

Performance evaluation of Turkish cement firms with fuzzy analytic hierarchy process and TOPSIS methods

İrfan Ertuğrul *, Nilsen Karakaşoğlu

Business Administration Department, Pamukkale University, 20070 Denizli, Turkey

Abstract

In today's competitive environment evaluating firms' performance properly, is an important issue not only for investors and creditors but also for the firms that are in the same sector. Determining the competitiveness of the firms and evaluating the financial performance of them is also crucial for the sector's development.

The aim of this study is developing a fuzzy model to evaluate the performance of the firms by using financial ratios and at the same time, taking subjective judgments of decision makers into consideration. Proposed approach is based on Fuzzy Analytic Hierarchy Process (FAHP) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) methods. FAHP method is used in determining the weights of the criteria by decision makers and then rankings of the firms are determined by TOPSIS method. The proposed method is used for evaluating the performance of the fifteen Turkish cement firms in the Istanbul Stock Exchange by using their financial tables. Then the rankings of the firms are determined according to their results.

© 2007 Elsevier Ltd. All rights reserved.

Keywords: Performance evaluation; Multi-criteria decision making; FAHP; TOPSIS; Cement sector

1. Introduction

Nowadays, cement demand has increased parallel to the increase in the construction sector. This increase is based on the economic stability, decrease in the interest and exchange rates and increase in the popularity of mortgage system. Turkey is the second manufacturer of the European and seventh of the world cement market with 39 cement firm and 18 grinding facility. Interest to the cement sector has increased with the rising in the cement demand. In this study, performance of the Turkish cement firms is evaluated by the help of financial ratios. Wang (2007) evaluated financial performance of domestic airlines in Taiwan with fuzzy TOPSIS method. Yurdakul and İc (2003) proposed to use TOPSIS method for evaluating the performance of the firms in the Turkish automotive

industry. Sekreter, Akyüz, and Çetin (2004) developed a model for determining the credibility of the Turkish firms in the food industry. Their model is based on AHP method and cluster analysis. Different from other studies in the literature, FAHP and TOPSIS methods are used together in this study. FAHP is utilized for determining the weights of the criteria. Then ranking of the firms is determined by the help of TOPSIS method.

The remainder of this paper is organized as follows. In the second section the ratios that are used in the performance evaluation of the firms are briefly explained. In the third section firstly fuzzy logic term is defined and then fuzzy numbers, algebraic operations with fuzzy numbers are explained. In the fourth section, FAHP method is summarized. In this section, literature review for FAHP is also given. In the fifth section, TOPSIS method is tried to be explained. An application in cement sector is given in section six. And finally in section seven, results of the application are presented and suggestions for the future studies are clarified. This section concludes the paper.

* Corresponding author. Tel.: +90 258 2952653; fax: +90 258 2952792.
E-mail addresses: iertugrul@pamukkale.edu.tr (İ. Ertuğrul), nkarakasoglu@pamukkale.edu.tr (N. Karakaşoğlu).

2. Financial ratios

Financial ratios are useful indicators of a firm's performance and financial situation. Financial ratios can be classified according to the information they provide. The following types of ratios are frequently used and we have used these ratios in our application:

Liquidity ratios. Liquid asset is one that can be easily converted to cash at a fair market value and a firm's liquidity position deals with the question: Will the firm be able to meet its current obligations? (Weston & Brigham, 1993) A firm that intends to remain a viable business entity must have enough cash on hand to pay its bills as they come due. In other words, the firms must remain liquid. One way to determine whether this is the case is to examine the relationship between the firm's current assets and approaching obligations. Liquidity ratios are quick measures of a firm's ability to provide sufficient cash to conduct business over the next few months (Moyer, McGuigan, & Kretlow, 1992). Briefly, liquidity ratios provide information about a firm's ability to meet its short-term obligations. Three frequently used liquidity ratios are the current ratio, liquidity ratio and quick ratio.

Current ratio. The current ratio is the ratio of current assets to current liabilities. It is key measure in determining a firm's ability to pay current debts and is a good measure of the adequacy of working capital (Price, Haddock, & Brock, 1993). Current assets include the cash, a firm already has on hand in the bank, plus any assets that can be converted into cash within a normal operating period of 12 months, such as marketable securities held as short term investments, account receivable, inventories, and prepayments. Current liabilities include financial obligations expected to fall due within next year, such as accounts payables, and various accruals such as taxes and wages due (Moyer et al., 1992).

Current Ratio = Current Assets/Current Liabilities

Quick ratio (Acid test ratio). Although the current ratio measures a firm's ability to meet current liabilities out of existing current assets, it is not a measure of immediate liquidity (Price et al., 1993). Immediate liquidity is measured by quick ratio. This ratio is a more stringent measure of liquidity than the current ratio. It recognizes that a firm's inventories are often one of its least liquid current assets (Moyer et al., 1992). This ratio is calculated by deducting inventories from current assets and dividing the remainder by current liabilities.

Quick Ratio = (Current Assets
– Inventories)/Current Liabilities

Cash ratio. Cash ratio is the most conservative liquidity ratio. The cash ratio is an indication of the firm's ability to pay off its current liabilities if for some reason immediate payment were demanded. This ratio excludes all current assets except the most liquid ones such as; cash and cash equivalents. The cash ratio is defined as

Cash Ratio = (Cash
+ Marketable Securities)/Current Liabilities

Financial leverage ratios. Financial leverage ratios indicate a firm's capacity to meet short- and long-term debt obligations. These ratios provide 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 (Foster, 1978). Unlike liquidity ratios that are concerned with short term assets and liabilities, financial leverage ratios measure the extent to which the firm is using long term debt.

Debt ratio. Debt ratio indicates what proportion of the firm's assets is being financed through debt. Debt encompasses all short term liabilities and long term borrowings. A ratio under 1 means a majority of assets are financed through equity, above 1 means they are financed more by debt.

Debt Ratio = Total Debt/Total Assets

Shareholder's equity to total assets ratio. This ratio indicates what proportion of the firm's assets financed through shareholders' equity. This ratio shows the financial power of the firm to the creditors that give long term loan.

Shareholder's Equity to Total Assets Ratio
= Shareholder's Equity/Total Assets

Fixed assets to shareholder's equity ratio. This ratio shows what proportion of the firm's fixed assets financed through shareholders' equity. A ratio under 1 means all of the firm's fixed assets are financed through equity, above 1 means they are financed more by debt.

Fixed Assets to Shareholder's Equity Ratio
= Fixed Assets/Shareholder's Equity

Fixed assets to long term debt ratio. If this ratio is above 1, it means the firm has fixed assets more than 1 \$ in contrast to firm's 1 \$ long term debt. And this situation is not preferred by long term creditors.

Fixed Assets to Long Term Debt Ratio
= Fixed Assets/Long Term Debt

Activity ratios (Asset turnover ratios). One objective of financial management is to determine how a firm's resources best can be distributed among the various asset accounts. Activity ratios indicate how much a firm has invested in a particular type of asset relative to the revenue the asset is producing. By comparing activity ratios for the various asset accounts of a firm with established industry norms, the analyst can determine how efficiently the firm is allocating its resources (Moyer et al., 1992).

Account receivable turnover. This ratio shows the number of times accounts receivable are paid and reestablished during the accounting period. The higher the turnover, the

faster the business is collecting its receivables and the more cash the client generally has on hand.

