkish cement companies. Zavadskas and Turskis [8] performed investigations on MCDM methods in economics. Sheu [9] developed an integrated model, fuzzy analytical hierarchy process (FAHP) and fuzzy TOPSIS for mode choice of global logistics. Yen and Chang (2009) developed a new fuzzy MCDM algorithm by extending the concept of the degree of optimality to incorporate criteria weights in the distance measurement. Surekha et al. [10] used fuzzy logic in forward and reverse mappings of the cement-bonded sand mould system.

Byun and Lee [11] modified the TOPSIS method for the selection of a rapid prototyping process. Mahdavi et al. [12] investigated the general fuzzy TOPSIS model in MCDM. Yong [13] studied plant location selection based on fuzzy TOPSIS. Yurdakul and Tansel [14] applied a correlation test to criteria selection for MCDM.

However, this is the first study on Iranian cement companies and it is different from other studies in the literature because two methods, FAHP and TOPSIS, were integrated in this study. FAHP is utilized for determining the weights of the criteria, and the ranking of the companies is determined by TOPSIS method.

The paper is organized as follows: In the second section, the ratios used in the performance evaluation of the companies are briefly explained. In the third section, fuzzy logic terms, including fuzzy numbers and algebraic operations with fuzzy numbers, are explained. Moreover, summaries of the FAHP method and the TOPSIS method are provided. An application in the cement sector is illustrated in Section four. Finally, in Section five, the results of the application and suggestions for future studies are presented.

2. Financial ratios

Economic ratios are suitable indicators to assess the financial situation and performance of a firm. Financial ratios can be categorized according to the information they afford. The following commonly used ratios were used in our application (Table 1).

2.1 Liquidity ratio

Liquid assets are those that can be easily converted to cash at a fair market value and a company's liquidity position deals with the following question: Will the firm be able to meet its current obligations [15, 16]? Briefly, liquidity ratios provide information about a company's ability to meet its short-term obligations (Table 1).

Current ratio:The current ratio is the ratio of current assets to current liabilities. It is a key measure in determining a company's ability to pay current debts and is a good measure of the adequacy of working capital [17, 18].

Quick ratio:The quick ratio is a more inflexible measure of liquidity than the current ratio. It recognizes that a company's inventories are often one of its least liquid current assets. This ratio is calculated by deducting inventories from current assets and dividing the remainder by current liabilities [19].

2.2 Financial leverage ratio

The financial leverage ratio indicates company's capacity to meet short- and long-term debt obligations. This ratio provides evidence on the extent to which non-equity capital is used in a firm and the long-term ability of a firm to meet payments to non-equity suppliers of capital [16].

Debt ratio:The debt ratio indicates what proportion of the company's assets is being financed through debt. Debt encompasses all short-term liabilities and long-term borrowings [19]

Shareholder's equity to total assets ratio*:*This ratio indicates what proportion of the company'stotal assets are financed through shareholders' equity. This ratio shows the financial power of the firm to the creditors that give long-term loans [16, 20].

Fixed assets to shareholder's equity ratio*:*This ratio shows what proportion of the company's fixed assets is financed through shareholders' equity [16, 20].

Fixed assets to long term debt ratio: If this ratio is above1.0, then it means the firm has fixed assets more than $1.0 in contrast to company's$1.0 long-term debt; this situation is not preferred by long-term creditors [20].

2.3 Activity ratios

Activity ratios indicate how much a firm has invested in a particular type of asset relative to the revenue the asset is producing [18].

Account receivable turnover ratio: This ratio shows the number of times accounts receivable are paid and reestablished during the accounting period [16].

Inventory turnover ratio: This ratio measures the number of times the average inventory had to be substituted during the period. Apparently, the higher the turnover, the less time that has elapsed between the date of purchase and date of sale [17, 18].

Current asset turnover ratio: This is the ratio of activity which shows the performance of assets. This ratio will increase as more business activity is indicated [19, 20].

Total asset turnover ratio: This ratio indicates how effectively a firm uses its total resources to generate sales and is a summary measure influenced by each of the activity ratios [20].

2.4 Profitability ratios

Profitability refers to the ability of a firm to generate revenues in excess of expenses [16]. Profitability ratios offer several different measures of the firm's success at generating profits [19].

Net profit margin ratio: This ratio measures how profitable a company's sales are after all expenses, including taxes and interest, have been deducted [18].

Return on equity ratio: This ratio measures the rate of return on the ownership interest of the common stock owners. Return on equity is viewed as one of the most important financial ratios [18,19].

2.5 Growth ratios

Growth ratios indicate how well the position of the firm is in the industry. It is classified into Sales growth, Operating profit growth, Shareholders' equity growth, and Assets growth [18].

A total of 16frequently used financial ratios were used in the present study (Table 1).

Table 1: Classes of financial ratios used in the present study

Financial Ratios	Types & Computation of Ratios
Liquidity Ratios	Current Ratio = Current Assets / Current Liabilities
	Quick Ratio = (Current Assets – Inventories) / Current Liabilities
Financial Leverage Ratios	Debt Ratio= Total Debt/Total Assets
	Shareholder's Equity to Total Assets Ratio = Shareholder's Equity/Total Assets
	Fixed Assets to Shareholder's Equity Ratio = Fixed Assets/Shareholder's Equity
	Fixed Assets to Long Term Debt Ratio = Fixed Assets/Long Term Debt
Activity Ratios	Accounts Receivable Turnover = Total Net Sales/Accounts Receivables
	Inventory Turnover = Costs of Goods Sold/Average Inventory Current asset turnover ratio = sales/Currentassets
	Total Asset Turnover Ratio = Sales/Total Assets
Profitability Ratios	Net Profit Margin Ratio =Earnings after taxes/Sales
	Return on Equity =Net Profit before Taxes/Net worth Growth ratios
Growth ratios	Sales Growth= $[(s_t - s_{t-1})/(s_{t-1})] * 100$ S_t=Net sales of the current period St_1 = Net sales of the previous period
	Operating Profit Growth = $[(P_t - P_{t-1})/(P_{t-1})] * 100$ Pt = Operating profit with current prices Pt_1 = Operating profit of the previous period
	Shareholders' Equity Growth = $[(E_t - E_{t-1})/(E_{t-1})] * 100$ Et = Shareholders' Equity of the current period Et_1 = Shareholders' Equity of the previous period
	Assets Growth = $[(A_t - A_{t-1})/(A_{t-1})] * 100$ At = Assets of the current period At_1 = Assets of the previous period

3. Research methodology

3.1 Fuzzy sets and fuzzy numbers

3.1.1 Fuzzy sets

Fuzzy set theory was introduced to deal with the ambiguity of human thought [21]. Moreover, crisp sets only allow full membership or no membership at all, whereas fuzzy sets allow fractional membership. In other words, an element may incompletely belong to a fuzzy set [22].