Accounts Receivable Turnover

$$= \text{Total Net Sales} / \text{Accounts Receivables}$$

Inventory turnover ratio. It is important that a firm's inventory be turned over rapidly, so that excess amounts of working capital are not tied up in unnecessary merchandise. Since the cost of the merchandise that has been moved during the year is shown on the income statement as the cost of goods sold, the inventory turnover is easily determined. The ratio is computed by dividing the cost of goods sold during the period by the average inventory on hand. This ratio measures the number of times the average inventory had to be replaced during the period. Obviously, the higher the turnover, the less time that has elapsed between the date of purchase and date of sale (Price et al., 1993).

Inventory Turnover

$$= \text{Costs of Goods Sold} / \text{Average Inventory}$$

Current assets turnover ratio. This ratio indicates the number of times current assets are renovated during the accounting period.

Current Assets Turnover Ratio

$$= \text{Net Sales} / \text{Current Assets}$$

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.

Total Asset Turnover Ratio = Sales/Total Assets

Accounts payable turnover ratio. This ratio is meaningful especially for creditors.

Accounts Payable Turnover Ratio

$$= \text{Purchases on credit} / \text{Average Accounts Payable}$$

Profitability ratios. Profitability refers to the ability of a firm to generate revenues in excess of expenses (Foster, 1978). Profitability ratios offer several different measures of the success of the firm generating profits. A firm's profits demonstrate how well the firm is making investment and financing decisions. If a firm is unable to provide adequate returns in the form of dividends and share price appreciation to investors, it may be unable to maintain its asset base. Anyone whose economic interests are tied to the long term survival of a firm will be interested in profitability ratios (Moyer et al., 1992).

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

Net Profit Margin Ratio = Earnings after taxes/Sales

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. It measures a firm's efficiency at generating profits from every dollar of net assets, and shows how well a company uses investment dollars to gen-

erate earnings growth. It is equal to a fiscal year's net income (after preferred stock dividends but before common stock dividends) divided by total equity (excluding preferred shares), expressed as a percentage.

Return on Equity = Net Profit before Taxes/Net worth

Growth ratios. Growth ratios indicate how well the position of the firm in the industry.

Sales growth

$$\text{Sales Growth} = [(S_t - S_{t-1}) / S_{t-1}] * 100$$

Here, S_t = Net sales of the current period

S_{t-1} = Net sales of the previous period

Operating profit growth

$$\text{Operating Profit Growth} = [(P_t - P_{t-1}) / P_{t-1}] * 100$$

Here, P_t = Operating profit with current prices

P_{t-1} = Operating profit of the previous period

Shareholders' equity growth

$$\text{Shareholders' Equity Growth} = [(E_t - E_{t-1}) / E_{t-1}] * 100$$

Here, E_t = Shareholders' Equity of the current period

E_{t-1} = Shareholders' Equity of the previous period

Assets growth

$$\text{Assets Growth} = [(A_t - A_{t-1}) / A_{t-1}] * 100$$

Here, A_t = Assets of the current period

A_{t-1} = Assets of the previous period

3. Fuzzy sets and fuzzy numbers

3.1. Fuzzy sets

In order to deal with vagueness of human thought, Zadeh (1965) first introduced the fuzzy set theory. A fuzzy set is an extension of a crisp set. Crisp sets only allow full membership or no membership at all, whereas fuzzy sets allow partial membership. In other words, an element may partially belong to a fuzzy set.

The classical set theory is built on the fundamental concept of set of which is either a member or not a member. A sharp, crisp and unambiguous distinction exists between a member and non-member for any well-defined set of entities in this theory and there is a very precise and clear boundary to indicate if an entity belongs to the set. But many real-world applications cannot be described and handled by classical set theory (Chen & Pham, 2001). Zadeh (1965) proposed to use 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 (Ertuğrul & Karakaşoğlu, 2006b).

"Not very clear", "probably so", "very likely", these terms of expression 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 (Tsaur, Chang, & Yen, 2002). Fuzzy sets theory providing a more widely frame than classic sets theory, has been contributing to capability of reflecting real world (Ertuğrul & Tuş, 2007). Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling: uncertain systems in industry, nature and humanity; and facilitators for common-sense 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 (Bojadziev & Bojadziev, 1998). 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 study of a new decision analysis filed fuzzy decision making (Lai & Hwang, 1996).

3.2. Fuzzy numbers

A fuzzy number \tilde{M} is a convex normalized fuzzy set \tilde{M} of the real line R such that (Zimmermann, 1992):

It exists such that one $x_0 \in R$ with $\mu_{\tilde{M}}(x_0) = 1$

(x_0 is called mean value of \tilde{M})

$\mu_{\tilde{M}}(x)$ 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 (Baykal & Beyan, 2004). 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.

Triangular fuzzy numbers 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 triangular fuzzy number \tilde{M} is shown in Fig. 1 (Deng, 1999).

There are various operations on triangular fuzzy numbers. But here, three important operations used in this study are illustrated. If we define, two positive triangular fuzzy numbers (l_1, m_1, u_1) and (l_2, m_2, u_2) then:

$$(l_1, m_1, u_1) + (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (1)$$

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

$$(l_1, m_1, u_1)^{-1} \approx (1/u_1, 1/m_1, 1/l_1) \quad (3)$$

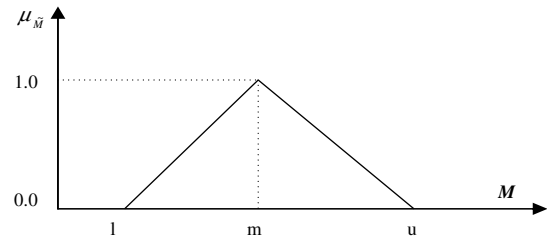


Fig. 1. Triangular fuzzy number, \tilde{M} .

4. Fuzzy Analytic Hierarchy Process (FAHP)

Analytic Hierarchy Process (AHP) is a widely used multiple criteria decision making tool and firstly proposed by Saaty (1980). Analytic Hierarchy Process, 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 (Vaidya & Kumar, 2006). Although the AHP is to capture the expert's knowledge, the traditional AHP still cannot really reflect the human thinking style (Kahraman, Cebeci, & Ulukan, 2003). The traditional AHP method is problematic in that it uses an exact value to express the decision maker's opinion in a comparison of alternatives (Wang & Chen, 2007). And AHP method is often criticized due to its use of unbalanced scale of judgments and its inability to adequately handle the inherent uncertainty and imprecision in the pair-wise comparison process (Deng, 1999). To overcome all these shortcomings, FAHP was developed for solving the hierarchical problems. Decision makers usually find that it is more confident to give interval judgments than fixed value judgments. This is because usually he/she is unable to explicit his/her preference to explicit about the fuzzy nature of the comparison process (Kahraman et al., 2003). In this paper we proposed to use FAHP for determining the weights of the main and sub-criteria.

4.1. Literature review of FAHP

There are many fuzzy AHP methods and applications in the literature proposed by various authors. Van Laarhoven and Pedrycz (1983) proposed the first studies that applied fuzzy logic principle to AHP. Buckley (1985) initiated trapezoidal fuzzy numbers to express the decision maker's evaluation on alternatives with respect to each criterion while Laarhoven and Pedrycz were using triangular fuzzy numbers. Chang (1996) introduced a new approach for handling FAHP, with the use of triangular fuzzy numbers for pair-wise comparison scale of FAHP, and the use of the extent analysis method for the synthetic extent values of the pair-wise comparisons. Triantaphyllou and Lin (1996) 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) presented a fuzzy approach for tackling qualitative multi-criteria anal-

ysis problems in a simple and straightforward manner. Zhu, Jing, and Chang (1999) proved the basic theory of the triangular fuzzy number and improved the formulation of comparing the triangular fuzzy number's size. On this basis, they introduced a practical example on petroleum prospecting. Leung and Cao (2000) proposed a fuzzy consistency definition with consideration of a tolerance deviation. Essentially, the fuzzy ratios of relative importance, allowing certain tolerance deviation, were formulated as constraints on the membership values of the local priorities. Chou and Liang (2001) proposed a fuzzy multi-criteria decision making model by combining fuzzy set theory, AHP and concept of entropy, for shipping company performance evaluation. Bozdağ, Kahraman, and Ruan (2003) proposed four different fuzzy multi-attribute group decision making methods to select the best computer integrated manufacturing system. One of these methods is FAHP and the others are Yager's weighted goals method, Blin's approach and fuzzy synthetic evaluation. Chang, Cheng, and Wang (2003) 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. Kahraman et al. (2003) used FAHP to select the best supplier firm providing the most satisfaction for the criteria determined. Kahraman, Ruan, and Doğan (2003) used four different fuzzy multi-attribute group decision making approaches for facility location selection. These approaches are; a fuzzy model proposed by Blin, fuzzy synthetic evaluation, Yager's weighted goals method and FAHP respectively. Hsieh, Lu, and Tzeng (2004) presented a fuzzy multi-criteria analysis approach for selecting of planning and design alternatives in public office buildings. The FAHP method is used to determine the weightings for evaluation criteria among decision makers. Mikhailov and Tsvetnikov (2004) applied a new fuzzy modification of the AHP for evaluating services. The proposed fuzzy prioritization method uses fuzzy pair-wise comparison judgments rather than exact numerical values of the comparison ratios and transforms initial fuzzy prioritization problem into non-linear program. Enea and Piazza (2004) focused on the constraints that have to be considered within FAHP. They used constrained FAHP in project selection. Kahraman, Cebeci, and Ruan (2004) used the FAHP for comparing catering firms in Turkey. The means of the triangular fuzzy numbers produced by the customers and experts for each comparison were successfully used in the pair-wise comparison matrices. Tang and Beynon (2005) used 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, Demircan, and Kahraman (2005) used fuzzy replacement analysis and AHP in the selection of operating system. The economic part of the decision process had been developed by fuzzy replacement analysis. Non-economic factors and financial figures had been com-

binated by using a FAHP approach. Başlıgil (2005) provided an analytical tool to select the best software providing the most customer satisfaction. Tang et al. (2005, Chap. XI) proposed a multi-objective model for Taiwan notebook computer distribution problem. Their model involves a mixed integer programming and fuzzy analytic hierarchy process approach. Gu and Zhu (2006) constructed fuzzy symmetry matrix as attribute evaluation space based on fuzzy decision matrix and improved the FAHP method using the approximate fuzzy eigenvector of such fuzzy symmetry matrix. Tüysüz and Kahraman (2006) provided an analytical tool to evaluate the project risks under incomplete and vague information. They used FAHP to evaluate the riskiness of an information technology project of a Turkish company. Ayağ and Özdemir (2006) proposed an intelligent approach based on FAHP for evaluating machine tool alternatives. They firstly used FAHP to weight the alternatives under multiple attributes and then carried out Benefit/Cost ratio analysis by using both the FAHP score and procurement cost of each alternative. Lee, Chen, and Chang (2008) constructed an approach based on the FAHP and balanced scorecard for evaluating an IT department in the manufacturing industry in Taiwan. Ertuğrul and Karakaşoğlu (2006a) proposed to use FAHP to select the best supplier for a textile firm in Turkey. Haq and Kannan (2006) proposed a structured model for evaluating vendor selection using AHP and FAHP. Huang, Chu, and Chiang (2006) presented a FAHP method for the selection of government sponsored technology development projects. Chan and Kumar (2007) proposed a model for providing a framework for an organization to select the global supplier by considering risk factors. They used fuzzy extended analytic hierarchy process in the selection of global supplier.

4.2. Methodology of FAHP

In this study the extent FAHP is utilized, which was originally introduced by Chang (1996). Let $X = \{x_1, x_2, x_3, \dots, x_n\}$ an object set, and $G = \{g_1, g_2, g_3, \dots, g_n\}$ be a goal set. According to the method of Chang's extent analysis, each object is taken and extent analysis for each goal is performed respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M_{gi}^1, M_{gi}^2, \dots, M_{gi}^m, \quad i = 1, 2, \dots, n, \quad (4)$$

where M_{gi}^j ($j = 1, 2, \dots, m$) all are TFNs. The steps of Chang's extent analysis (Chang, 1996) can be given as in the following:

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

$$S_i = \sum_{j=1}^m M_{gi}^j \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j \right]^{-1} \quad (5)$$

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

$$\sum_{j=1}^m M_{gi}^j = \left(\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j \right) \quad (6)$$

and to obtain $\left[\sum_{j=1}^n \sum_{i=1}^m M_{gi}^j \right]^{-1}$, the fuzzy addition operation of M_{gi}^j ($j = 1, 2, \dots, m$) values is performed such as

$$\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j = \left(\sum_{i=1}^n l_i, \sum_{i=1}^n m_i, \sum_{i=1}^n u_i \right) \quad (7)$$

and then the inverse of the vector above is computed, such as

$$\left[\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^n u_i}, \frac{1}{\sum_{i=1}^n m_i}, \frac{1}{\sum_{i=1}^n l_i} \right) \quad (8)$$

Step 2. As $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, 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

$$V(M_2 \geq M_1) = \sup_{y \geq x} [\min(\mu_{M_1}(x), \mu_{M_2}(y))] \quad (9)$$

and can be expressed as follows:

$$V(M_2 \geq M_1) = \text{hgt}(M_1 \cap M_2) = \mu_{M_2}(d) \quad (10)$$

$$= \begin{cases} 1 & \text{if } m_2 \geq m_1 \\ 0 & \text{if } l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{otherwise} \end{cases} \quad (11)$$

Fig. 2 (Chang, 1996) illustrates Eq. (10) where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_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 possibility for a convex fuzzy number to be greater than k convex fuzzy M_i ($i = 1, 2, \dots, k$) numbers can be defined by

$$V(M \geq M_1, M_2, \dots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \dots \text{ and } (M \geq M_k)] \\ = \min V(M \geq M_i), \quad i = 1, 2, 3, \dots, k \quad (12)$$

Assume that $d(A_i) = \min V(S_i \geq S_k)$ for $k = 1, 2, \dots, n; k \neq i$. Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^T \quad (13)$$

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

Step 4. Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T \quad (14)$$

where W is a non-fuzzy number.

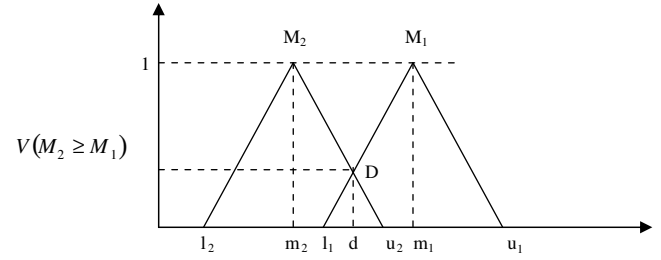


Fig. 2. The intersection between M_1 and M_2 .