Traditional set theory is built on the fundamental concept of a set of which there are either members or non-members. A sharp, crisp and unmistakable difference exists between a member and non-member for any well-defined set of entities in this theory, and there is a very accurate and clear boundary to indicate if an entity belongs to the set. But many real world requests cannot be labeled and handled by classical set theory [23, 24]. Zadeh [21] proposed the use of values ranging from 0 to 1 for showing the membership of the objects in a fuzzy set. Complete non-membership is represented by 0, and complete membership as 1. Values between 0 and 1 represent intermediate degrees of membership [25].

''Not very clear'', ''probably so'', and ''very likely'' are terms of expression which can be heard very often in daily life and their commonality is that they are more or less tainted with uncertainty. With different daily decision-making problems of diverse intensity, the results can be misleading if the fuzziness of human decision making is not taken into account [24, 26].

Furthermore, Fuzzy sets theory, providing a much wider frame than classic sets theory, has been contributing to the capability of reflecting the real world [22, 27]. Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling uncertain systems in industry, nature and humanity; and facilitate commonsense reasoning in decision making in the absence of complete and precise information. Their role is significant when applied to complex phenomena not easily described by traditional mathematical methods, especially when the goal is to find a good approximate solution [28]. Fuzzy set theory is a better means for modeling imprecision arising from mental phenomena which are neither random nor stochastic. Human beings are heavily involved in the process of decision analysis. A rational approach toward decision making should take into account human subjectivity, rather than employing only objective probability measures; this attitude towards imprecision of human behavior led to the study of a new decision analysis field of fuzzy decision making [24, 29].

3.1.2 Fuzzy numbers

A fuzzy number $\widetilde{M}$ is a convex normalized fuzzy set $\widetilde{M}$ of the real line R [30]; it exists such that, "$X_0 \in$R" with $U_{\widetilde{M}}(X_0)$ =1, so that X_0 is called the mean value of $\widetilde{M}$; and $U_{\widetilde{M}}(X_0)$ is piecewise continuous.

It is possible to use different fuzzy numbers according to the situation. Generally, in practice, triangular and trapezoidal fuzzy numbers are used [24]. In applications it is often convenient to work with triangular fuzzy numbers (TFNs) because of their computational simplicity, and they are useful in promoting representation and information processing in a fuzzy environment. In this study TFNs in the FAHP are adopted.

TFNs can be expressed as (l, m, u). The parameters l, m, and u respectively, indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. A "TFNs" is shown in Fig.1 [24, 31].

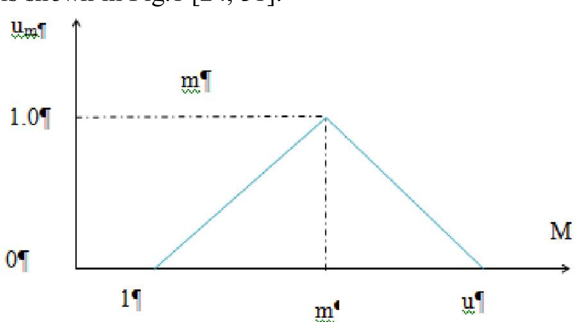

Fig. 1.Triangular fuzzy number

There are various operations on TFNs; however, three important operations used in this study are illustrated here. If we define, two positive TFNs (l1, m1, u1) and (l2, m2, u2) then:

$(l_1, m_1, u_1) + (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$

$(l_1, m_1, u_1) \times (l_2, m_2, u_2) = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2)$ (2)

$(l_1, m_1, u_1)^{-1} \approx (1/u_1, 1/m_1, 1/l_1)$

3.2FAHP application

AHP is a widely used multiple criteria decision-making tool first proposed by Saaty [32].AHP, since its invention, has been a tool at the hands of decision makers and researchers; and it is one of the most widely used multiple criteria decision-making tools[33]. Even though AHP is used to capture an expert's knowledge, the customary AHP still cannot really reflect the human thinking style [34–36]. The traditional AHP method is knotty in that it uses an exact value to express the decision maker's opinion in an evaluation of alternatives [37].In addition, the AHP method is often criticized due to its use of an unbalanced scale of judgments and its inability to adequately handle the inherent uncertainty and imprecision in the pairwise comparison process [31]. To overcome these shortcomings, FAHP was developed to solve the hierarchical problems.

Decision makers usually find greater confidence to give interval judgments than fixed value judgments [38] because usually they are unable to explicitly state their preference about the fuzzy nature of the comparison process [33–35]. In this paper we propose to use FAHP for determining the weights of the main and sub-criteria.

3.3 A review of FAHP

There are several fuzzy AHP methods and applications proposed in the literature. The first study that applied a fuzzy logic principle to AHP was proposed by Van Laarhoven and Pedrycz [39]. Buckley [40] introduced trapezoidal fuzzy numbers to define the decision maker's evaluation of alternatives with respect to each criterion, whereas Van Laarhoven and Pedrycz [39] used TFNs. Chang [41] presented a new method for handling FAHP, with the use of TFNs for pairwise comparison scale of FAHP, and the use of the extent analysis method for the synthetic extent values of the pairwise comparisons [38].

Triantaphyllou and Lin [42] presented the development of fuzzy multi-attribute decision-making methods. These methods are based on AHP, the weighted sum model, the weighted product model and the TOPSIS method. Deng (1999) proposed a fuzzy approach for undertaking qualitative multi-criteria analysis problems in a simple and up-front manner [43].

Chou and Liang [44] proposed a fuzzy MCDM model by combining fuzzy set theory, AHP and concept of entropy, for the evaluation of shipping company performance. Talluri [45] supported it in buyer–seller selection. Bozdag et al. [46] proposed four different fuzzy multi-attribute group decision-making methods to select the best computer integrated manufacturing system. Chang et al. [47] developed a methodology for performance evaluation of airports. They used the gray statistics method in selecting the criteria, and FAHP method in determining the weights of criteria. And finally they adopted fuzzy synthetic and TOPSIS approach for the ranking of airport performance. Kahramanet al. [34] used FAHP to select the best supplier firm providing the most satisfaction for the criteria determined. Kahraman et al. [34] used four different fuzzy multi-attribute group decision-making approaches for facility location selection. Hsieh et al.[48] presented a fuzzy multi-criteria analysis approach for the selecting of planning and design alternatives in public office buildings. Yong [13] studied plant location selection based on fuzzy TOPSIS. Mahdavi et al. [12] investigated general fuzzy TOPSIS model in MCDM. Byun and Lee [11] modified the TOPSIS method for the selection of a rapid prototyping process.