5. TOPSIS method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is one of the useful MADM techniques to manage real-world problems (Yoon & Hwang, 1985). TOPSIS method was firstly proposed by Hwang and Yoon (1981). 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 (Benitez, Martin, & Roman, 2007). 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 (Wang & Elhag, 2006). In short, the positive ideal solution is composed of all best values attainable of criteria, whereas the negative ideal solution consists of all worst values attainable of criteria (Wang, 2007). In this paper TOPSIS method is used for determining the final ranking of the cement firms.

Step 1. Decision matrix is normalized via Eq. (15):

$$r_{ij} = \frac{w_{ij}}{\sqrt{\sum_{j=1}^J w_{ij}^2}}, \quad j = 1, 2, 3, \dots, J, \\ i = 1, 2, 3, \dots, n \quad (15)$$

Step 2. Weighted normalized decision matrix is formed:

$$v_{ij} = w_i * r_{ij}, \quad j = 1, 2, 3, \dots, J, \quad i = 1, 2, 3, \dots, n \quad (16)$$

Step 3. Positive ideal solution (PIS) and negative ideal solution (NIS) are determined:

$$A^* = \{v_1^*, v_2^*, \dots, v_n^*\} \quad \text{maximum values} \quad (17)$$

$$A^- = \{v_1^-, v_2^-, \dots, v_n^-\} \quad \text{minimum values} \quad (18)$$

Step 4. The distance of each alternative from PIS and NIS are calculated:

$$d_i^* = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^*)^2}, \quad j = 1, 2, \dots, J \quad (19)$$

$$d_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2}, \quad i = 1, 2, \dots, J \quad (20)$$

Step 5. The closeness coefficient of each alternative is calculated:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad i = 1, 2, \dots, J \quad (21)$$

Step 6. By comparing CC_i values, the ranking of alternatives are determined.

6. Application

The aim of this study is to evaluate the performance of 15 Turkish cement firms¹ in the Istanbul Stock Exchange, with the help of financial ratios. Firstly financial ratios are calculated for each firm. Then, three decision makers from different areas evaluate the importance of these ratios with the help of questionnaires. FAHP is utilized for determining the weights of main and sub-criteria. Finally, TOPSIS method is proposed for evaluating the performance of the cement firms, considering financial ratios and weights of the criteria. By this way, the ranking of the firms according to their general performance is obtained.

The ratios in Fig. 3 are used for evaluating the cement firms. Here, the ratio that forms each sub-criterion has different preference degree. During the formation of the model, the places of the numerator and denominator are changed for the small value preferences. By this way big values gain a more preferable situation in this ratio. For instance, ratio of Total Debt/Assets is preferred to take small value. So, numerator and denominator change their place while this ratio is calculated. Preference degree changes from one decision maker to another. In this condition, these ratios are revised according to the decision maker's preference.

Because different groups inside and outside the firm have varying objectives and expectations, they approach financial analysis from different perspectives (Moyer et al., 1992). So, financial ratios have different level of significance for different users. For instance, managers of firms are especially interested in activity and growth ratios. While investors and shareholders focus on profitability ratios, creditors concerned with financial leverage ratios (Sekreter et al., 2004). For this reason, three decision makers are selected from different areas and these decision makers evaluate the criteria. The first decision maker is a creditor, the second one is investment consultant, and the last one is shareholder. FAHP is proposed to take the decision makers subjective judgments into consideration and to reduce the uncertainty and vagueness in the decision process.

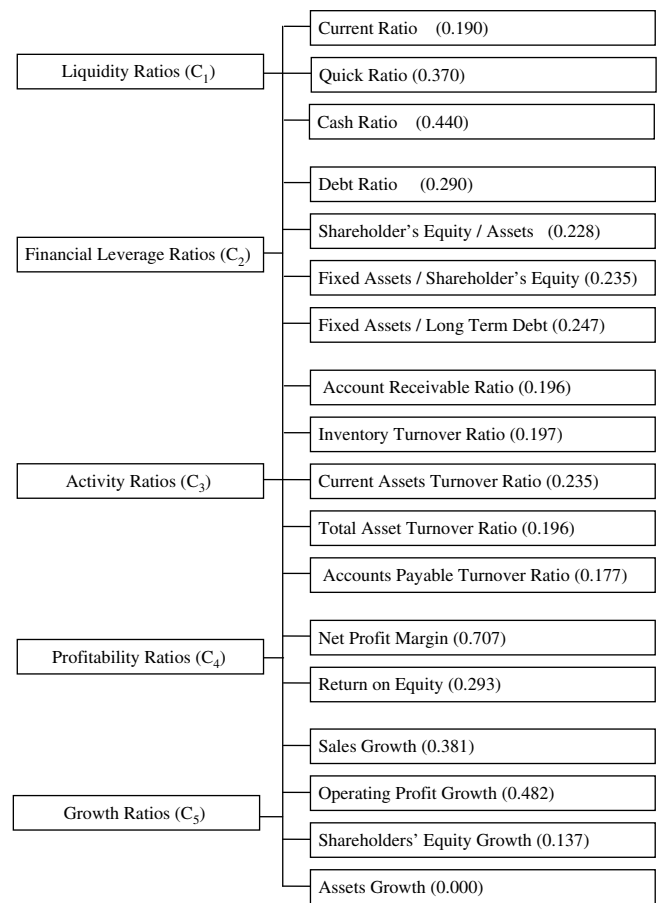


Fig. 3. Hierarchical structure of model in application.

Decision makers from different backgrounds may define different weight vectors. They usually cause not only the imprecise evaluation but also serious persecution during decision process. For this reason, we proposed a group decision based on FAHP to improve pair-wise comparison. Firstly each decision maker (D_p), individually carry out pair-wise comparison by using Saaty's 1–9 scale (Chen, 2004):

$$D_1 = \begin{matrix} & C_1 & C_2 & C_3 & C_4 & C_5 \\ \begin{matrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \end{matrix} & \begin{bmatrix} 1 & 3 & 3 & 5 & 7 \\ 1/3 & 1 & 1 & 5 & 3 \\ 1/3 & 1 & 1 & 3 & 1 \\ 1/5 & 1/5 & 1/3 & 1 & 1/3 \\ 1/7 & 1/3 & 1 & 3 & 1 \end{bmatrix} \end{matrix}$$

$$D_2 = \begin{matrix} & C_1 & C_2 & C_3 & C_4 & C_5 \\ \begin{matrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \end{matrix} & \begin{bmatrix} 1 & 1 & 7 & 1/5 & 3 \\ 1 & 1 & 5 & 1/3 & 3 \\ 1/7 & 1/5 & 1 & 1/7 & 1/5 \\ 5 & 3 & 7 & 1 & 3 \\ 1/3 & 1/3 & 5 & 1/3 & 1 \end{bmatrix} \end{matrix}$$

$$D_3 = \begin{matrix} & C_1 & C_2 & C_3 & C_4 & C_5 \\ \begin{matrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \end{matrix} & \begin{bmatrix} 1 & 3 & 5 & 1/5 & 1/3 \\ 1/3 & 1 & 3 & 1/7 & 1/5 \\ 1/5 & 1/3 & 1 & 1/7 & 1/7 \\ 5 & 7 & 7 & 1 & 3 \\ 3 & 5 & 7 & 1/3 & 1 \end{bmatrix} \end{matrix}$$

Then, a comprehensive pair-wise comparison matrix is built as in Table 1 by integrating three decision makers'

¹ Adana Cement, Afyon Cement, Aslan Cement, Bolu Cement, Batı-Söke Cement, Batı Cement, Bursa Cement, Çimsa Cement, Çimentaş Cement, Göltaş Cement, Konya Cement, Mardin Cement, Nuh Cement, Oysa Cement, Ünye Cement.