Buyukozkan et al. [49] selected logistics with two-phase fuzzy MCDM in a case study. Dodangeh et al. [50] proposed a model by designing a fuzzy MCDM model for best selection of areas improvement in a European Foundation for Quality Management model. Doumpos and Zopounidis [51] presented a review study on preference disaggregation and statistical learning for multi-criteria decision support. Also, Yeh and Chang [52] proposed a model to evaluate fuzzy group MCDM. Yurdakul and Tansel [14] applied a correlation test to criteria selection for MCDM. Yen and Chang [52] developed a new fuzzy MCDM algorithm by extending the concept of the degree of optimality to incorporate criteria weights in the distance measurement. Moreover, other authors (e.g. [45, 53–55]) have worked on MCDM.

Tang and Beynon [56] used the FAHP method for the application and development of a capital investment study. They tried to select the type of fleet car to be adopted by a car rental company. Tolga et al. [57] used fuzzy replacement analysis and AHP in the selection of an operating system. The economic part of the decision process had been developed by fuzzy replacement analysis. Tuysuz and Kahraman [58] provided an analytical tool to evaluate the project risks under incomplete and vague information using FAHP. Haq and Kannan [59] proposed a structured model for evaluating vendor selection using AHP and FAHP. Chan and Kumar [60] proposed a model for providing a framework for an organization to select the global supplier by considering risk factors. They used fuzzy extended AHP in the selection of global supplier. Ertugrul and Karakaşog [61] applied fuzzy AHP and fuzzy TOPSIS methods with a comparative approach for facility location selection. Moreover a fuzzy model combining FAHP and TOPSIS was used to evaluate the performance of companies using financial ratios [7]. Aydogan [62] proposed a performance measurement model for Turkish aviation firms using the rough-AHP and TOPSIS methods under a fuzzy environment. Joshi et al. [63] developed a benchmarking framework (Delphi-AHP-TOPSIS) that evaluates the cold chain performance of a company. They claimed that this framework also facilitates the decision makers to better understand the complex relationships of the relevant cold chain performance factors in decision making.

In addition, several researchers have combined non-economic elements and financial factors by using a FAHP approach [64–74].

3.4 Procedure of FAHP

In this study the extent FAHP, which was originally introduced by Chang [41], was utilized. Let X = {x1, x2, x3, . . . ,xn} an object set, and G = {g1, g2, g3, . . . , gn} be a goal set. Referring to the method of Chang's extent analysis, each object is taken and extent analysis for each goal is performed correspondingly. Thus, m extent analysis values for each object were obtained, with the following signs:

$$M_{gi}^{1}, M_{gi}^{2}, \ldots, M_{gi}^{m}, \; i= 1.2\ldots.n \qquad (2)$$

Where M_{gi}^{1} (j= 1, 2, …, m) are all TFN_S

The steps in Chang's extent analysis [41] are illustrated in Table 2.

Table 2: Process of FAHP operations

Steps	Details
Step 1	**The value of fuzzy synthetic extent with respect to the i_{th} object is defined as:** $s_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes [\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1}$ (3) To obtain $\sum_{j=1}^{m} M_{gi}^{j}$ the fuzzy addition operation of m extent analysis values for a particular matrix is performed such as: $\sum_{j=1}^{m} M_{gi}^{j} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j)$ (4) *and to obtain* $[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1}$, *the fuzzy addition operation of* M_{gi}^{j} *(j=1, 2, . . . , m) values is performed such as:* $\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j)$ (5) *and then the inverse of the vector above is computed, such as* $[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1} = (\frac{1}{\sum_{i=1}^{m} u_i}, \frac{1}{\sum_{i=1}^{m} m_i}, \frac{1}{\sum_{i=1}^{m} l_i})$ (6)

Step 2	**As M1 = (l_1, m_1, u_1) and M2 = (l_2, m_2, u_2) are two triangular fuzzy numbers, the degree of possibility of M2 = (l_2, m_2, u_2) ≥ M_1 = (l_1, m_1, u_1) is defined as:** $V(M_2 \geq M_1) = \sup [\min (u_{m1}(x), u_{m2}(y))] \quad y \geq x$ (7) and can be expressed as follows: $V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = u_{m2}(d)$ (8) 1 if $M2 \geq M_1$ (9) 0 $I_1 \geq u_1$ $\dfrac{I_1 - u_2}{(m_2 - u_2) - (m_1 - I_1)}$
Step 3	**The degree possibility for a convex fuzzy number to be greater than k convex fuzzy Mi (i = 1, 2. . . k) numbers can be defined by:** $V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1); (M \geq M_2); \ldots; (M \geq M_K)]$ (10) Assume that $d(Ai) = \min V(S_i \geq S_k)$ for k = 1, 2, …, n; $k \neq i$ Then the weight vector is given by $W' = [d'(A_1); d'(A_2); \ldots; d'(A_n)]^T$ (11) where A_i (i = 1, 2, . . . , n) are n elements.
Step 4	**Via normalization, the normalized weight vectors are** $W' = [d(A_1); d(A_2); \ldots; d(A_n)]^T$ (12) where W is a non-fuzzy number.

Fig. 2 [41] illustrates Equation 10 (Table 2), where d is the ordinate of the highest intersection point D between uM1 and uM2. To compare M1 and M2, we need both the values of V (M1 ≥ M2) and V (M2 ≥ M1).

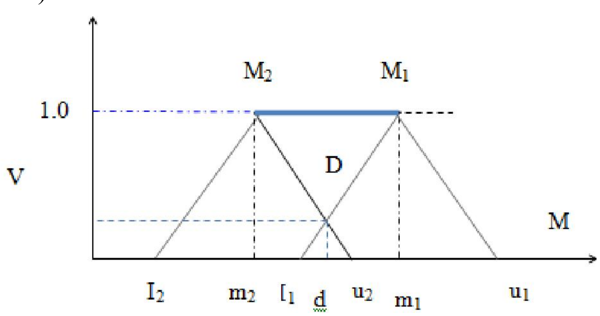

Fig. 2. The interconnection between M1 and M2

3.5 TOPSIS method

TOPSIS is a useful multiple attribute decision making technique to manage real-world problems. The TOPSIS method was first proposed by Hwang and Yoon [75]. According to this technique, the best alternative would be the one that is nearest to the positive ideal solution and farthest from the negative ideal solution [76]. The positive ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria [77]. In short, the positive ideal solution is composed of all best attainable values of the criteria, whereas the negative ideal solution consists of all worst attainable values of the criteria [37]. In this paper the TOPSIS method was used for determining the final ranking of the cement companies. The TOPSIS steps are outlined in Table 3.

Table 3: Process of TOPSIS Operations

Steps	Details
Step 1	**Step 1.** Decision matrix is normalized via Eq. $N_{ij} = \dfrac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}$ i= 1, 2,k . . . ,n and j= 1, 2, . . . , J (13)
Step 2	**Step 2.** Weighted normalized decision matrix is formed: $Vij = ai \times N_{ij}$ i= 1, 2, . . . ,n and j= 1, 2, . . . , J (14)
Step 3	**Step 3.** Positive ideal solution (PIS) and negative ideal solution (NIS) are determined: $A^* = \{V_1^*, V2^*, \ldots, V_n^*\}$ maximum values (15) $A^- = \{V_1^-, V_2^-, \ldots, V_n^-\}$ minimum values (16)

Step 4	**Step 4.** The distance of each alternative from PIS and NIS are calculated: $$d_j^+ = \sqrt{\sum_{j=1}^{n}(V_{ij} - V_j^+)^2} \quad ,i = 1,2,...,m \qquad (17)$$ $$d_j^- = \sqrt{\sum_{j=1}^{n}(V_{ij} - V_j^+)^2} \quad ,i = 1,2,...,m \qquad (18)$$
Step 5.	The closeness coefficient of each alternative is calculated: $$CL_i^* = \frac{d_i^-}{d_i^- + d_i^+} \quad , i= 1, 2,..., m \qquad (19)$$
Step 6.	By comparing CCi values, the ranking of alternatives are determined.

4. Present application

The aim of the present study was to evaluate the performance of eight Iranian cement companies listed in the Tehran Stock Exchange, with the help of financial ratios. Firstly, financial ratios were calculated for each firm. Then, three decision makers from different areas of proficiency evaluated the importance of these ratios with the help of questionnaires. FAHP was utilized for determining the weights of main- and sub-criteria. Finally, the TOPSIS method was used to evaluate the performance of the cement companies, considering financial ratios and weights of the criteria. The companies were then ranked according to their general performance. Research framework is shown in Fig.3.

A total of 16financial ratios were used to evaluate the cement companies (Fig.4). Here, the ratios that form each sub-criterion had different degrees of preference. During the formation of the model, the places of the numerator and denominator were changed for small value preferences. In this way, big values gain a more preferable situation in this ratio. Preference degree changes from one decision maker to another and the ratios were revised according to the decision maker's preference.

As the groups inside and outside the firm have varying objectives and expectations, they approach financial analysis from different perspectives [43]. So, financial ratios have different levels of significance for different users. For instance, managers of companies are especially interested in activity and growth ratios, whereas investors and shareholders focus on profitability ratios, and creditors are concerned with financial leverage ratios [19]. For this reason, three decision makers were selected from different areas and these decision makers evaluated the criteria. It was proposed that FAHP take the decision makers' subjective judgments into consideration to reduce uncertainty and vagueness in the decision process.