Table 1
Fuzzy pair-wise comparison matrix

	C_1	C_2	C_3	C_4	C_5
C_1	(1, 1, 1)	(1, 2.33, 3)	(3, 5, 7)	(0.2, 1.8, 5)	(0.333, 3.444, 7)
C_2	(0.33, 0.55, 1)	(1, 1, 1)	(1, 3, 5)	(0.143, 1.825, 5)	(0.2, 2.067, 3)
C_3	(0.143, 0.225, 0.333)	(0.2, 0.511, 1)	(1, 1, 1)	(0.143, 1.095, 3)	(0.143, 0.478, 1)
C_4	(0.2, 3.4, 5)	(0.2, 3.4, 7)	(0.333, 4.78, 7)	(1, 1, 1)	(0.333, 2.111, 3)
C_5	(0.143, 1.159, 3)	(0.333, 1.89, 5)	(1, 4.33, 7)	(0.333, 1.222, 3)	(1, 1, 1)

grades through Eq. (22) (Chen, Lin, & Huang, 2006). By this way, decision makers' pair-wise comparison values are transformed into triangular fuzzy numbers as in Table 1.

$$(\tilde{x}_{ij}) = (a_{ij}, b_{ij}, c_{ij})$$

$$l_{ij} = \min_k \{a_{ijk}\}, \quad m_{ij} = \frac{1}{K} \sum_{k=1}^K b_{ijk}, \quad u_{ij} = \max_k \{d_{ijk}\} \quad (22)$$

After forming fuzzy pair-wise comparison matrix, weights of all criteria and sub-criteria are determined by the help of FAHP. According to the FAHP method, firstly synthesis values must be calculated. From Table 1, synthesis values respect to main goal are calculated like in Eq. (5):

$$S_{C_1} = (5.53, 13.57, 23) \otimes (1/86.33, 1/49.62, 1/14.71) \\ = (0.064, 0.274, 1.563)$$

$$S_{C_2} = (2.68, 8.45, 15) \otimes (1/86.33, 1/49.62, 1/14.71) \\ = (0.031, 0.170, 1.020)$$

$$S_{C_3} = (1.63, 3.31, 6.33) \otimes (1/86.33, 1/49.62, 1/14.71) \\ = (0.019, 0.067, 0.430)$$

$$S_{C_4} = (2.07, 14.69, 23) \otimes (1/86.33, 1/49.62, 1/14.71) \\ = (0.024, 0.296, 1.563)$$

$$S_{C_5} = (2.81, 9.60, 19) \otimes (1/86.33, 1/49.62, 1/14.71) \\ = (0.033, 0.193, 1.291)$$

These fuzzy values are compared by using Eq. (11) and these values are obtained:

$$\begin{aligned} V(S_{C_1} \geq S_{C_2}) &= 1, \quad V(S_{C_1} \geq S_{C_3}) = 1, \quad V(S_{C_1} \geq S_{C_4}) = 0.99, \quad V(S_{C_1} \geq S_{C_5}) = 1 \\ V(S_{C_2} \geq S_{C_1}) &= 0.9, \quad V(S_{C_2} \geq S_{C_3}) = 1, \quad V(S_{C_2} \geq S_{C_4}) = 0.89, \quad V(S_{C_2} \geq S_{C_5}) = 0.98 \\ V(S_{C_3} \geq S_{C_1}) &= 0.64, \quad V(S_{C_3} \geq S_{C_2}) = 0.79, \quad V(S_{C_3} \geq S_{C_4}) = 0.64, \quad V(S_{C_3} \geq S_{C_5}) = 0.76 \\ V(S_{C_4} \geq S_{C_1}) &= 1, \quad V(S_{C_4} \geq S_{C_2}) = 1, \quad V(S_{C_4} \geq S_{C_3}) = 1, \quad V(S_{C_4} \geq S_{C_5}) = 1 \\ V(S_{C_5} \geq S_{C_1}) &= 0.94, \quad V(S_{C_5} \geq S_{C_2}) = 1, \quad V(S_{C_5} \geq S_{C_3}) = 1, \quad V(S_{C_5} \geq S_{C_4}) = 0.93 \end{aligned}$$

Then priority weights are calculated by using Eq. (12):

$$d'(C_1) = \min(1, 1, 0.99, 1) = 0.99$$

$$d'(C_2) = \min(0.9, 1, 0.89, 0.98) = 0.89$$

$$d'(C_3) = \min(0.64, 0.79, 0.64, 0.76) = 0.64$$

$$d'(C_4) = \min(1, 1, 1, 1) = 1$$

$$d'(C_5) = \min(0.94, 1, 1, 0.93) = 0.93$$

Table 2
Liquidity ratios for the cement firms

	Liquidity ratios		
	Current ratio	Quick ratio	Cash ratio
Adana Cement	8.58	7.16	6.56
Afyon Cement	4.05	3.00	2.14
Akçansa Cement	4.15	3.17	1.64
Aslan Cement	1.60	1.23	0.28
Batı Cement	3.57	2.62	1.68
Batı-Söke Cement	5.89	4.20	3.63
Bolu Cement	7.47	5.54	4.02
Bursa Cement	5.05	3.38	0.92
Çimentoş Cement	0.94	0.58	0.12
Çimsa Cement	2.02	1.31	0.66
Gölaş Cement	2.43	1.78	1.21
Konya Cement	5.20	3.92	2.55
Mardin Cement	5.28	4.55	3.88
Nuh Cement	2.35	1.82	0.77
Ünye Cement	4.96	4.15	3.56

Priority weights form $W' = (0.99, 0.89, 0.64, 1, 0.93)$ vector. After the normalization of these values priority weights respect to main goal are calculated as (0.22, 0.20, 0.14, 0.23, 0.21). Then, weights of sub-criteria are calculated similarly. Weights of sub-criteria are shown in Fig. 3.

After determining the weights of the criteria with FAHP method, financial ratios are calculated. Firstly, financial tables of the Turkish cement firms are obtained from the web site of Istanbul Stock Exchange² Then the liquidity,

financial leverage, activity, profitability and growth ratios that are used in the performance evaluation process are calculated separately for each firm. These ratios are indicated from Tables 2–6.

² <http://www.imkb.gov.tr/bilanco/mtablodnem.htm>.