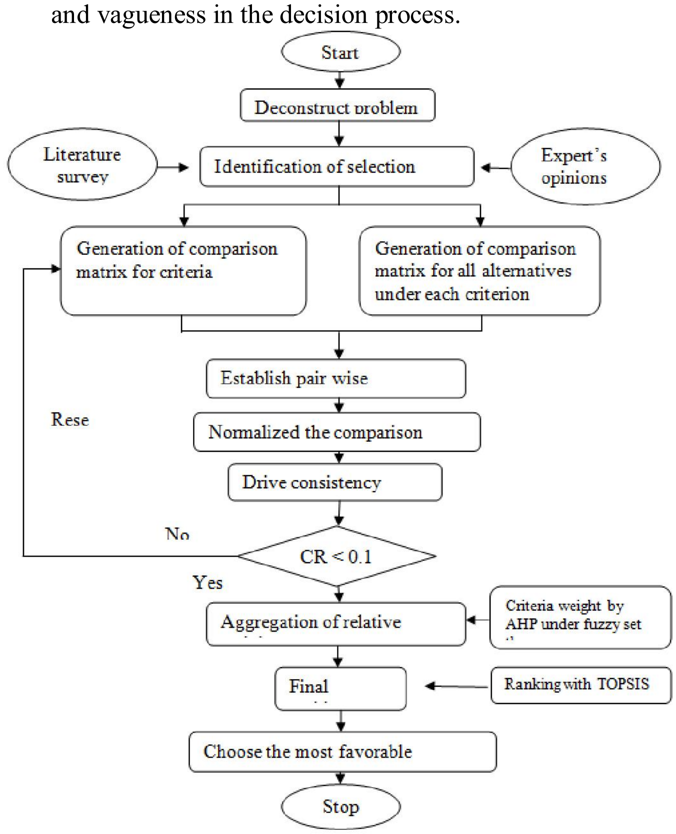

Fig. 3. Research framework of this study

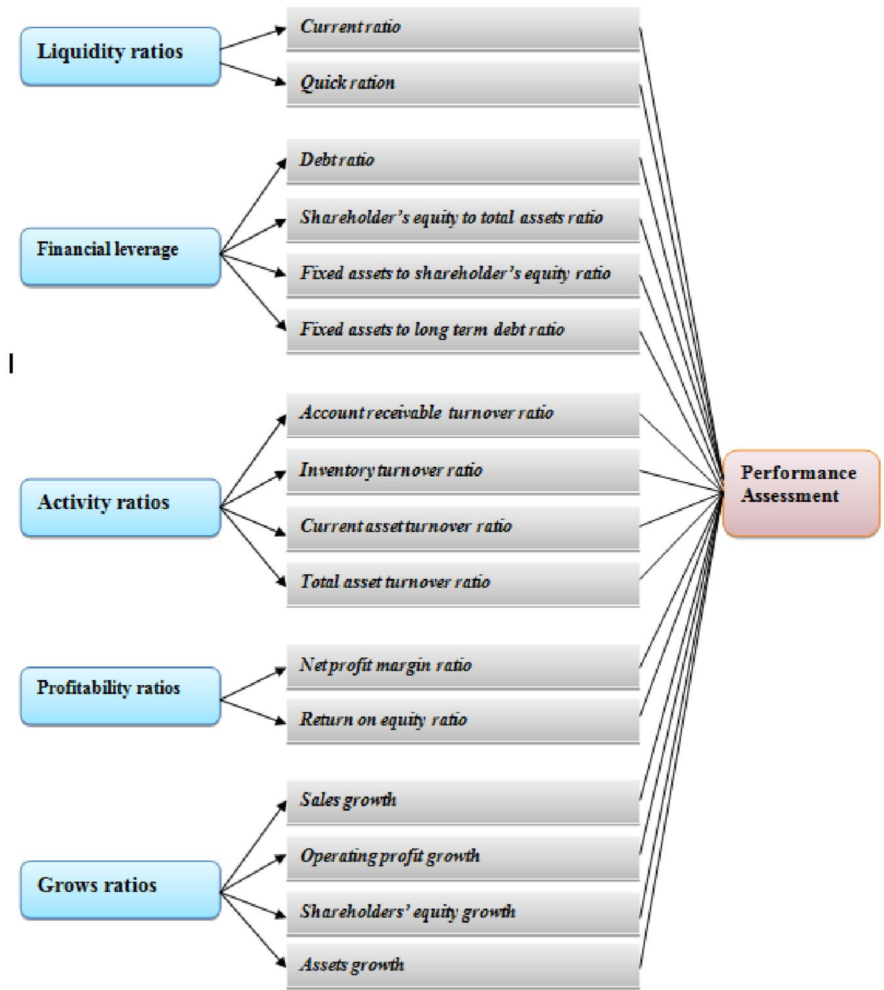

Fig. 4.Performance assessment based on financial ratios

Decision makers from different backgrounds may define different weight vectors and this causes imprecise evaluation during the decision process. For this reason we propose a group decision based on FAHP to improve pairwise comparison. Each decision maker (DM) would individually carry out pairwise comparison using Saaty's 1–9 scale (Table 4; [38, 78]).

Table 4: Pairwise comparison of criteria by decision makers

$$D_1 = \begin{array}{cc} & \begin{array}{ccccc} I_1 & I_2 & I_3 & I_4 & I_5 \end{array} \\ \begin{array}{c} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{array} & \begin{bmatrix} 1 & 3 & 3 & 7 & 5 \\ \frac{1}{3} & 1 & 1 & 5 & 3 \\ \frac{1}{3} & 1 & 1 & \frac{1}{5} & \frac{1}{7} \\ \frac{1}{7} & \frac{1}{5} & 5 & 1 & 3 \\ \frac{1}{5} & \frac{1}{3} & 7 & \frac{1}{3} & 1 \end{bmatrix} \end{array}$$

$$D_2 = \begin{array}{cc} & \begin{array}{ccccc} I_1 & I_2 & I_3 & I_4 & I_5 \end{array} \\ \begin{array}{c} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{array} & \begin{bmatrix} 1 & 1 & 3 & 5 & 7 \\ 1 & 1 & \frac{1}{3} & \frac{1}{7} & \frac{1}{5} \\ \frac{1}{3} & 3 & 1 & 3 & 5 \\ \frac{1}{5} & 7 & \frac{1}{3} & 1 & 3 \\ \frac{1}{7} & 5 & \frac{1}{5} & \frac{1}{3} & 1 \end{bmatrix} \end{array}$$

$$D_3 = \begin{array}{cc} & \begin{array}{ccccc} I_1 & I_2 & I_3 & I_4 & I_5 \end{array} \\ \begin{array}{c} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{array} & \begin{bmatrix} 1 & 3 & 5 & \frac{1}{3} & \frac{1}{7} \\ \frac{1}{3} & 1 & 3 & \frac{1}{5} & \frac{1}{3} \\ \frac{1}{5} & \frac{1}{3} & 1 & \frac{1}{7} & \frac{1}{7} \\ 3 & 5 & 7 & 1 & 3 \\ 7 & 3 & 7 & \frac{1}{3} & 1 \end{bmatrix} \end{array}$$

A comprehensive pairwise comparison matrix was built (Table 1) by integrating the three decision makers' grades through Equation 22 (Chen, Lin, and Huang, 2006). The decision makers' pairwise comparison values were then transformed into TFNs (Table 5).

Table 5: Fuzzy pairwise comparison matrix

Criteria	I_1	I_2	I_3	I_4	I_5
I_1	(1,1,1)	(1,2.33,3)	(3,3.67,5)	(0.33,4.11,7)	(0.14,4.05,7)
I_2	(0.33,0.55,1)	(1,1,1)	(0.33,1.44,3)	(0.14,1.78,5)	(0.2,1.18,3)
I_3	(0.2,0.28,0.33)	(0.33,1.44,3)	(1,1,1)	(0.14,1.11,3)	(0.14,1.76,5)
I_4	(0.14,1.11,3)	(0.2,4.07,7)	(0.33,4.11,7)	(1,1,1)	(3,3,3)
I_5	(0.14,2.45,7)	(0.33,2.78,5)	(0.2,4.73,7)	(0.33,0.33,0.33)	(1,1,1)

. $\tilde{x}$ij= (aij, bij, cij)

$$L_{ij} = \min\{a_{ijk}\} \quad m_{ij} = \frac{1}{k}\sum_{k=1}^{k} b_{ijk} \quad u_{ij} = \max\{d_{ijk}\} \tag{20}$$

After forming a fuzzy pairwise comparison matrix, the weights of all criteria and sub-criteria were determined with the help of FAHP. The synthesis values were calculated in accordance with the FAHP method (Table 5; Eq. 5) and based on the following formula.

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \times \left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1}$$

.

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} L_i, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_i \right)$$

$$\sum_{i=1}^{n}\sum_{i=1}^{m} M_{g_i}^{j} = \left(\sum_{i=1}^{n} L_i, \sum_{i=1}^{n} m_j, \sum_{i=1}^{n} u_i \right) \tag{21}$$

$$\left[\sum_{i=1}^{n}\sum_{i=1}^{m} M_{g_i}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_j}, \frac{1}{\sum_{i=1}^{n} L_i} \right)$$

Then, big values of triangle numbers were calculated using the following formulae:

$$V(S_1 \geq S_2, \ldots, S_k) = V(S_1 \geq S_2), V(S_1 \geq S_k)$$

$$V(S_1 \geq S_k) = \frac{u_1 - L_2}{(u_1 - L_2) + (m_2 - m_1)} \tag{22}$$

And weights of non-normalized criteria were determined as follows:

$$W' = \min(d'(s_1), d'(s_2), d'(s_3), \ldots)^T$$

Finally, the weights of normalized criteria were determined as follows:

$$W_i = \frac{W_i'}{\sum W_i'}$$

Determining the Si vector

Vector 1: sum of fuzzy numbers in each level

Vector 2: sum of total triangle numbers in last matrix –this victor is the same for all Si

The inverse of triangle number was calculated as follows:

aij: a triangle fuzzy[$a_{ij} = (l, m, u)$]; the inverse will be [$a^{-1}{}_{ij} = (1/u, 1/m, 1/l)$

$$S_1 = (5.47,15.16,23) \otimes (\frac{1}{89.66}, \frac{1}{51.28}, \frac{1}{16.06}) = (0.06, 0.29, 1.43)$$

$$S_2 = (2,5.95,13) \otimes (\frac{1}{89.66}, \frac{1}{51.28}, \frac{1}{16.06}) = (0.02, 0.12, 0.81)$$

$$S_3 = (1.81,5.59,12.33) \otimes (\frac{1}{89.66}, \frac{1}{51.28}, \frac{1}{16.06}) = (0.02, 0.11, 0.77)$$

$$S_4 = (4.67,13.29,21) \otimes (\frac{1}{89.66}, \frac{1}{51.28}, \frac{1}{16.06}) = (0.05, 0.26, 1.31)$$

$$S_5 = (2,11.29,20.33) \otimes (\frac{1}{89.66}, \frac{1}{51.28}, \frac{1}{16.06}) = (0.02, 0.22, 1.26)$$

The fuzzy values were then compared S_0–S_1, by using Equation 11 and the following were obtained:

$$V(S_1 \geq S_2) = 1$$

$$V(S_1 \geq S_3) = 1$$

$$V(S_1 \geq S_4) = 1$$

$$V(S_1 \geq S_5) = 1$$

$$V(S_1 \geq S_2) = 1 \ldots \text{اگر} \ S_1 \geq S_2$$

$$V(S_1 \geq S_2) = \frac{l_2 - u_1}{(m_1 - u_1) - (m_2 - u_2)} \cdots \text{if } S_2 \geq S_1$$

Where

$$S_1 = (l_1, m_1, u_1)$$

$$S_2 = (l_2, m_2, u_2)$$

$$V(S_2 \geq S1) = \frac{0.06 - 0.81}{(0.12 - 0.81) - (0.29 - 0.06)} = 0.82$$

$$V(S_2 \geq S_3) = 1$$

$$V(S_2 \geq S_4) = \frac{0.05 - 0.81}{(0.12 - 0.81) - (0.26 - 0.05)} = 0.84$$

$$V(S_2 \geq S_5) = \frac{0.02 - 0.81}{(0.12 - 0.81) - (0.22 - 0.02)} = 0.89$$

$$V(S_3 \geq S_1) = \frac{0.06 - 0.77}{(0.11 - 0.77) - (0.29 - 0.06)} = 0.8$$

$$V(S_3 \geq S_2) = \frac{0.02 - 0.77}{(0.11 - 0.77) - (0.12 - 0.02)} = 0.99$$

$$V(S_3 \geq S_4) = \frac{0.05 - 0.77}{(0.11 - 0.77) - (0.26 - 0.05)} = 0.83$$

$$V(S_3 \geq S_5) = \frac{0.02 - 0.77}{(0.11 - 0.77) - (0.22 - 0.02)} = 0.87$$

$$V(S_4 \geq S_1) = \frac{0.06 - 1.31}{(0.26 - 1.31) - (0.29 - 0.06)} = 0.98$$

$$V(S_4 \geq S_2) = 1$$

$$V(S_4 \geq S_3) = 1$$

$$V(S_4 \geq S_5) = 1$$

$$V(S_5 \geq S_1) = \frac{0.06 - 1.26}{(0.22 - 1.26) - (0.29 - 0.06)} = 0.94$$

$$V(S_5 \geq S_2) = 1$$

$$V(S_5 \geq S_3) = 1$$

$$V(S_5 \geq S_4) = \frac{0.05 - 1.26}{(0.22 - 1.26) - (0.26 - 0.05)} = 0.97$$

$$d'(I1) = MIN(S_1 \geq S_2, S_3, S_4, S_5) = MIN(1,1,1,1) = 1$$

$$d'(I2) = MIN(S_2 \geq S_1, S_3, S_4, S_5) = MIN(0.82, 1, 0.84, 0.89) = 0.82$$

$$d'(I3) = MIN(S \geq S, S, S, S) = MIN(0.8, 0.99, 0.83, 0.87) = 0.8$$

$$d'(I4) = MIN(S \geq S, S, S, S) = MIN(0,98, 1, 1, 1) = 0.98$$

$$d'(I5) = MIN(S \geq S, S, S, S) = MIN(0.94, 1, 1, 0.97) = 0.94$$

$$W' = (1, 0.82, 0.8, 0.98, 0.94)^T$$

$$W = (0.22, 0.18, 0.176, 0.216, 0.21)$$

Then priority weights, d (I), were then calculated using Equation 12:

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

Thus, based on the FAHP method priority of criteria are as listed in Table 6.

Table 6: Final matrix of priority by FAHP method

No	Criteria		Weight average
1	I_1	Liquidity Ratios	0.220
2	I_4	Profitability ratios	0.216
3	I_5	Growth ratios	0.210
4	I_2	Financial Leverage Ratios	0.180
5	I_3	Activity ratios	0.176

According to the FAHP method the most important financial ratios are Liquidity ratios, Profitability ratios, and Growth ratios (Table 6). In prioritizing the cement companies by the TOPSIS method, the ranking of the companies based on the 16 sub-criteria are as listed in Tables 7 to Table 11.