Table 3
Financial leverage ratios for the cement firms

	Financial leverage ratios			
	Debt ratio	Shareholders' equity total assets	Fixed assets/ shareholders' equity	Fixed assets/ long term debt
Adana Cement	0.06	0.94	0.15	16.45
Afyon Cement	0.19	0.81	0.59	7.24
Akçansa Cement	0.12	0.87	0.53	11.21
Aslan Cement	0.31	0.67	0.82	11.35
Batı Cement	0.20	0.71	0.77	6.25
Batı-Söke Cement	0.12	0.88	0.69	12.27
Bolu Cement	0.09	0.91	0.37	32.30
Bursa Cement	0.18	0.65	0.00	0.00
Çimentoş Cement	0.50	0.49	0.87	1.19
Çimsa Cement	0.34	0.66	0.52	1.59
Gölaş Cement	0.19	0.74	0.87	10.38
Konya Cement	0.15	0.85	0.66	9.03
Mardin Cement	0.11	0.89	0.39	13.79
Nuh Cement	0.29	0.71	0.71	2.80
Ünye Cement	0.24	0.76	0.60	3.35

Table 4
Activity ratios for the cement firms

	Activity ratios				
	Accounts receivable turnover	Inventory turnover	Current assets turnover	Total assets turnover	Accounts payable turnover
Adana Cement	1.10	3.48	0.74	0.34	1.16
Afyon Cement	1.09	2.62	1.18	0.61	1.08
Akçansa Cement	1.13	4.83	1.50	0.48	1.14
Aslan Cement	1.22	7.72	1.69	0.72	1.29
Batı Cement	1.08	4.51	1.26	0.49	0.99
Batı-Söke Cement	1.08	2.44	0.86	0.33	2.00
Bolu Cement	1.09	3.87	0.88	0.55	1.15
Bursa Cement	1.16	4.58	2.00	1.24	1.10
Çimentoş Cement	1.34	4.13	1.94	0.26	1.23
Çimsa Cement	1.23	4.25	1.67	0.41	1.82
Gölaş Cement	1.07	4.72	1.10	0.33	1.03
Konya Cement	1.12	2.55	1.13	0.49	1.14
Mardin Cement	1.25	7.22	1.07	0.49	1.12
Nuh Cement	1.13	6.80	1.92	0.52	1.07
Ünye Cement	1.20	0.26	0.86	0.46	1.02

After the financial ratios are calculated, normalization of these values is made via Eq. (15). Then, weighted normalized matrix is formed by multiplying each value with their weights. All weighted values that form each sub-criterion are aggregated to form Table 7.

Then, the values in Table 7 and the weights of each main criterion are multiplied to form Table 8.

Table 5
Profitability ratios for the cement firms

	Profitability ratios	
	Net profit margin	Return on equity
Adana Cement	0.55	0.20
Afyon Cement	0.32	0.24
Akçansa Cement	0.31	0.17
Aslan Cement	0.17	0.18
Batı Cement	0.29	0.20
Batı-Söke Cement	0.41	0.15
Bolu Cement	0.47	0.28
Bursa Cement	1.91	0.56
Çimentoş Cement	0.003	0.002
Çimsa Cement	0.22	0.14
Gölaş Cement	0.26	0.12
Konya Cement	0.35	0.20
Mardin Cement	0.64	0.35
Nuh Cement	0.25	0.18
Ünye Cement	0.41	0.25

Table 6
Growth ratios for the cement firms

	Growth ratios			
	Sales growth	Operating profit growth	Shareholders' equity growth	Assets growth
Adana Cement	8.72	53.31	12.90	11.85
Afyon Cement	−4.07	47.16	35.45	23.27
Akçansa Cement	37.64	19.33	8.37	6.53
Aslan Cement	53.68	107.41	12.15	18.59
Batı Cement	24.84	150.06	21.25	20.42
Batı-Söke Cement	14.82	52.92	12.56	8.49
Bolu Cement	25.13	91.50	19.57	21.64
Bursa Cement	49.62	89.95	22.85	14.93
Çimentoş Cement	48.45	−96.98	97.14	126.56
Çimsa Cement	46.24	13.29	14.60	49.87
Gölaş Cement	6.53	8.24	11.90	6.75
Konya Cement	26.84	53.52	23.01	15.06
Mardin Cement	29.32	55.80	28.17	27.90
Nuh Cement	51.69	31.41	33.52	25.77
Ünye Cement	38.28	12.48	27.35	21.42

Positive and negative ideal solution are determined by taking the maximum and minimum values for each criterion:

$$A^* = \{0.2148, 0.0998, 0.1076, 0.0781, 0.0740\} \quad \text{maximum values}$$

$$A^- = \{0.0110, 0.0187, 0.0002, 0.0392, 0.0095\} \quad \text{minimum values}$$

Then the distance of each firm from PIS and NIS with respect to each criterion are calculated with the help of Eqs. (19) and (20). Then closeness coefficient of each firm is calculated by using Eq. (21) and the ranking of the firms are determined according to these values. The ranking of the cement firms are shown in Table 9.

After the performance evaluation of the Turkish Cement firms in Istanbul Stock Exchange by taking financial ratios into consideration, the order of the firms are found as in Table 9. Besides the financial ratios, the decision makers'

Table 7
Total values of main criteria

	Liquidity ratios	Financial leverage ratios	Profitability ratios	Activity ratios	Growth ratios
Adana Cement	0.97	0.50	0.23	0.19	0.13
Afyon Cement	0.36	0.20	0.17	0.22	0.11
Akçansa Cement	0.34	0.26	0.15	0.25	0.15
Aslan Cement	0.10	0.17	0.11	0.32	0.35
Batı Cement	0.30	0.17	0.15	0.23	0.36
Batı-Söke Cement	0.56	0.25	0.17	0.21	0.15
Bolu Cement	0.68	0.42	0.23	0.22	0.25
Bursa Cement	0.30	0.10	0.75	0.34	0.32
Çimentaş Cement	0.05	0.09	0.00	0.26	0.07
Çimsa Cement	0.14	0.14	0.11	0.28	0.17
Göltaş Cement	0.21	0.19	0.12	0.21	0.05
Konya Cement	0.46	0.22	0.17	0.21	0.19
Mardin Cement	0.59	0.30	0.30	0.27	0.21
Nuh Cement	0.18	0.14	0.13	0.29	0.24
Ünye Cement	0.54	0.16	0.20	0.17	0.16

Table 8
Total weighted values of main criteria

	Liquidity ratios	Financial leverage ratios	Profitability ratios	Activity ratios	Growth ratios
Adana Cement	0.2148	0.0998	0.0327	0.0431	0.0274
Afyon Cement	0.0808	0.0393	0.0245	0.0500	0.0228
Akçansa Cement	0.0746	0.0516	0.0210	0.0568	0.0308
Aslan Cement	0.0229	0.0350	0.0154	0.0728	0.0731
Batı Cement	0.0674	0.0342	0.0214	0.0522	0.0740
Batı-Söke Cement	0.1243	0.0507	0.0244	0.0482	0.0307
Bolu Cement	0.1503	0.0844	0.0328	0.0495	0.0524
Bursa Cement	0.0670	0.0211	0.1076	0.0765	0.0668
Çimentaş Cement	0.0110	0.0187	0.0002	0.0578	0.0146
Çimsa Cement	0.0312	0.0276	0.0157	0.0622	0.0350
Göltaş Cement	0.0470	0.0388	0.0166	0.0481	0.0095
Konya Cement	0.1012	0.0438	0.0240	0.0477	0.0403
Mardin Cement	0.1312	0.0597	0.0433	0.0597	0.0437
Nuh Cement	0.0399	0.0280	0.0188	0.0661	0.0490
Ünye Cement	0.1204	0.0321	0.0289	0.0386	0.0330

priorities also affected the ranking of the firms. If there will be a difference in the priority of the decision makers, the ranking may change. For this reason decision maker should know his priority properly and then determine the weights of the criteria.