Table 7: Liquidity ratios for Iranian Cement Companies

Companies	Liquidity Ratios	
	Current Ratio	**Quick Ratio**
Sabhan	1.26	0.39
Sarab	0.94	0.40
Sedasht	1.69	1.18
Safar	0.63	0.32
Sekaroun	0.58	0.27
Sakarma	1.13	0.48
Sanir	2.04	0.97
Sahrmoz	1.83	1.33

Table 8: Financial Leverage Ratios of Iranian Cement Companies

Companies	Financial Leverage Ratios			
	Debt Ratio	Shareholder's Equity to Total Assets	Fixed Assets to Shareholder's Equity	Fixed Assets to Long Term Debt Ratio
Sabhan	0.47	0.53	0.74	4.39
Sarab	0.47	0.53	0.76	4.52
Sedasht	0.26	0.73	1.38	0.59
Safar	0.51	0.48	0.99	7.17
Sekaroun	0.60	0.39	0.30	0.38
Sakarma	0.29	0.70	0.34	3.98
Sanir	0.38	0.61	0.66	5.13
Sahrmoz	0.49	0.50	0.56	30.03

Table 9: Activity Ratios of Iranian Cement Companies

	Activity Ratios			
Companies	Accounts Receivable Turnover	Inventory Turnover	Current Asset Turnover Ratio	Total Asset Turnover Ratio
Sabhan	76.61	1.64	1.96	1.03
Sarab	15.12	0.88	1.62	0.47
Sedasht	3.26	2.22	1.38	0.59
Safar	74.44	2.04	3.42	0.89
Sekaroun	9	2.52	2.38	0.36
Sakarma	9.83	0.96	2.20	0.66
Sanir	7.67	1.72	1.55	0.82
Sahrmoz	8.66	1.21	0.55	0.45

Table 10: Profitability ratios for Iranian Cement Companies

Companies	Profitability Ratios	
	Net Profit Margin	**Return on Equity**
Sabhan	0.34	0.66
Sarab	0.43	0.38
Sedasht	0.50	0.41
Safar	0.38	0.71
Sekaroun	0.41	0.38
Sakarma	0.44	0.41
Sanir	0.38	0.51
Sahrmoz	0.41	0.37

Table 11: Growth Ratios of Iranian Cement Companies

Companies	Growth Ratios			
	Sales Growth	**Operating Profit Growth**	**Shareholders' Equity Growth**	**Assets Growth**
Sabhan	34.52	59.78	32.68	27.98
Sarab	13.94	30.82	24.25	7.91
Sedasht	29	66	25	0.11
Safar	26	47	45	(7)
Sekaroun	3	(4)	(5)	43
Sakarma	25.92	28.20	17.25	(1.29)
Sanir	11	25	12	16
Sahrmoz	54	108	(17)	6

Based on the results of the performance evaluation of the Iranian cement companies taking into consideration financial ratios, the ranking of the companies are as illustrated in Tables 7–11. Besides the financial ratios, the decision makers' priorities also affected the ranking of the companies. If there was a difference in the priority of the decision makers, the ranking would change. It is imperative therefore that decision makers should know their priorities and then determine the weights of the criteria. The whole process involves the following seven steps.

Step 1.The results should provide the first decision-making matrix (Table 12).

Table 12: First decision-making matrix

$$D=\begin{bmatrix} 1.26 & 0.39 & 0.47 & 0.53 & 0.74 & 4.39 & 76.6 & 1.64 & 1.96 & 1.03 & 0.34 & 0.66 & 34.5 & 59.8 & 32.7 & 28 \\ 0.94 & 0.4 & 0.47 & 0.53 & 0.76 & 4.52 & 15.1 & 0.88 & 1.62 & 0.47 & 0.43 & 0.38 & 13.9 & 30.8 & 24.3 & 7.9 \\ 1.69 & 1.18 & 0.26 & 0.73 & 1.38 & 0.59 & 3.3 & 2.22 & 1.38 & 0.59 & 0.5 & 0.41 & 29 & 66 & 25 & 0.11 \\ 0.63 & 0.32 & 0.51 & 0.48 & 0.99 & 7.17 & 74.4 & 2.04 & 3.42 & 0.89 & 0.38 & 0.71 & 26 & 47 & 45 & -7 \\ 0.58 & 0.27 & 0.6 & 0.39 & 0.3 & 0.38 & 9 & 2.52 & 2.38 & 0.36 & 0.41 & 0.38 & 3 & -4 & -5 & 43 \\ 1.13 & 0.48 & 0.29 & 0.7 & 0.34 & 3.98 & 9.83 & 0.96 & 2.2 & 0.66 & 0.44 & 0.41 & 25.9 & 28.2 & 17.3 & -1.3 \\ 2.04 & 0.97 & 0.38 & 0.61 & 0.66 & 5.13 & 7.67 & 1.72 & 1.55 & 0.82 & 0.38 & 0.51 & 11 & 25 & 12 & 16 \\ 1.83 & 1.33 & 0.49 & 0.5 & 0.56 & 30.03 & 8.66 & 1.21 & 0.75 & 0.45 & 0.41 & 0.37 & 54 & 108 & -17 & 6 \end{bmatrix}$$

Step 2. Develop the normalized decision-making matrix(Table 13).

D matrix by $N_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}}$ changes to ND matrix

Table 13: Normalized matrix

$$ND = \begin{bmatrix} 0.33 & 0.18 & 0.37 & 0.33 & 0.33 & 0.14 & 0.70 & 0.33 & 0.34 & 0.52 & 0.29 & 0.47 & 0.42 & 0.38 & 0.46 & 0.51 \\ 0.24 & 0.18 & 0.37 & 0.33 & 0.34 & 0.14 & 0.14 & 0.18 & 0.28 & 0.24 & 0.37 & 0.27 & 0.17 & 0.20 & 0.34 & 0.14 \\ 0.44 & 0.54 & 0.21 & 0.45 & 0.62 & 0.02 & 0.03 & 0.45 & 0.24 & 0.3 & 0.43 & 0.29 & 0.36 & 0.42 & 0.35 & 0.01 \\ 0.16 & 0.15 & 0.4 & 0.30 & 0.44 & 0.22 & 0.68 & 0.41 & 0.59 & 0.45 & 0.32 & 0.51 & 0.32 & 0.30 & 0.63 & -0.13 \\ 0.15 & 0.12 & 0.47 & 0.24 & 0.13 & 0.01 & 0.08 & 0.51 & 0.41 & 0.18 & 0.35 & 0.27 & 0.04 & -0.03 & -0.07 & 0.78 \\ 0.29 & 0.22 & 0.23 & 0.44 & 0.15 & 0.12 & 0.09 & 0.19 & 0.38 & 0.34 & 0.38 & 0.29 & 0.32 & 0.18 & 0.24 & -0.02 \\ 0.53 & 0.44 & 0.3 & 0.38 & 0.30 & 0.16 & 0.07 & 0.35 & 0.27 & 0.42 & 0.32 & 0.36 & 0.14 & 0.16 & 0.17 & 0.29 \\ 0.47 & 0.61 & 0.39 & 0.31 & 0.25 & 0.93 & 0.08 & 0.25 & 0.13 & 0.23 & 0.35 & 0.26 & 0.66 & 0.69 & -0.24 & 0.11 \end{bmatrix}$$