Table 9
Rankings of cement firms according to CC_i values

	CC_i
1	Adana Cement
2	Bolu Cement
3	Mardin Cement
4	Batı Söke Cement
5	Bursa Cement
6	Ünye Cement
7	Konya Cement
8	Batı Cement
9	Akçansa Cement
10	Afyon Cement
11	Lafarge Aslan Cement
12	Nuh Cement
13	Çimsa Cement
14	Göltaş Cement
15	Çimentaş Cement

7. Conclusion

Today cement sector is an emerging market. The main reason of this is the increase in house and infrastructure investments. It is supposed that cement production will rise according to the increase in the house demand. Also implementation of mortgage system, and increase in investments will affect the cement demand. Evaluating the performance of the cement firms is an important issue for investors, shareholders and creditors. In this study, an objective evaluation system is developed for evaluating the performance of firms by using the financial tables.

The proposed method is used in determining the ranking of the firms in the same sector by comparing the firms according to the criteria determined. Financial tables of the firms are used for performance evaluation and the subjective judgments of the decision makers incorporated into the evaluation process. Different from other studies in the literature, in this study FAHP and TOPSIS methods are used together. FAHP is utilized for determining the weights of the criteria and TOPSIS method is used for determining the ranking of the firms. In the application, ranking result of the cement firms is reached by considering the performance of the firms. As the weights of criteria are determined by the decision makers from different areas, the result indicates an overall performance ranking. If it is desired, it is possible to make an evaluation only for creditors, investors or shareholders. But in such a case, the weights of the criteria are varied, so the ranking of the firms can change.

In future studies other multi-criteria methods can be used to evaluate the performance of cement firms. And also the proposed method can be applied for evaluating the firms in other sectors.

Appendix 1

See Fig. A1.

	Importance of one main criterion over another	
<i>Main Criteria</i>	Absolute (9) Very Strong (7) Fairly Strong (5) Weak (3) Equal (1) Weak (3) Fairly Strong (5) Very Strong (7) Absolute (9)	
Liquidity Ratios		Financial Leverage Ratios
Liquidity Ratios		Activity Ratios
Liquidity Ratios		Profitability Ratios
Liquidity Ratios		Growth Ratios
Financial Leverage Ratios		Activity Ratios
Financial Leverage Ratios		Profitability Ratios
Financial Leverage Ratios		Growth Ratios
Activity Ratios		Profitability Ratios
Activity Ratios		Growth Ratios
Profitability Ratios		Growth Ratios

	Importance of one sub-criterion over another	
<i>Sub- Criteria of Liquidity Ratios</i>	Absolute (9) Very Strong (7) Fairly Strong (5) Weak (3) Equal (1) Weak (3) Fairly Strong (5) Very Strong (7) Absolute (9)	
Current Ratio		Quick Ratio
Current Ratio		Cash Ratio
Quick Ratio		Cash Ratio

	Importance of one sub-criterion over another	
<i>Sub- Criteria of Financial Leverage Ratios</i>	Absolute (9) Very Strong (7) Fairly Strong (5) Weak (3) Equal (1) Weak (3) Fairly Strong (5) Very Strong (7) Absolute (9)	
Debt Ratio		Shareholders' Equity/ Total Assets
Debt Ratio		Fixed Assets/ Shareholders' Equity
Debt Ratio		Fixed Assets/ Long Term Debt
Shareholders' Equity / Total Assets		Fixed Assets / Shareholders' Equity
Shareholders' Equity / Total Assets		Fixed Assets/ Long Term Debt
Fixed Assets / Shareholders' Equity		Fixed Assets/ Long Term Debt

Fig. A1. Questionnaire forms used to facilitate comparisons of main and sub-criteria.

	Importance of one sub-criterion over another								
<i>Sub- Criteria of Activity Ratios</i>	Absolute (9)	Very Strong (7)	Fairly Strong (5)	Weak (3)	Equal (1)	Weak (3)	Fairly Strong (5)	Very Strong (7)	Absolute (9)
Accounts Receivable Turnover									Inventory Turnover
Accounts Receivable Turnover									Current Assets Turnover
Accounts Receivable Turnover									Total Assets Turnover
Accounts Receivable Turnover									Accounts Payable Turnover
Inventory Turnover									Current Assets Turnover
Inventory Turnover									Total Assets Turnover
Inventory Turnover									Accounts Payable Turnover
Current Assets Turnover									Total Assets Turnover
Current Assets Turnover									Accounts Payable Turnover
Total Assets Turnover									Accounts Payable Turnover

	Importance of one sub-criterion over another								
<i>Sub- Criteria of Profitability Ratios</i>	Absolute (9)	Very Strong (7)	Fairly Strong (5)	Weak (3)	Equal (1)	Weak (3)	Fairly Strong (5)	Very Strong (7)	Absolute (9)
Net profit Margin									Return on Equity

	Importance of one sub-criterion over another								
<i>Sub- Criteria of Growth Ratios</i>	Absolute (9)	Very Strong (7)	Fairly Strong (5)	Weak (3)	Equal (1)	Weak (3)	Fairly Strong (5)	Very Strong (7)	Absolute (9)
Sales Growth									Operating Profit Growth
Sales Growth									Shareholders' Equity Growth
Sales Growth									Assets Growth
Operating Profit Growth									Shareholders' Equity Growth
Operating Profit Growth									Assets Growth
Shareholders' Equity Growth									Assets Growth

Fig. A1 (continued)

References

- Ayağ, Z., & Özdemir, R. G. (2006). A fuzzy AHP approach to evaluating machine tool alternatives. *Journal of Intelligent Manufacturing*, 17, 179–190.
- Başılgil, H. (2005). The fuzzy analytic hierarchy process for software selection problems. *Journal of Engineering and Natural Sciences*, 3, 24–33.
- Baykal, N., & Beyan, T. (2004). *Bulamk Mantık İlke ve Temelleri*. Ankara, Bıçaklar Kitabevi.
- Benitez, J. M., Martin, J. C., & Roman, C. (2007). Using fuzzy number for measuring quality of service in the hotel industry. *Tourism Management*, 28(2), 544–555.
- Bojadziev, G., & Bojadziev, M. (1998). *Fuzzy sets fuzzy logic applications*. Singapore: World Scientific Publishing.
- Bozdağ, C. E., Kahraman, C., & Ruan, D. (2003). Fuzzy group decision making for selection among computer integrated manufacturing systems. *Computer in Industry*, 51, 13–29.
- Buckley, J. J. (1985). Fuzzy hierarchical analysis. *Fuzzy Sets and Systems*, 17, 233–247.
- Chan, F. T. S., & Kumar, N. (2007). Global supplier development considering risk factors using fuzzy extended AHP-based approach. *Omega International Journal of Management Science*, 35, 417–431.
- Chang, D. Y. (1996). Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research*, 95, 649–655.
- Chang, Y. H., Cheng, C. H., & Wang, T. C. (2003). Performance evaluation of international airports in the region of east Asia. In *Proceedings of Eastern Asia Society for transportation studies* (Vol. 4, pp. 213–230).
- Chen, C. T., Lin, C. T., & Huang, S. F. (2006). A fuzzy approach for supplier evaluation and selection in supply chain management. *International Journal of Production Economics*, 102, 289–301.
- Chen, G., & Pham, T. T. (2001). *Introduction to fuzzy, sets fuzzy, logic and fuzzy control systems*. Florida: CRC Press.
- Chen, H. (2004). A research based on fuzzy AHP for multi-criteria supplier selection in supply chain. Master thesis, National Taiwan University of Science and Technology, Department of Industrial Management.
- Chou, T. Y., & Liang, G. S. (2001). Application of a fuzzy multi-criteria decision making model for shipping company performance evaluation. *Maritime Policy & Management*, 28(4), 375–392.
- Deng, H. (1999). Multicriteria analysis with fuzzy pair-wise comparison. *International Journal of Approximate Reasoning*, 21, 215–231.
- Enea, M., & Piazza, T. (2004). *Project selection by constrained fuzzy AHP. Fuzzy Optimization and Decision Making* (Vol. 3). New York: Kluwer Academic Publishers, pp. 39–62.
- Ertuğrul, İ., & Karakaşoğlu, N. (2006). The fuzzy analytic hierarchy process for supplier selection and an application in a textile company. In *Proceedings of 5th international symposium on intelligent manufacturing systems* (pp. 195–207).
- Ertuğrul, İ., & Karakaşoğlu, N. (2006). Fuzzy TOPSIS method for academic member selection in engineering faculty. In *Proceedings of the international joint conferences on computer, information, and systems sciences, and engineering (CIS²E 06)*, USA.
- Ertuğrul, İ., & Tuş, A. (2007). Interactive fuzzy linear programming and an application sample at a textile firm. *Fuzzy Optimization and Decision Making*, 6, 29–49.
- Foster, G. (1978). *Financial statement analysis*. Englewood Cliffs, NJ: Prentice-Hall.
- Gu, X., & Zhu, Q. (2006). Fuzzy multi-attribute decision making method based on eigenvector of fuzzy attribute evaluation space. *Decision Support Systems*, 41, 400–410.
- Haq, A. N., & Kannan, G. (2006). Fuzzy analytical hierarchy process for evaluating and selecting a vendor in a supply chain model. *International Journal of Advanced Manufacturing*, 29, 826–835.
- Hsieh, T. Y., Lu, S. T., & Tzeng, G. H. (2004). Fuzzy MCDM approach for planning and design tenders selection in public office buildings. *International Journal of Project Management*, 22, 573–584.
- Huang, C. C., Chu, P. Y., & Chiang, Y. H. (2006). A fuzzy AHP application in government-sponsored R&D project selection. *Omega The International Journal of Management Science*, in press, doi:10.1016/j.omega.2006.05.03.
- Hwang, C. L., & Yoon, K. (1981). *Multiple attributes decision making methods and applications*. Berlin: Springer.
- Kahraman, C., Cebeci, U., & Ulukan, Z. (2003). Multi-criteria supplier selection using fuzzy AHP. *Logistics Information Management*, 16(6), 382–394.
- Kahraman, C., Ruan, D., & Doğan, İ. (2003). Fuzzy group decision making for facility location selection. *Information Sciences*, 157, 135–153.
- 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, 171–184.
- Lai, Y. J., & Hwang, C. L. (1996). *Fuzzy multiple objective decision making*. Berlin: Springer.
- Lee, A. H. I., Chen, W. C., & Chang, C. J. (2008). A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan. *Expert System with Applications*, 34, 96–107.
- Leung, L., & Cao, D. (2000). On consistency and ranking of alternatives in fuzzy AHP. *European Journal of Operational Research*, 124, 102–113.
- Mikhailov, L., & Tsvetov, P. (2004). Evaluation of services using a fuzzy analytic hierarchy process. *Applied Soft Computing*, 5, 23–33.
- Moyer, R. C., McGuigan, J. R., & Kretlow, W. J. (1992). *Contemporary financial management*. USA: West Publishing Company.
- Price, J. E., Haddock, M. D., & Brock, H. R. (1993). *College accounting* (7th ed.). New York: Macmillan/McGraw-Hill.
- Saaty, T. L. (1980). *The analytic hierarchy process*. New York: McGraw-Hill.
- Sekreter, M. S., Akyüz, G., & Çetin, E. İ. (2004). Şirketlerin derecelendirilmesine ilişkin bir model önerisi: gıda sektörüne yönelik bir uygulama. *Akdeniz Üniversitesi İBF Dergisi*, 4(8), 139–155.
- Tang, L. L., Kuo, Y. C., & Lee E. S. (2005). A multi-objective model for Taiwan notebook computer distribution problem. In Y.-C. Lan (Ed.), *Global integrated supply chain systems* (pp. 171–182). Hershey, PA, USA: Idea Group Publishing.
- Tang, Y., & Beynon, M. J. (2005). Application and development of a fuzzy analytic hierarchy process within a capital investment study. *Journal of Economics and Management*, 1(2), 207–230.
- Tolga, E., Demircan, M., & Kahraman, C. (2005). Operating system selection using fuzzy replacement analysis and analytic hierarchy process. *International Journal of Production Economics*, 97, 89–117.
- Triantaphyllou, E., & Lin, C. T. (1996). Development and evaluation of five fuzzy multiattribute decision-making methods. *International Journal of Approximate Reasoning*, 14, 281–310.
- Tsaur, S. H., Chang, T. Y., & Yen, C. H. (2002). The evaluation of airline service quality by fuzzy MCDM. *Tourism Management*, 23, 107–115.
- Tüysüz, F., & Kahraman, C. (2006). Project risk evaluation using a fuzzy analytic hierarchy process: an application to information technology projects. *International Journal of Intelligent Systems*, 21, 559–584.
- Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of Operational Research*, 169, 1–29.
- Van Laarhoven, P. J. M., & Pedrcyz, W. (1983). A fuzzy extension of Saaty's priority theory. *Fuzzy Sets and Systems*, 11, 229–241.
- Wang, Y. M., & Elhag, T. M. S. (2006). Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment. *Expert Systems with Applications*, 31, 309–319.

- Wang, Y. J. (2007). Applying FMCDM to evaluate financial performance of domestic airlines in Taiwan. *Expert Systems with Applications*, in press, doi:10.1016/j.eswa.2007.02.029.
- Wang, T. C., & Chen, Y. H. (2007). Applying consistent fuzzy preference relations to partnership selection. *Omega, the International Journal of Management Science*, 35, 384–388.
- Weston, J. F., & Brigham, E. F. (1993). *Essentials of managerial finance* (10th ed.). India: Southwest Press.
- Yoon, K., & Hwang, C. L. (1985). Manufacturing plant location analysis by multiple attribute decision making: Part II. Multi-plant strategy and plant relocation. *International Journal of Production Research*, 23(2), 361–370.
- Yurdakul, M., & İç, Y. T. (2003). Türk otomotiv firmalarının performans ölçümü ve analizine yönelik TOPSIS yöntemini kullanan bir örnek çalışma. *Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi*, 18(1), 1–18.
- Zadeh, L. A. (1965). Fuzzy sets. *Information and Control*, 8, 338–353.
- Zimmermann, H. J. (1992). *Fuzzy set theory and its applications*. New York: Kluwer Academic Publishers.
- Zhu, K., Jing, Y., & Chang, D. (1999). A discussion on extent analysis method and applications of fuzzy AHP. *European Journal of Operational Research*, 116, 450–456.