Step 3. W vector (values of criteria) is assumed to be equal to a unique vector. So, determine the values of the criteria matrix (Table 14) as follows:

$$V = ND \times W$$

Table 14: Values of criteria matrix

$$ND = \begin{bmatrix} 0.33 & 0.18 & 0.37 & 0.33 & 0.33 & 0.14 & 0.70 & 0.33 & 0.34 & 0.52 & 0.29 & 0.47 & 0.42 & 0.38 & 0.46 & 0.51 \\ 0.24 & 0.18 & 0.37 & 0.33 & 0.34 & 0.14 & 0.14 & 0.18 & 0.28 & 0.24 & 0.37 & 0.27 & 0.17 & 0.20 & 0.34 & 0.14 \\ 0.44 & 0.54 & 0.21 & 0.45 & 0.62 & 0.02 & 0.03 & 0.45 & 0.24 & 0.3 & 0.43 & 0.29 & 0.36 & 0.42 & 0.35 & 0.01 \\ 0.16 & 0.15 & 0.4 & 0.30 & 0.44 & 0.22 & 0.68 & 0.41 & 0.59 & 0.45 & 0.32 & 0.51 & 0.32 & 0.30 & 0.63 & -0.13 \\ 0.15 & 0.12 & 0.47 & 0.24 & 0.13 & 0.01 & 0.08 & 0.51 & 0.41 & 0.18 & 0.35 & 0.27 & 0.04 & -0.03 & -0.07 & 0.78 \\ 0.29 & 0.22 & 0.23 & 0.44 & 0.15 & 0.12 & 0.09 & 0.19 & 0.38 & 0.34 & 0.38 & 0.29 & 0.32 & 0.18 & 0.24 & -0.02 \\ 0.53 & 0.44 & 0.3 & 0.38 & 0.30 & 0.16 & 0.07 & 0.35 & 0.27 & 0.42 & 0.32 & 0.36 & 0.14 & 0.16 & 0.17 & 0.29 \\ 0.47 & 0.61 & 0.39 & 0.31 & 0.25 & 0.93 & 0.08 & 0.25 & 0.13 & 0.23 & 0.35 & 0.26 & 0.66 & 0.69 & -0.24 & 0.11 \end{bmatrix}$$

Step 4.Determining ideal and anti-ideal solution

$$A^+ = \{MAXvi\ 1, MAXvi\ 2, \ldots, MAXvi\ 16\}$$

$$A^+ = \{0.53, 0.61, 0.47, 0.45, 0.62, 0.93, 0.70, 0.51, 0.59, 0.52, 0.43, 0.51, 0.66, 0.69, 0.63, 0.78\}$$

$$A^- = \{MINvi\ 1, MINvi\ 2, \ldots, MINvi\ 16\}$$

$$A^- = \{0.15, 0.12, 0.21, 0.24, 0.13, 0.01, 0.03, 0.18, 0.13, 0.18, 0.32, 0.26, 0.04, -0.03, -0.24, -0.13\}$$

Then the distances of each company with respect to each criterion are calculated with the help of Equations 17 and 18. After calculating the distances, the closeness coefficient of each firm is calculated using Equation19, and the ranking of each company is determined according to these values. The rankings of the cement companies are shown in Table 15.

Step5.Calculate alternative distance by ideal solution and anti-ideal solution

$$d_i^+ = \left\{ \sum_{i=1}^{n} (V_{ij} - V_j^+)^2 \right\}^{1/2}, (i = 1,2,\ldots,m)$$

$$d_i^- = \left\{ \sum_{i=1}^{n} (V_{ij} - V_j^-)^2 \right\}^{1/2}, (i = 1,2,\ldots,m)$$

$d_1^+ = 1.16$ $d_1^- = 1.42$

$d_2^+ = 1.62$ $d_2^+ = 0.79$

$d_3^+ = 1.56$ $d_3^- = 1.15$

$d_4^+ = 1.43$ $d_4^- = 1.4$

$d_5^+ = 1.87$ $d_5^- = 1.06$

$d_6^+ = 1.71$ $d_6^- = 1.74$

$d_7^+ = 1.53$ $d_7^- = 0.91$

$d_8^+ = 1.48$ $d_8^- = 1.49$

Step 6. Calculate consistency

$$C_i = \frac{d_i^-}{(d_i^- + d_i^+)}, (i = 1,2,...,n)$$

$C_1^+ = 0.55$ $C_5^+ = 0.36$

$C_2^+ = 0.33$ $C_6^+ = 0.51$

$C_3^+ = 0.42$ $C_7^+ = 0.37$

$C_4^+ = 0.49$ $C_8^+ = 0.50$

Step 7. Develop priority scores of companies (Table 15)

Table 15: Priority scores for Iranian cement companies

Companies	Score
Sabhan	0.55
Sarab	0.51
Sedasht	0.50
Safar	0.49
Sekaroun	0.42
Sakarma	0.37
Sanir	0.36
Sahrmoz	0.33

5. Conclusion

Evaluating the performance of the companies is an important issue for investors, shareholders and creditors. In this study, an objective evaluation system was developed for evaluating the performance of Iranian cement companies using financial tables. Financial tables of the companies were used for performance evaluation and the subjective judgments of decision makers were incorporated into the evaluation process.

In contrast to other studies in the literature, both FAHP and TOPSIS methods were used together in this study. FAHP was utilized for determining the weights of the criteria and the TOPSIS method was used to determine the ranking of the companies. According to the FAHP method the most important financial ratios are Liquidity ratios, Profitability ratios, and Growth ratios (Table 6). Based on the results of the performance evaluation of the Iranian cement companies taking into consideration financial ratios, the rankings of the companies are: Sabhan (0/55), Sarab (0/51), Sedasht (0/50), Safar (0/49), Sekaroun (0/42), Sakarma (0/37), Sanir(0/36) and Sahrmoz (0/33).

In the application, ranking of the cement companies was based on the performance of the companies. As the weights of criteria were determined by decision makers from different areas, the results indicate an overall performance ranking. If it is desired, it is possible to make an evaluation only for creditors, investors or shareholders, however, in such cases the weights of the criteria will vary and the ranking of the companies can change. The proposed method can also be applied to the evaluation of companies in other sectors.

The notable characteristics of this research include:

It is the first study on Iranian cement companies in this area.

development of a fuzzy model “based on fuzzy AHP and TOPSIS methods” to evaluate the performance of the companies by using financial ratios as well as taking subjective judgments of decision makers into consideration.

The proposed method can be used as benchmarking for other cement companies as well as other industries.

Recommendation

In future studies other multi-criteria methods should also be considered for evaluating the performance of the cement companies.

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